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HAL Authorization

Adults learn to identify pain in babies' cries

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eTOC blurb

Using playback experiments, Corvin et al. show that current parents of young babies are able to identify a baby's pain cries even if they have never heard this baby before, whereas inexperienced individuals are typically unable to do so. This shows how parenting shapes our ability to decode the information conveyed by babies' communication signals.

Because the expression of pain in babies' cries is based on universal acoustic features, it is assumed that adult listeners should be able to detect when a crying baby is experiencing pain^{1-5,51-54}. Here, we show that detecting that a baby's cry expresses pain actually requires learning through experience. Indeed, our psychoacoustic experiments reveal that adults with no experience of caring for babies are unable to identify whether a baby's cry is a pain cry induced by vaccination or a mild discomfort cry recorded during a bath, even when they are familiar with the discomfort cries from this particular baby. In contrast, people with prior experience of babies (parents or professional caregivers) identify a familiar baby's pain cries without having heard these cries before. Parents of very young children are even able to identify the pain cries of a baby who is completely unfamiliar to them. These results underline the extent to which exposure through caregiving and/or parenting shapes the auditory and cognitive abilities involved in decoding the information conveyed by the baby's communication signals.

In mammals, parental care is often accompanied by striking acoustic displays from the offspring⁵⁵. These vocalizations -called "distress calls" or "cries"- are typically triggered by pain, discomfort, hunger, or separation from parents or other caregivers⁵⁶. While some of the information carried by these calls is static and relates to individual characteristics of the emitter (sex, age, size), some is dynamic and related to their current emotional and physiological states (immediate needs)⁴. Caregivers can therefore acquire critical information by listening to these vocalizations, and the amount of parental care they will provide depends primarily on this information^{3,57}.

The expression of pain is vital information that prompts caregivers to act⁵⁸. Compared with signals of lesser distress, infant cries expressing pain are longer, louder, with more variable pitch, as well as harsher and rougher due to nonlinear phenomena (chaos, sub-harmonics, etc)^{6,59}. Previous studies have highlighted the ubiquity of these pain-coding acoustic features in infant cries from a range of mammalian species, and suggested that caregivers are able to innately decode these universal acoustic properties^{5,510-513}. However, recent research has shown that experience and familiarity can affect the perception of infant cries, both between and within species. For example, human listeners unfamiliar with bonobos and chimpanzees have a limited ability to range the emotional content of these apes' infant vocalizations, because humans rate these usually high-pitched calls according to the same scaling rule they use for human babies⁵¹⁴. More crucially for our species, it is well-established that exposure

and familiarity improve the ability of human parents to recognize their babies from their cries, suggesting that experience shapes our ability to decode infant cries^{7,8}. However, the factors driving human listeners' judgements and responses to baby cries have not been thoroughly explored², and it is not known whether experience improves caregivers' ability to judge whether a baby's cry is expressing pain.

In the present study, we tested the hypothesis that having prior caregiving experience with babies facilitates the identification of cries expressing pain. We predicted that listeners with extensive prior exposure to baby cries (such as parents or baby care professionals) would be more successful at this task. We also predicted that listener familiarity with the cries of a given baby would facilitate the identification of their pain cries. To test this we recorded cries produced by babies in two contexts: mild-discomfort cries given during bathing at home and pain cries during a vaccination sequence in the paediatrician's medical office (Figure 1A), and then conducted psychoacoustic experiments with adult participants having different levels of experience with babies: individuals with no experience with babies (N = 25 men, 25 women), non-parents with moderate non-professional experience such as occasional babysitting or caring for younger siblings (N = 25 men, 26 women), parents with children at least 5 years old at the time of the experiments (N = 25 fathers, 25 mothers), parents with babies less than 2 years old (N = 25 fathers, 27 mothers), and non-parents with extensive professional caregiving experience (N = 1 man, 30 women).

The experimental procedure consisted of a training phase followed by a test phase (Figure 1B). During the training phase which occurred on two successive days, each participant heard 8 different discomfort cries (4 on each day) from the same assigned baby (mean duration of sequences = 6.3 ± 1.1 seconds). Previous studies have established that adult listeners become familiar with an assigned baby's cries after a small number of short crying sequences, and quickly become able to recognize this familiar baby from their cries alone⁸. A few hours after the end of the training phase, each participant entered the test phase in which they listened to new cry sequences from their familiar baby (2 discomfort and 2 pain cries) and from an unknown baby (2 discomfort and 2 pain cries), and was asked to categorise each of these cries as "discomfort" or "pain" (see Supplemental information for methodological details).

The results show that listeners' ability to categorize baby cries as discomfort or pain depends on their prior and current experience with babies (Figure 1C, Table S1). Nonparents without experience with babies were unable to identify the two contexts better than chance (Bayesian mixed model, 54.3 % of correct recognition, 95 % CI [45.9, 62.3], 84.4 % of the posterior distribution PD above the chance level of 50 %). Nonparents with moderate experience showed a moderate ability to identify the crying context (57.3 % [49.0, 65.0], 96.2 % of PD > 50 %), only recognizing the pain cries of their familiar baby better than chance (65.3 % [51.8, 77.3]). In contrast, adults with strong experience with babies, either because they were parents or because they were pediatric care professionals, identified the crying context of their familiar baby better than chance (65.5% [56.4, 74.1], 71.2 % [61.7, 78.9] and 71.1% [60.2, 80.2] with 99.9, 100 and 100 % of PD > 50 %, respectively for parents of children older than five years of age, parents of younger babies, and professional pediatric caregivers). Remarkably, parents of younger babies were also able to identify the crying contexts of an unknown baby they had never heard before (64.2 % [53.8, 73.1], 99.5 % of PD > 50 %). Interestingly, we found that both parents of children older than five and non-parents with extensive experience performed at chance level in their ability to identify pain cries from an unfamiliar baby. This is consistent with observations indicating that experienced listeners can develop a resistance that decreases their sensitivity to acoustic cues of pain^{S3, S15, S16}. We found no effect of listener sex (see Supplemental information for details of the results).

In short, our results indicate that having experience with babies facilitates the correct identification of pain condition through the use of acoustic information. The acquisition of this ability through exposure is likely supported by the neurobiological changes that accompany parenthood and, more generally, infant care^{9,10,S17,S18}. From an evolutionary perspective, it is now well established that humans are cooperative breeders, which is rare among primates^{S19}. Human baby cries have thus evolved in a network of emitters and listeners, including the core of the baby's family (the baby, mother, father and siblings) as well as other potential caregivers (e.g. grandparents and more distant relatives, unrelated individuals)^{S20,S21}. Our study shows that it is through experience that these diverse caregivers become expert interpreters of the infants' cries, allowing them to efficiently identify, and thus appropriately respond to the encoding of pain in cries.

Supplemental information

Supplemental information including experimental procedures, one table, references and sound files can be found with this article online at [XXX](#).

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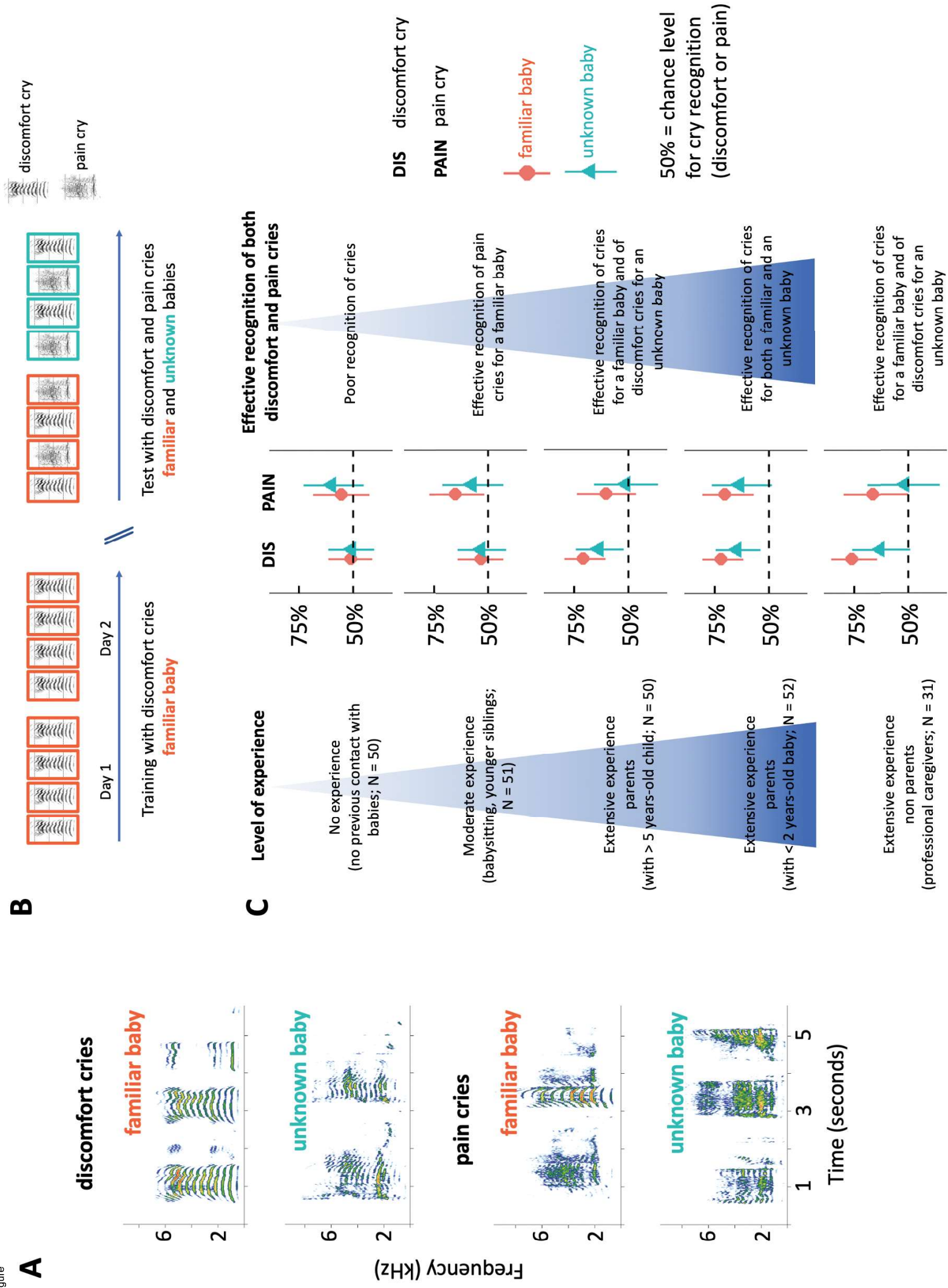
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Declaration of Interests

The authors declare no competing interests.

Figure Legend

Figure 1. Playback experiment testing the ability of Human adult listeners to identify pain in a baby's cry. (A) Examples of babies' cries used in the experiments. Pain cries differ from discomfort cries by being more chaotic (higher levels of roughness). The cries are from two different babies, highlighting the inter-individual differences (these sound files are available as Supplementary material). (B) Timeline of the experimental procedure. Adult subjects began by hearing discomfort cries from an assigned baby in two successive sessions (training sessions with a « familiar » baby; cries previously recorded while the baby was bathing; 8 different cry sequences from the same baby; duration of cry sequences = 6.3 ± 1.1 seconds). In a second step, subjects listened to successive sequences of cries from either their familiar baby or an unknown baby (4 different sequences from each baby). The cries were either discomfort cries or pain cries (recorded during vaccination sessions). Subjects were asked to classify each cry as either « discomfort » or « pain » cry. The discomfort cries from the familiar baby were different between the training and test sessions. Familiar and unknown babies differed between the tested subjects. The order of presentation of the discomfort and pain cries was random, and the order of presentation of the familiar and unknown baby cries was balanced among the tested subjects (see Supplemental Information for details). (C) Results of the playback tests. Solid disks and triangles represent the medians of the posterior distributions, with bars indicating the 95% CI. The dotted lines indicate the 50% chance level. The ability of tested adults to recognize cries as cries of "discomfort" or "pain" depended on their experience with babies. Whereas inexperienced individuals randomly categorized both the familiar and unknown baby's cries, parents currently raising a baby correctly identified the cries in both cases. Overall, the ability to identify cry is improved by prior and current experience with babies.



SUPPLEMENTAL INFORMATION:

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	Discomfort cries		Pain cries		Familiar baby (discomfort and pain cries)	Unknown baby (discomfort and pain cries)
	Familiar baby	Unknown baby	Familiar baby	Unknown baby		
Nonparents without experience with babies	54.3 [45.9 - 62.3] P($\delta > 50$) = 84.4%				53.3 [43.7 - 62.8] P($\delta > 50$) = 75.8%	55.3 [45.1 - 64.6] P($\delta > 50$) = 85.7%
	51.0 [42.4 - 59.7] P($\delta > 50$) = 59.8%		57.7 [45.0 - 69.0] P($\delta > 50$) = 89.7%			
	51.1 [41.0 - 61.2] P($\delta > 50$) = 58.6%	50.8 [40.1 - 61.3] P($\delta > 50$) = 56.5%	55.4 [42.3 - 68.3] P($\delta > 50$) = 80.0%	59.9 [45.1 - 72.6] P($\delta > 50$) = 91.1%		
Nonparents with moderate experience	57.3 [49.0 - 65.0] P($\delta > 50$) = 96.2%				59.4 [49.9 - 68.2] P($\delta > 50$) = 97.4%	55.4 [45.1 - 64.6] P($\delta > 50$) = 85.6%
	53.4 [44.5 - 62.0] P($\delta > 50$) = 78.4%		61.3 [49.2 - 72.4] P($\delta > 50$) = 96.9%			
	53.5 [43.1 - 64.1] P($\delta > 50$) = 74.3%	53.3 [41.7 - 64.1] P($\delta > 50$) = 71.8%	65.3 [51.8 - 77.3] P($\delta > 50$) = 98.3%	57.6 [42.7 - 70.8] P($\delta > 50$) = 84.8%		
Parents with child at least 5 years old	61.4 [53.3 - 69.3] P($\delta > 50$) = 99.5%				65.5 [56.4 - 74.1] P($\delta > 50$) = 99.9%	57.2 [46.8 - 67.1] P($\delta > 50$) = 92.5%
	67.1 [58.7 - 74.7] P($\delta > 50$) = 100%		55.8 [43.4 - 67.6] P($\delta > 50$) = 83.8%			
	70.8 [60.6 - 79.2] P($\delta > 50$) = 100%	63.7 [51.9 - 73.9] P($\delta > 50$) = 98.8%	60.4 [46.3 - 73.5] P($\delta > 50$) = 93.4%	51.2 [36.4 - 65.6] P($\delta > 50$) = 56.9%		
Parents with baby under 2 years old	67.6 [59.6 - 74.8] P($\delta > 50$) = 100%				71.2 [61.7 - 78.9] P($\delta > 50$) = 100%	64.2 [53.8 - 73.1] P($\delta > 50$) = 99.5%
	68.3 [59.8 - 76.0] P($\delta > 50$) = 100%		66.8 [55.0 - 76.9] P($\delta > 50$) = 99.5%			
	72.2 [61.7 - 80.8] P($\delta > 50$) = 100%	64.7 [53.6 - 74.6] P($\delta > 50$) = 99.5%	70.4 [57.1 - 80.7] P($\delta > 50$) = 99.6%	63.7 [48.8 - 76.3] P($\delta > 50$) = 96.5%		
Professional caregivers	64.1 [54.8 - 72.7] P($\delta > 50$) = 99.7%				71.1 [60.2 - 80.2] P($\delta > 50$) = 100%	57.2 [45.5 - 69.0] P($\delta > 50$) = 88.4%
	69.5 [59.4 - 78.5] P($\delta > 50$) = 100%		58.8 [45.0 - 71.6] P($\delta > 50$) = 90.1%			
	76.3 [64.3 - 85.3] P($\delta > 50$) = 100%	63.1 [49.1 - 75.7] P($\delta > 50$) = 96.6%	66.4 [49.9 - 79.7] P($\delta > 50$) = 97.4%	51.5 [35.5 - 68.6] P($\delta > 50$) = 57.2%		

Table S1. Results of the analysis of participants' responses to the playback experiment.

Adult subjects listened to cries from either a familiar baby or an unknown baby. They were asked to classify each cry as either « discomfort » or « pain » cry. Bayesian mixed model: outcome variable = success in recognizing the context of crying (discomfort or pain); fixed factors = correct context (discomfort or pain), baby status (familiar or unknown), participant experience with babies (5 levels of experience; see Supplemental Experimental Procedures for details); random factors = participant identity and baby identity. Posteriors distributions of model parameters are summarized by their medians, 95% credible intervals, and the percentage of posteriors being above the chance level of 50%.

	No experience	Moderate experience	Extensive experience: parents with > 5 years-old baby	Extensive experience: parents with < 2 years-old baby	Extensive experience: non-parents professional caregivers
Age: mean \pm SD (min-max)	24.3 \pm 5.4 (18-39)	24.2 \pm 4.7 (18-38)	40.0 \pm 5.6 (28-50)	32.3 \pm 5.5 (20-40)	28.7 \pm 6.7 (23-51)
Correlation between age and success	r = 0.03; p = 0.85	r = 0.11; p = 0.42	r = 0.22; p = 0.11	r = 0.04; p = 0.78	r = 0.21; p = 0.26
Nationality of participants	Average success in % (number of participants)				
Belgium	62,5% (2)		62,5% (1)		
Brazil		75% (1)			
Bulgaria			75% (1)	62,5% (2)	
Colombia				50% (1)	
Egypt			50% (1)		
Estonia				62,5% (2)	
France		50% (2)	58,3% (3)		62,5% (27)
Germany	50% (1)	37,5% (1)	75% (1)		
Hungary	75% (1)				
India	75% (1)	75% (1)		25% (1)	
Iran		87,5% (1)			
Ireland		75% (1)	70,8% (3)	62,5% (1)	
Israel				62,5% (1)	
Italy	54,2% (9)	55,4% (14)	57,5% (5)		75% (2)
Latvia				75% (1)	
Lithuania				87,5% (1)	
Luxembourg		50% (1)			
Morocco		75% (1)			
Netherlands			50% (2)	75% (2)	
Nigeria		62,5% (2)		75% (2)	
Pakistan		75% (1)	62,5% (1)		
Poland	50% (1)		62,5% (1)	60,4% (12)	
Portugal	54,2% (21)	52,1% (12)	51,8% (7)	43,8% (2)	75% (2)
Romania				75% (1)	
Russian Federation			75% (1)	87,5% (2)	
Serbia		25% (1)			
Spain	56,3% (2)	62,5% (5)	70% (5)	75% (1)	
Syrian Arab Republic		12,5% (1)			
Turkey	37,5% (2)	75% (1)			
Ukraine	37,5% (1)				
United Kingdom	47,2% (9)	57,5% (5)	60,3% (17)	71,1% (19)	
United States				87,5% (1)	
NA			100% (1)		

Table S2. Age and nationality of participants.

SUPPLEMENTAL EXPERIMENTAL PROCEDURES

Sound recordings.

Cry recordings were extracted from a cry database previously built by the ENES Laboratory⁴. Discomfort cries were recorded during bathing, undressing, or dressing by parents at the baby's home. Pain cries were recorded during scheduled routine vaccination at the doctor's office (N = 22 babies, 10 boys and 12 girls; age = 60.3 ± 3.4 days on the vaccination day; delay between recording sessions of discomfort cries and pain cries for a given baby = 6.9 ± 3 days). Two different vaccine were injected: a hexavalent DTPa-HBV-IPV/Hib vaccine (Infanrix Hexa[®]) and a 13-valent pneumococcal conjugate vaccine (Prevenar 13[®]). Cries were recorded with a microphone (Sennheiser MD42) placed at about 30 cm from the baby and connected to a portable digital audio recorder (Zoom H4n, sampling rate = 48 kHz, uncompressed .wav files). Using Audacity software (www.audacityteam.org), we isolated 284 cry sequences from these raw recordings (mean sequence duration = 6.3 ± 1.1 s; 4 sequences of pain cry per baby and 2-19 sequences of discomfort cry per baby). We took care to isolate sequences without background noise such as adult voices, water flowing or door slamming.

To limit pseudoreplication of stimuli among the participants tested in the playback experiment, we retained only those babies for whom we had at least 10 sequences of discomfort cry and 4 sequences of pain cry (N = 9; 3 boys, 6 girls). The sound intensity of the cry sequences was normalized to 100% of the maximal amplitude using the "normalize" function of the tuneR package (cran.r-project.org/web/packages/tuneR/index.html). These sequences were used as stimuli during the experiment, and are referred to as "discomfort cries" and "pain cries".

Participants.

Participants (N = 234) were recruited through the online platform Prolific (www.prolific.co/). They all reported normal hearing and were distributed as follows (mean age = 30 ± 8.2 years, min-max = 18-51):

- 50 participants were non-parents with no experience with babies (25 men, 25 women; mean age = 24.3 ± 5.4 years, min-max = 18-39);
- 51 participants were non-parents, had never had a child, and had moderate, nonprofessional experience with babies, such as occasional babysitting or looking after younger siblings (25 men, 26 women; mean age = 24.2 ± 4.7 years, min-max = 18-38);
- 50 participants were parents with children who were at least 5 years old at the time of the experiment (25 fathers, 25 mothers; mean age = 40.0 ± 5.6 years, min-max = 28-50).
- 52 participants were parents with at least one child under 2 years old at the time of the experiment (25 fathers, 27 mothers; mean age = 32.3 ± 5.5 years, min-max = 20-40);
- 31 participants were non-parents, had never had a child, and had extensive professional experience with babies (30 women, 1 man; mean age = 28.7 ± 6.7 years, min-max = 23-51; mean duration of professional exposure to babies = 5.2 ± 5.4 years, min - max = 5 months - 20 years).

All participants lived in Europe. The majority of participants (213 out of 234) were Europeans. The remaining 21 participants were from a variety of countries (India, North America, South America, Africa, Middle East).

Once recruited, participants were redirected to the Labvanced online platform (<https://www.labvanced.com/>) where the experiment was hosted. After completing the experiment, subjects were redirected to Prolific and paid at the recommended rate of 7.5 GBP per hour.

To ensure that participants were homogeneously motivated to participate in the test, we recruited regular users of the Prolific platform. On this platform, each participant is characterized by a Prolific score based on the approval/rejection ratio obtained during their participation in previous Prolific studies. When selecting subjects, we imposed a minimum threshold of 75/100 for this score. In the end, the average scores were much higher than this threshold, (around 99 for all groups tested), attesting to the high level of engagement of participants regardless of their category. Both the drop-out rate (number of participants who dropped out before the end/number of participants who started the study) and the time taken

by participants to answer each question (reaction time) were similar between groups (drop-out rate: min-max = 14-18 %; reaction time: min-max = 2-3 seconds).

Experimental procedure.

The experimental procedure consisted of two successive phases: a training phase in which participants listened to the discomfort cries of an assigned baby, and a testing phase in which participants were asked to rate the cries of their assigned baby and those of an unknown baby as “discomfort cry” or “pain cry”. The timeline of the experiment is shown on Figure 1B.

At the beginning of their training session, participants received the following instruction: “You are going to hear several cries of one baby, who will be named YOUR baby for the rest of this study. YOUR baby is in the bath, it is uncomfortable, YOUR baby is crying.” Then they listened to a succession of four discomfort cries from their assigned baby. This training was repeated a day later, using four more discomfort cries from the same assigned baby.

Participants then performed their test session a few hours after the end of the second training session (mean = 6.8 ± 5.5 h, range [3 - 29.3 h]). During the test, they listened to two successive sets of four cries: two pain cries and two discomfort cries presented in a random order. One of the two sets of cries came from their assigned, “familiar” baby. The other set of cries came from an unknown baby. The order of presentation of the two sets, familiar and unknown, was balanced among the participants. Before the start of each set of cries, participants were informed whether they would hear the cries of their assigned baby or an unknown baby. After each cry, participants were asked to estimate in a two-alternative forced choice whether the cry they heard was due to discomfort or pain. Participants were not told how many cries of discomfort or pain they would listen to.

Each participant was trained and tested with different cries, which avoided the possibility of idiosyncratic acoustic characteristics biasing the results. Randomization of cry stimuli across participants was achieved using the “*sample*” function in R statistical software (<https://www.r-project.org/>).

In this study, we chose to train the subjects only with discomfort cries because this design corresponds to the most common situation in real life. Indeed familiarity is expected to be acquired in discomfort cries rather than pain cries, as caregiver will regularly hear a baby

crying in discomfort (during bathing, nappy changing, etc.), whereas they should rarely hear a baby crying in pain.

Data analysis.

Participants' responses were analyzed with a Bayesian mixed model using the Stan modeling language (*brms* R package, cran.r-project.org/web/packages/brms/index.html). The outcome variable was success in recognizing the context of crying (discomfort or pain). Correct context (discomfort or pain), baby status (familiar or unknown), and participant experience with babies were included in the model as fixed factors. Participant identity and baby identity were included as random factors. Random slopes were defined using the Watanabe-Akaike information criterion for model selection (*WAIC*). To improve convergence and avoid overfitting, we specified mildly informative conservative priors. Posteriors distributions of model parameters were summarized by their medians and 95% credible intervals, reported as 95% CIs (see ^{S21} for interpretation of Bayesian CIs). The structure of the model in *brms* syntax was as follows: $\text{success} \sim \text{baby_status} \times \text{experience} \times \text{correct_context} + (\text{baby_status} + \text{correct_context} \mid \text{subjectID} + \text{babyID_stim})$.

Furthermore, focusing on the four groups of participants with a balanced number of men and women (i.e., excluding the group of participants with high professional experience with babies that was predominantly composed of women), we tested the potential effect of participant sex using the following model: $\text{success} \sim \text{sex} * \text{baby_status} * \text{experience} * \text{correct_context} + (\text{baby_status} + \text{correct_context} \mid \text{subjectID} + \text{babyID_stim})$. We found no effect of participants' sex on the attribution of cry context (in contrast to men, women were 1.2 % more successful [-4.5, 6.8], 66.3 % of posterior distribution (PD) > 0).

Ethical statement.

All experiments were approved by the local ethics committee (October 2019 – Comité d'Éthique du CHU de Saint-Etienne, Institutional Review Board: IORG0007394), and informed consent was obtained from all participants.

Resource availability

The distribution of the sound stimuli among the tested listeners, the code for the statistical analysis, and any other material are available upon request (mathevon@univ-st-etienne.fr).

Authors contributions.

All authors conceived the original idea for this research and designed the experiments. SC conducted the experiments and analyzed the results. All authors helped shape the research, analysis and manuscript. SC and NM took the lead in writing the manuscript with the help of CF and DR. All authors provided critical feedback.

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