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Contagious crying beyond the first days of life

Elena Geangu[a,*], Oana Benga[b], Daniel Stahl[c], Tricia Striano[d,e]

[a] "George Baritiu" Institute of the Romanian Academy of Science, Psychosocial Research, 8, M. Kogalniceanu Street, 3400 Cluj-Napoca, Cluj, Romania
[b] Babes-Bolyai University, Romania
[c] Kings College London, United Kingdom
[d] Hunter College, City University of New York, United States
[e] Max Planck Institute for Human Cognitive and Brain Sciences, Germany

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ABSTRACT

Newborns cry in response to another newborn cry and researchers agree that these are the very early signs of empathy development. Yet, little is known about the development of these affect sharing reactions in infancy, beyond the very first few days after birth. The aim of this study is to investigate the presence of contagious cry phenomenon in infancy. Infants aged 1-, 3-, 6-, and 9-month-old were presented with the sound of another infant cry vocalizations. Their emotional reactions were recorded in terms of vocal (presence of vocal distress, latency, and intensity) and facial (anger and sadness) expressions of emotions. Results show that during the presentation of a pain cry sound, 1, 3, 6, and 9 months old infants manifest increased vocal and facial expressions of distress. These affect sharing reactions do not decrease with age. Both boys and girls manifest similar levels of contagious crying reactions. The results are discussed in terms of early empathy development.

Contagious crying or reflexive crying refers to the distress reactions (vocal, facial or physiological) manifested as a response to the perception of another conspecific cry (Simner, 1971). Both developmental researchers and parents anecdotally mention this phenomenon when referring to the newborns 'and infants' reactions to another child vocal and facial distress, and it is considered as a precursor of fully developed empathic reactions (Hoffman, 2000; Simner, 1971).

Previously studied in relative isolation from contagious crying, empathy is considered to be an affective state elicited by and isomorphic with the one observed or imagined in another person, while associated with at least minimal awareness that the source of one's own affect lays in the other (Cialdini, Brown, Lewis, Luce, & Neuberg, 1997; Decety & Jackson, 2004; Eisenberg & Fabes, 1990; Hoffman, 2000; De Vignemont & Singer, 2006). The complexity of empathy is reflected in its "functional architecture" which encompasses several major components – affect sharing, self-other awareness, regulatory processes, and mental flexibility to adopt the subjective perspective of another, with constant interplay between these mechanisms (Decety & Lamm, 2006; Decety, 2007).

Empathy has previously been related to affect sharing or emotional contagion. Hess and Blairy (2001) distinguishes between emotional contagion and other similar processes (i.e. facial mimicry) by conceptualizing it as an affective state that matches the other's emotional display. Contagious crying is an affective response triggered by and similar to the emotional expressions perceived in another therefore seems to be a form of affect sharing, with high relevance for empathy development (Decety & Jackson, 2004; Hoffman, 2000). It is of significance that an investigation of the development of empathic processes related to contagious crying has not yet systematically studied responses throughout the first postnatal year.

* Corresponding author.
E-mail address: elenageangu@psychology.ro (E. Geangu).

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In humans, the first systematic study of contagious crying was undertaken by Buhler and Hetzer (1928), indicating that newborns start crying if they are exposed to a crying infant. Their results were impressive since 84% of the subjects included in the study manifested this type of response. Questions were therefore raised regarding the nature of this response and its possible significance. Simner (1971), Sagi and Hoffman (1976), Martin and Clark (1982) and much later Dondi, Simion, and Caltran (1999) and Field, Diego, Hernandez-Reif, and Fernandez (2007) investigated the characteristics of the contagious cry phenomenon in newborns, although little work has otherwise been conducted in this respect.

A newborn is manifesting contagious crying when, being exposed to another newborn cry sound, the infant manifests reactions of distress both facially and vocally (Dondi et al., 1999; Martin & Clark, 1982; Sagi & Hoffman, 1976; Simner, 1971). These overt reactions are usually accompanied by physiological arousal modifications such as changes in heart rate (Field et al., 2007; Simner, 1971).

Several characteristics of the cry stimulus are related with the generation of the contagious cry phenomenon. The source of the cry is one such aspect. It appears that newborns can discriminate between their own cry and the cry of another newborn, by manifesting a decrease in the heart rate and a reduction in non-nutritive sucking for the latter, both during wake and sleep states (Dondi et al., 1999; Field et al., 2007). They also tend to show more facial expressions of distress in response to the cry of another infant than for their own cry (Dondi et al., 1999).

Acoustic characteristics of the cry sound are important for the production of the emotional contagion phenomenon in newborns. Although different sounds of cry are efficient in eliciting contagious cry reactions in newborns (Simner, 1971), those cries which more closely resemble the characteristics of the listener's age seem to elicit more affect sharing, more facial and vocal distress (Martin & Clark, 1982; Simner, 1971). Relatedly, it appears that the generation of the contagious cry phenomenon is species specific. Confronted with the cry of a 16-day-old male chimpanzee, 18-hour-old infants vocalized distress significantly less than when hearing their own cry or the cry of an older infant (Martin & Clark, 1982).

Another issue related to the nature of the contagious/reflexive cry phenomenon concerns its innateness. Attempting to investigate it as early as possible in postnatal life has been the strategy of choice (Sagi & Hoffman, 1976). Contagious crying can be triggered at the age of 18-h (Martin & Clark, 1982), 34-h (Sagi & Hoffman, 1976), 43-h (Dondi et al., 1999), 66–72-h (Simner, 1971), and 14 days (Field et al., 2007). Although it is difficult to infer from data collected using these paradigms that contagious crying is innate, it can at least be said that it is present as early as a few hours following birth and it is consistent across the first 3 days of postnatal life.

Cry-like sounds trigger emotional reactions of distress in older children as well. In different studies, toddlers (Spinrad & Stifter, 2006), as well as preschool and school age children (Fabes, Eisenberg, Karbon, Troyer, & Switzer, 1994; Zahn-Waxler, Friedman, & Cummings, 1983) were presented with cry sounds of premature and/or full-term infants (Zahn-Waxler et al., 1983). The stimulus triggered negative emotional reactions evident both at the level of facial and vocal expressivity in 30–40% of the participants (Spinrad & Stifter, 2006; Zahn-Waxler et al., 1983), and at the level of heart activity (Fabes, Eisenberg, Karbon, Bernzweig, et al., 1994; Fabes, Eisenberg, Karbon, Troyer, et al., 1994). These measures also covaried significantly, suggesting the consistency of the effect (Fabes, Eisenberg, Karbon, Bernzweig, et al., 1994; Fabes, Eisenberg, Karbon, Troyer, et al., 1994).

Taken together, these studies show that cry-like stimuli are efficient for consistently inducing emotional sharing or emotional contagion for the first few days of postnatal life. Similar reactions were also observed in older children, from 4 to 9 years of age, particularly at the level of facial expressivity and physiological indices of heart rate variability. One obvious change consists in the disappearance of the vocal reactions of distress (i.e. crying), and, possibly, there are also significant modifications at the level of the other indices of emotional reactions (e.g., facial expressivity, physiologic indices) and at the level of the ability to discriminate between cries of different intensities. It seems therefore that, with age, there are alterations to the emotional reactions in response to the cry of another person. Up to now though, little work investigated these possible developments in emotional contagion reactions. One set of data indicates their existence very early in life, and another group reveals similar reactions in much older children, starting with the age of 48 months. It has been hypothesized that contagious crying reactions diminish towards the age of 6 months (Hoffman, 2000) due to the development of several factors implicated in its modulation, such as emotion regulation development and/or an increasingly better ability to differentiate between self and other entities. This view is partially supported by the reduced emotional reactions expressed by preschoolers when hearing a distress cry sound. But the ontogenetic trajectory of contagious cry phenomenon, persistence and characteristics, beyond the first few days of life, remain uninvestigated.

After birth, humans encounter rapid and significant changes in different areas of social and emotional development. Concerning emotional responses, there is a trend towards differentiation in both reactivity and expressivity (Camras, Oster, Campos, & Bakeman, 2003; Gartstein & Rothbart, 2003). Facial expressions associated with emotional reactions become more differentiated towards the age of 12 months (Bennett, Bendersky, & Lewis, 2005; Messinger, Fogel, & Dickson, 1999; Messinger, Fogel, & Dickson, 2001), as well as substantial changes in emotional regulatory abilities (Buss & Goldsmith, 1998; Calkins & Hill, 2007; Campos, Frankel, & Camras, 2004, Kopp, 1982; Rothbart, Ziaie, & O'Boyle, 1992). Further, work on temperament suggests that patterns of reactivity become more stable during this age interval (Gartstein & Rothbart, 2003), and the experience with different types of emotion inducing stimuli increases. These developments might be associated with a change in infants' responses to the sound of another's distress (Zahn-Waxler et al., 1983; Fabes, Eisenberg, Karbon, Bernzweig, et al., 1994; Fabes, Eisenberg, Karbon, Troyer, et al., 1994).

The issue of continuity of contagious crying as an index of emotional sharing remains open, as previous studies do not allow for inter-age comparisons due to differences in stimuli used and in modulations in the assessment of emotional responses across different ages. Therefore, the aim of the present study is to document the presence of emotional sharing as indexed by the contagious cry phenomenon beyond the first days after birth.

A pain cry sound of a 3-month-old infant was used in order to trigger contagious cry responses in 1-, 3-, 6- and 9-month-old infants. Previous studies on the development of cry suggest that this is a salient and efficient type of stimulus. The analyses of infant's cry vocalizations have differentiated between cries specific for sudden intense distress (e.g., the acute sensation of pain) and cries that signal low intensity but growing discomfort (e.g., the sensation of hunger, frustration) (Green, Gustafson, Irwin, Kalinowski, & Wood, 1995; Green, Gustafson, & McGhie, 1998; Gustafson, Wood, & Green, 2000). It seems thus that infants' cries differ as a function of the intensity of the distress that it signals, and not as a function of the specific distress situation (e.g., hunger, pain) with which it is associated (Gustafson et al., 2000). The cry stimulus we used was recorded during a painful procedure, a situation that often triggers sudden intense distress. The age of the infant that produced this cry (i.e. 3 months) is also the age when cry melodies become better at signaling acute distress by presenting a peak in the front section, and increased fundamental frequency (Rothgänger, 2003). This type of cry triggers the highest emotional reactions in adults (Rothgänger, 1999) and it has been suggested that around the age of 3 months, infants start to intentionally use this cry in order to obtain the attention of their caregiver. This type of stimuli has a highly adaptive value by signaling a potential threat, bearing, therefore, relevance for emotional contagion. Also, starting with the age of 2 months infant cry melodies become increasingly complex (Wermke, Mende, Manfredi, & Bruscaglioni, 2002). Consequently there may be an increased similarity between the infants' own cry and the cry sound of another infant, even when they differ in age, which may favor emotional contagion.

Diverse vocal and facial indices of distress were used as indexes for the contagious cry phenomenon, in order to track fine-grained ontogenetic differences. We expected a decline in emotional contagion as children approach the age of 9 months. This decline should be stronger for the vocal reactions of distress (presence, intensity and latency), since school age children did not manifest these types of reactions when hearing a newborn cry. The presence of contagious cry reactions and possible differences between the four age groups are the target of the present investigation.

1. Methods

1.1. Participants

The final sample consisted of 121 full-term born infants: 19 1-month-old (12 males, mean age: 31.50 days); 32 3-month-old (16 males, mean age: 95.73 days); 34 6-month-old (17 males, mean age: 181.87 days); and 36 9-month-old (18 males, mean age: 270.96 days). Participants were recruited by phone from a larger database to which parents subscribed shortly after the birth of their child. Parents were instructed to choose an appointment that suited the infant's daily rhythm. Additional 18 1-month-old; 21 3-month-old; 13 6-month-old; and 12 9-month-old participants responded to the invitation to participate in the study, but were not included in the final sample. The main reason for exclusion for the 1-month-old infants was sleepiness. This was mostly due to their lack of established biological rhythm. Mothers encountered difficulties in making an appointment that matched their infants' waking state. Several measures to overcome this situation (e.g. waiting for a reasonable amount of time in order for the participant to reach an adequate state of alertness) have been adopted in order to keep a low attrition rate. For the other age groups, the main reason for exclusion was fussiness/crying immediately before the procedure and/or refusal to sit in the designated infant chair. As the main purpose of our study is to document cry vocalizations and facial expressions of distress in reaction to a cry sound, any negative affect preceding the study would represent a confound for the current results.

All subjects were living in a mid-sized European city. Infants were rewarded with a small toy for their participation, and, if necessary, parents received a reimbursement for their parking fare.

1.2. Apparatus and stimulus

Subjects were tested in a quiet room in the infant laboratory. The room was split into two by a dark curtain. The procedure for the present study took place in one half of the room. The infant's chair, the parent's chair and the camera were the only objects presented in the testing area. Infants were seated in an infant chair, reclined approximately 25° for the 1-month-old group and approximately 65° for the other age groups. The parent was seated approximately 100 cm away from the infant, slightly backwards and out of view for the infant, and was instructed not to interact with the infant unless requested explicitly by the experimenter, and to maintain a neutral facial expression throughout the procedure. One camera recorded the infant behavior from a distance of ~100 cm in front of the child. The experimenter sat behind the camera and was partially occluded by it. A speaker placed behind the dark curtain, ~200 cm away from the subject, and ~150 cm above the floor was used in order to display the stimulus. The camera's microphone was directed to the infant. In addition, by placing the camera in close proximity to the participant, ensured that their vocal reactions of distress were the main sound heard during coding, while the stimulus was perceived as a background sound. A computer from the next room and connected to the speaker played the stimulus. The sound play settings were the same for all subjects in the study.

The stimulus was represented by the sound of a 3-month-old male infant crying, recorded while the infant was undergoing a blood sampling procedure, in a nearby hospital unit. The blood sampling triggered a cry from first to last vocalization of 199 s. During the procedure, this cry sound was played continuously twice, for a maximum duration of 398 s. By using a single stimulus for all participants, we ensured that they were uniformly presented with the same signal of distress, allowing between group comparisons.

1.3. Procedure

The procedure consisted of a *baseline* and a *test* episode as per previous work in this area (Dondi et al., 1999). During the 60 s *baseline episode*, in the absence of any auditory or visual stimulation, the infant's behavior was recorded. The *test episode* consisted of the presentation of the cry stimulus, and varied in duration as follows: 300 s for those infants who did not manifest cry vocalizations during this interval or a maximum of 360 s for those participants who started crying after the first 290 s after the stimulus onset. If the infant started to cry, a maximum of 30 s continuous cry was allowed until the parent was requested to start soothing him/her. The duration of the baseline and test episodes was similar to those used in previous studies (Dondi et al., 1999; Field et al., 2007; Sagi & Hoffman, 1976; Simner, 1971).

The entire procedure was video recorded for further off-line coding.

1.4. Coding

Both baseline and test phase recordings were divided in equal units, with a length of 10 s.

Subjects' behavior was coded in terms of different dimensions of facial expressivity and vocal reactions of crying as indices of emotional reactions (Kochanska, Coy, Tjebkes, & Husarek, 1998). Aspects including intensity of distress vocalizations, latency to signs of distress, facial expression patterns characteristic to different emotions are all considered to be parameters of emotional reactivity (Kochanska et al., 1998; Rothbart, Ellis, & Posner, 2004), conferring a more complex image of infants' responses to an emotional inducing stimuli. The use of this composite measure brings an additional improvement to previous studies in an attempt to obtain a more detailed picture of the emotional response triggered by the sound cry of another infant.

Each of the following variables was coded as present or absent for each single unit by an experimenter blind to the aims of the study. Twenty percent of the data were coded by a second experimenter for reliability. Intraclass correlation coefficient for absolute agreement is reported for each measure in parentheses.

Facial expressivity – it is documented that development of facial expressivity is very dynamic in the first months of life (Messinger et al., 2001), evolving towards specific facial expressions known to be associated with emotional experiences. In this regard we had to find a common factor between facial expressions of 1-month-old infants and facial expressions for the older age groups that could allow us inter-age comparisons. Analysis of the criteria used for facial expression of distress in newborns (Dondi et al., 1999) shows resemblance with the criteria for facial expressions of anger in older age groups (Goldsmith & Rothbart, 1999). This further supports the need to investigate facial distress reactions of 1-month-old infants with 3-, 6-, and 9-month-olds facial expressions of anger.

Criteria derived from AFFEX were used for coding expressions of anger and sadness for 3-, 6-, and 9-month-old subjects, as described by Goldsmith and Rothbart (1999). For either a *facial expression of anger* (.976) or a *facial expression of sadness* (.875) to be coded, specific movements in at least two of the following face regions should be displayed: movements in forehead/brows regions; movements in the eyes/nose/cheek regions; movements in mouth/lips/chin regions. For the 1-month-old subjects, we used the criteria similar to those presented by Dondi et al. (1999) for the facial expression of distress. In this case, for a facial expression of distress to be coded, all of the following facial movements should be present at the same time: brows lowered, eye fissure tightly closed, angular squarish mouth or open tensed mouth.

Facial movements that are specific for anger and sadness can appear simultaneously, leading to mixed facial expressions (Sullivan & Lewis, 2003). If this was the case for the 3-, 6-, and 9-month-old subjects, expressions of both anger and sadness were coded as present for the same 10-second unit. Also, in cases where a facial expression started in one unit and continued for more than one unit, it was coded as present for each of them.

Cry vocal reactions – cry was defined as an audible, intermittent vocalization of distress (Simner, 1971). For the *cry vocalizations* (.911), we scored the variable as present or absent for each unit. *Intensity of the cry* (.958) was rated for each unit on a scale from 1 to 5, where an intensity of 1 referred to mild protest verbalization that may be difficult to identify as negative and an intensity of 5 referred to full intensity cry/scream (where the child is losing control) (Goldsmith & Rothbart, 1999). Where a cry was elicited in one unit and lasted for more than one unit, the cry was scored as present for each of them, and the intensity was rated separately for each unit. If the cry intensity varied during one unit, the higher intensity was scored for that unit. The *latency to the onset of crying* (.960) was recorded as the number of units from the beginning of stimulus presentation to the onset of the first bout of cry. We have coded the latency to the onset of crying only for the test phase, where we could establish with precision the beginning of the stimulation.

2. Results

The percentage of units each participant spent crying, manifesting anger/distress, and sadness were computed for all age groups, for both the baseline and the test phase. The mean intensity of crying was computed for an entire phase. The number of units from the beginning of the stimulus presentation to the first bout of crying represented the latency to the onset of crying. Means and standard deviations for each variable according to the age group, as well as the percentage of children who manifested cry vocalizations, facial expressions of anger and sadness are presented in Table 1. Within the age

Table 1
Means, standard deviations, and percentages for the variables measured during baseline and test phase for each age group.

		Age groups											
		1-month-olds (*N* = 19)			3-month-olds (*N* = 32)			6-month-olds (*N* = 34)			9-month-olds (*N* = 36)		
		M	SD	%	*M*	SD	%	*M*	SD	%	*M*	SD	%
Cry vocalizations	Baseline	.00	.00	0	.00	.00	0	1.51	4.86	9	1.38	6.13	5.4
	Test	23.89	25.72	68.42	24.62	29.98	59.38	43.04	37.78	76.47	38.03	29.03	77.78
Mean intensity of cry	Baseline	.00	.00	N/A	.00	.00	N/A	.09	.29	N/A	.05	.23	N/A
	Test	1.65	1.50	N/A	1.57	1.61	N/A	2.41	1.80	N/A	2.00	1.33	N/A
Latency to onset of cry	Baseline		N/A			N/A			N/A			N/A	
	Test	17.89	11.87	N/A	19.81	11.40	N/A	12.91	11.97	N/A	12.64	10.87	N/A
Facial expression of anger	Baseline	3.50	11.88	10.53	2.87	7.80	12.50	1.51	7.86	8.82	2.31	7.07	11.11
	Test	24.62	25.72	65.16	32.97	31.72	84.38	41.15	36.95	73.53	37.58	29.95	77.78
Facial expression of sadness	Baseline		N/A		.00	.00	0	.50	2.9	2.94	.00	.00	0
	Test		N/A		3.45	6.11	34.37	16.90	29.95	50	6.26	15.68	27.78

groups, for the test phase, 68.42% of the 1-month-olds, 59.38% of the 3-month-olds, 76.47% of the 6-month-olds, and 77.78% of the 9-month-olds expressed cry vocalizations. Among them, 47.4% 1-month-old infants, 38.7% 3-month-old infants, 64.7% 6-month-old infants, and 69.4% 9-month-old infants had the onset of crying within 199 s from the beginning of the stimulus presentation.

2.1. Contagious crying measurement

We have proposed to use several indices of vocal expressions of emotions (cry vocalizations, intensity of cry vocalizations, and latency to the onset of cry) as an optimal measure of contagious crying reactions and of facial emotional expressivity (facial expressions of anger and distress). As a consequence, we analyzed if these measures are indeed tapping aspects of the same emotional reaction. Factor analysis with principal component analysis has been conducted for this purpose, including the data from the entire sample. All the indices have been included in the analysis after meeting the multicollinearity and singularity criterion (see Table 2). Further, the pattern of correlation between these indices is relatively compact (KMO = .821), showing that they are related (Bartlett's $X^2 = 470.769$, $p = .0001$), and that the analysis is adequate.

The contagious cry indices loaded on a single factor that explains 73.74% of the variance. The loadings of indices (cry vocalizations .961; latency to the onset of cry −.933; mean intensity of cry .909; facial expression of anger .896; facial expression of sadness .513) suggest that they reflect different, but related, aspects of the contagious cry reaction. Particularly, facial expression of sadness loaded less on the general factor compared to the other indices, and it may represent a subcomponent of emotional reactivity to another's distress (Zahn-Waxler, Radke-Yarrow, Wagner, & Chapman, 1992). For this reason, further analysis was based on individual scores for each dimension of contagious crying.

2.2. Age and gender differences

2.2.1. Age

A two-way 2 (condition: baseline vs. test phase) × 4 (age: 1-month-old vs. 3-month-old vs. 6-month-old vs. 9-month-old) mixed ANOVA, with repeated measures on the first variable, was performed for cry vocalizations, intensity of cry, and anger. We are reporting the results using the Greenhouse–Geisser correction for the violations of the assumptions of variance homogeneity.

No significant main effect was found for whether infants differed in their cry vocalizations according to their age ($F(3, 113) = 2.491$, $p > .05$). Importantly, for infants of all ages we had a significant effect of condition ($F(1, 113) = 122.899$, $p < .01$), but no significant interaction between condition and the age group ($F(3, 113) = 1.904$, $p > .05$). This shows that infants man-

Table 2
The intercorrelations matrix between indices of contagious crying.

	Cry vocalizations	Mean intensity of cry	Latency to the onset of cry	Facial expression of sadness	Facial expression of anger
Cry vocalizations	1.00	.83**	−.92**	.36**	.87**
Mean intensity of cry	.83**	1.00	−.79**	.44**	.75**
Latency to onset of cry	−.92**	−.79**	1.00	−.38**	−.78**
Facial expression of sadness	.36**	.44**	−.38**	1.00	.30**
Facial expression of anger	.87**	.75**	−.78**	.30**	1.00

Determinant = .008 (the value is greater than .00001 suggesting that the multicollinearity criterion for the matrix is met – Field, 2000).
** $p < .001$.

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ifested statistically significant more crying vocalizations during the presentation of the cry sound, and these differences have no significant chances to be related to the fact that naturally infants of a certain age group may cry more or less in the absence of any stimulation (Table 1).

Also, it seems that infants of all ages included in the study happen to cry with a similar intensity ($F(3, 113) = 1.802$, $p > .05$). We found a significant main effect of condition ($F(1, 113) = 163.717$, $p < .01$), with infants crying more intensely during the cry stimulus presentation than during the silent baseline. The effect recorded during the test phase seems to be mainly due to the stimulus presentation, as we had no significant effect for the interaction between age and condition ($F(3, 113) = 1.250$, $p > .05$) (Table 1).

In terms of emotional facial expressivity, infants express significantly more anger during the cry stimulus presentation than during baseline ($F(1, 113) = 101.725$, $p < .01$). There was no main effect of age group ($F(3, 113) = .842$, $p > .05$). Further, we found no effect of the interaction between the age group and the condition ($F(3, 113) = 1.441$, $p > .05$), showing that infants express significantly more anger during the test phase than during the baseline, and that these effects are not due to the fact that some age groups manifest naturally more angry facial expression than others.

For the case of the facial expression of sadness, due to a lack of normal distribution within the data (Kolmogorov–Smirnov $Z = 3.092$, $p > .05$), we performed between subjects nonparametric comparisons on the difference score between the test phase and the baseline. Infants manifested similar levels of facial expression of sadness changes irrespective of the age group to which they belonged ($\chi^2(2, 98) = 4.941$, $p > .05$).

Kruskal–Wallis nonparametric tests were used to investigate age differences for the latency to the first bout of crying during the test phase (as a non-normal distribution of the data was recorded – Kolmogorov–Smirnov $Z = 3.092$, $p > .05$). We found a significant overall age effect ($\chi^2(3, 121) = 2.081$, $p = .05$). Pair wise comparisons revealed that 3-month-old infants had a longer latency to the first bout of cry vocalizations from the initiation of the auditory stimulation than both 6- ($U = 365.00$, $p < .05$) and the 9-month-old infants ($U = 397.500$, $p < .05$). All the other age groups manifested similar latencies to the first bout of cry vocalizations.

Pearson Chi-squared show that infants from all age groups manifested cry vocalizations ($\chi^2(3) = 3.464$, $p = .325$), facial expression of anger ($\chi^2(3) = 3.127$, $p = .372$), and facial expression of sadness ($\chi^2(3) = 3.859$, $p = .145$) with the same frequency during the test phase.

2.2.2. Gender

No significant gender differences have been recorded for any of the contagious crying indices ($ps > .05$), with males and females within each age group manifesting similar patterns of facial and vocal expressivity in response to the perception of another infant cry when compared to the silent baseline (Fig. 1).

3. Discussion

This aim of the current study was to investigate the contagious cry phenomenon beyond the first few days of postnatal life. The results show that infants 1, 3, 6, and 9 months of age manifest contagious crying reactions in response to the sound of an infant vocalizations of distress (i.e. cry). Previous studies have documented that the detection of another conspecific's sound of distress triggers distress reactions in newborns, preschoolers and school age children (Dondi et al., 1999; Fabes, Eisenberg, Karbon, Troyer, et al., 1994; Martin & Clark, 1982; Simner, 1971; Sagi & Hoffman, 1976; Zahn-Waxler et al., 1983). Contagious crying reactions are regarded as a first sign of emotional sharing in humans, with relevance for empathy development (Decety & Jackson, 2004; Hoffman, 1975, 2000; Singer, 2006; Zahn-Waxler et al., 1983), and they have been hypothesized to diminish around the age of 6 months (Hoffman, 2000), due to the development of several factors implicated in its modulation, such as emotion regulation development and/or an increasingly better ability to differentiate between self and other entities. Our data indicated that this did not occur, and showed for the first time that there was uniform processing and reactivity to the cry of a conspecific throughout the first postnatal year.

We presented infants aged 1–9 months with the sound of a 3-month-old infant cry recorded during a blood sampling procedure. Given the complexity of the behavioral aspects that index emotional reactivity (Weinberg & Tronick, 1994; Yale, Messinger, Cobo-Lewis, Oller, & Eilers, 1999), different, but related aspects of emotional expressivity (facial expressions of anger and sadness, cry vocalizations, intensity, and latency of vocal reactions of distress) have been recorded. The cry stimulus triggered emotional reactions of distress, as has been previously reported in newborns (Dondi et al., 1999; Martin & Clark, 1982; Sagi & Hoffman, 1976; Simner, 1971). During the first 3 months after birth, infants cry more than later on during infancy (Barr, 1990). Since the age of 3 months is the end of such a higher frequency crying period, it could have been expected that the younger age groups in our study would cry more than the older infants during both the baseline and the test phase. However, such an effect was not found.

Contrary to predictions, infants of all ages included in the study expressed similar levels of vocal and facial expressions of distress. Although it has been expected that vocalizations of distress would be lower for older infants due to increased regulatory abilities when contrasted with younger infants, we found that, in general, infants of 1, 3, 6, and 9 months cried with the same duration and intensity. Importantly, older infants, of 6 and 9 months of age appear to have a shorter latency for cry vocalizations than the 3-month-olds, suggesting a faster emotional contagion reaction to the perception of another infant cry.

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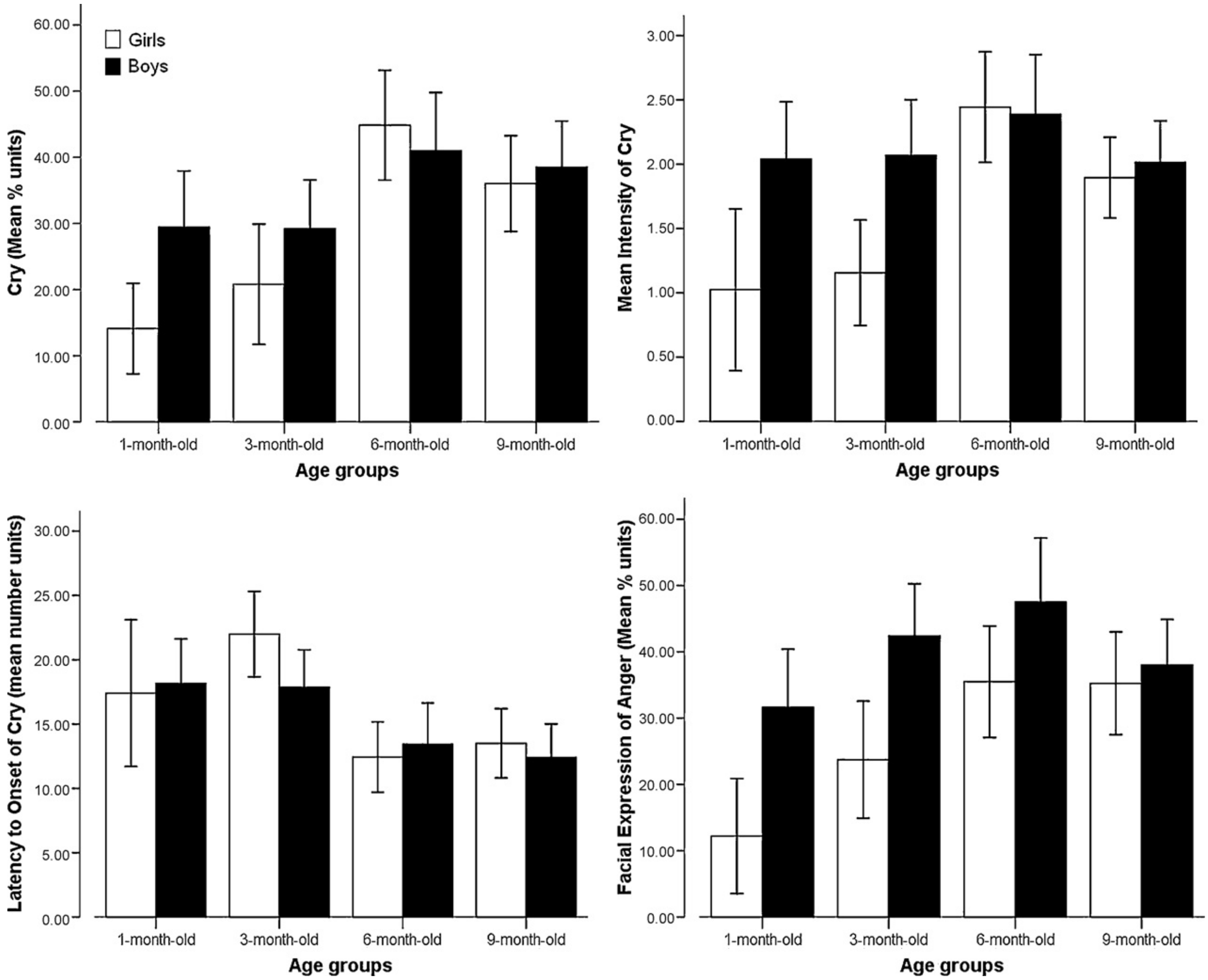

Fig. 1. Mean values for contagious crying indices (with SEs) during test phase for girls and boys according to the age groups.

The differences found in terms of latency to vocal distress might be partially explained by increased vocal reactivity during the second half of the first year (Gartstein & Rothbart, 2003). Further, starting with the age of 5 months, infants are better at discriminating between vocal expressions of emotions (Walker-Andrews & Grolnick, 1983; Walker-Andrews & Lennon, 1991). In addition, even in the absence of visual stimuli indicating facial expressivity, auditory stimuli that are affectively loaded trigger enhanced sensory processing, and 7-month-old infants allocate more attentional resources to words spoken with an angry prosody than to neutral words (Grossmann, Striano, & Friederici, 2005), suggesting that affective auditory stimuli are highly salient, and are processed with priority.

The salience of the stimulus along with infants' increasing abilities to discriminate between emotional prosodies may explain why for infants at 1, 6, and 9 months of age the cry of an infant from a different age to their own (i.e. a 3-month-old infant) was successful in triggering emotional contagion reactions. Also, the increased similarity between the infants' own cry and the cry sound of another infant, even when they differ in age (Wermke et al., 2002), may have favored the emotional contagion. That infants from all the age groups included in the study manifest similar levels of emotional contagion reactions in response to a 3-month-old pain cry partially supports its efficiency.

Further investigations will help shed light on infant's abilities to process and discriminate between different non-verbal vocalizations with negative or positive affective valence, and how they reflect on affect sharing. It would thus be of interest to analyze what are the behavioral and neurobiological correlates of non-verbal emotional prosodies like crying and laughing. Also, given the differences in communication value between cries with different intensities (Gustafson et al., 2000), it would be of particular importance to investigate if these are associated with differences in the emotional response induced in the perceiver. Is it necessary, for example, for an emotional prosody to have a specific intensity in order to trigger an affect sharing response in infants?

We measured contagious crying reactions both at the level of vocal and facial expressivity. Emotional facial expressions of anger and sadness produced during the presentation of the cry stimulus closely support vocal reactivity. Infants aged

1–9 months manifested anger when they heard the sound of distress of another infant, independently of the age group to which they belonged. Although less present, facial expressions of sadness were also triggered by the cry stimulus, and their significant association with the other contagious cry aspects argue for its inclusion in further analysis of these types of emotional reactions.

Importantly, emotional facial expressions have been triggered by an auditory stimulus. Previous studies with newborns suggest that the emotional reactions to the perception of another infant cry are the result of emotional contagion, rather than reactions to an aversive sound. In adults, facial muscle activity specific for a certain emotion expression is triggered also by the perception of vocal and bodily expressions of the same emotion (Magnée, Stekelenburg, Kemner, & de Gelder, 2007), suggesting that different modalities of emotion expressivity (facial, verbal, postural) are connected, and, as a result, the perception of one emotional modality might activate the generation of a variety of connected expressive acts. This might also be the case for infants, where the perception of vocalizations of distress can lead to the same vocal reactions in the observer, along with emotional expressions in another modality (i.e., facial expressions). Our study does not provide a definitive test for this hypothesis. Further studies that will investigate infants' emotional reactions in different modalities to other infant facial, facial + vocal, and/or vocal expressions of emotion might provide additional evidence for the exact processes underlying the affective sharing phenomena in infancy.

Mirroring the emotions observed in other people plays a significant role in social interaction (Bavelas, Black, Lemery, & Mullett, 1987; Gallese, Keysers, & Rizzolatti, 2004). This is particularly important as empathy plays a key role in social-cognitive functioning. For example, children who seem to construe a shared representation for their own emotions and those observed in people they encounter report higher empathic reactions for everyday life events, and are seen by others as more socially competent (Pfeifer, Iacoboni, Mazziotta, & Dapretto, 2008). Emotional mirroring or emotional contagion seems to involve complex processes relying on both action-relevant and emotion-relevant brain circuitries, including the mirror neuron system, the amygdala and the anterior insula (Keysers & Gazzola, 2006; Pfeifer et al., 2008). Patterns of neural activity that suggests the presence of these mechanisms already in infancy have been investigated (Del Giudice, Manera, & Keysers, 2009; Lepage & Théoret, 2007; Nyström, 2008), and they may be potentially relevant for the study of the development of emotional contagion. Further research that investigates both behavioral and neurophysiological aspects of infants' reactions to emotional prosodies with positive and negative valence will facilitate a better understanding of the mechanisms underlying affect sharing development during infancy.

Despite our initial hypothesis, contagious crying did not diminish or disappear as infants grew older. Rather, the cry reactions in 6- and 9-month-olds were either similar in length and intensity to those of their younger peers or tended to have a faster latency. Further, facial expressivity suggesting distress, either in the form of anger or sadness, recorded a similar pattern across ages. Although for the sample included in the current study there seems to be a trend towards an increase in contagious cry reactions starting at 6 months of age, it did not reach significant levels. During this age interval, important changes take place in the development of children's emotional reactivity (Gartstein & Rothbart, 2003) and of specific neural mechanisms involved in translating the emotions of others into the observer's own emotions (Del Giudice et al., 2009; Lepage & Théoret, 2007; Nyström, 2008). These changes may be associated with the ontogenetic course of emotional contagion.

Although present as early as few days after birth, emotional contagion reactions seem to be already under the influence of the infants' social environment. For example, 2-week-old infants of depressed mothers do not differentiate between their own cry and the cry of another infant (Field et al., 2007). We know that maternal emotional disposition influences the way infants process the emotional expressions they see in others (de Haan, Belsky, Reid, Volein, & Johnson, 2004), and that mothers tend to manifest a stable interaction style with their infants (Bigelow & Rochat, 2006). Therefore, it would be interesting to further investigate what are the relations between the development of emotional contagion reactions and different aspects of the social environment in early infancy.

Several pathologies with early onset in development, like autistic spectrum disorders, are characterized by impairments in empathic reactions (Lombardo, Barnes, Wheelwright, & Baron-Cohen, 2007). As early as 20 months of age, children with autistic traits show reduced empathic concern in response to someone else's distress when contrasted with typically developing infants (Charman et al., 1997). Given that emotional contagion is an empathy component, a comparative analysis of responses to emotional non-verbal prosodies in typically developing infants and infants at risk for autism (i.e. siblings of children with autistic spectrum disorders) would be particularly informative for the understanding of the developmental mechanisms, and could prove to be useful for early diagnosis of this pathology.

Although the current study is an important step for advancing our understanding of infants' emotional resonance to the emotions they observe in others, there are several limitations that need to be acknowledged. The cross-sectional design and the limited age range does not allow for a full interpretation of results regarding the ontogeny of contagious crying. Further studies could address this limit by analyzing how the same infants respond to cry sounds at different ages. The longitudinal analysis will also be beneficial for the analysis of the predictive value of infants' emotional contagion responses for the later developing empathic concern. Zahn-Waxler et al. (1992) argued that sadness in response to the distress observed in another is more a sign of other-oriented empathic response, while anger is more a self-oriented distress. How sadness and anger triggered within a contagious crying paradigm early in infancy relate to the later emerging other-oriented and self-oriented emotions observed in classic tasks will be of particular interest for such a longitudinal study.

The use of a singular stimulus, the pain cry of a 3-month-old infant, could also be seen as a limit for the interpretation of our current results. Previous studies show that newborns manifest increased distress to the cry sound of another same age infant than to the cry of an older infant (Simner, 1971), and it may be argued that a similar effect could be encountered in older infants as well. Our 3-month-old group was presented with the cry of an infant same age with them, but they did not cry more or manifested other indices of negative affect more than the other age groups who were not presented with an age matched stimulus. Also, the 1-month-olds included in our study were the closest in age to the newborns included in previous studies. Despite being presented with the cry sound of an older infant, the percentage of infants that cried in our study is very similar to the one recorded in newborns (68.42% vs. 64% in Simner's study (1971)). Further studies that address this issue will have to surpass the methodological challenge of finding age matched stimuli that are uniform. While for newborns this has proven to be fairly easy because of the neonatal assessment that includes the pain inductive heel prick procedure, ethical considerations limit its use in older infants. As previously mentioned (Rothgänger, 2003) cry melodies become increasingly efficient in signaling acute distress with the age of 3 months. This may allow their use across ages, for both infants and older children (e.g., Spinrad and Stifter's study (2006) uses one cry stimulus for 18-month-old participants).

In sum, this study provides evidence for the existence of the contagious cry reaction during the age interval from 1 to 9 months. During the presentation of a pain cry sound, 1, 3, 6, and 9 months old infants manifested increased vocal and facial expressions of distress. These results support and expand the findings of previous studies investigating newborn behavior (Dondi et al., 1999; Field et al., 2007; Martin & Clark, 1982; Sagi & Hoffman, 1976; Simner, 1971), evidencing the presence of emotional contagion reactivity throughout infancy.

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