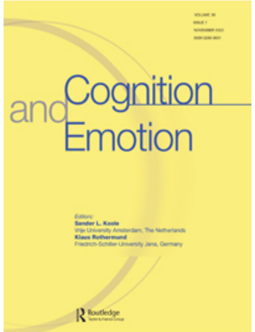

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Mothers need more information to recognise associated emotions in child facial expressions

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ABSTRACT

Parenting requires mothers to read social cues and understand their children. It is particularly important that they recognise their child's emotions to react appropriately, for example, with compassion to sadness or compersion to happiness. Despite this importance, it is unclear how motherhood affects women's ability to recognise emotions associated with facial expressions in children. Using videos of an emotionally neutral face continually and gradually taking on a facial expression associated with an emotion, we quantified the amount of information needed to match the emotion with the facial expression. Mothers needed more information than non-mothers to match the emotions with the facial expressions. Both mothers and non-mothers performed equally on a control task identifying animals instead of emotions, and both groups needed less information when recognising the emotions associated with facial expressions in adolescents than pre-schoolers. These results indicate that mothers need more information for to correctly recognise typically associated emotions in child facial expressions but not for similar tasks not involving emotions. A possible explanation is that child facial expressions associated with emotions may have a greater emotional impact on mothers than non-mothers leading to task interference but possibly also to increased compassion and compersion.

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Introduction

Parenting presents humans with a challenge: parents are responsible for understanding and caring for another human being that starts as completely dependent on them (Pereira & Ferreira, 2016). This requires them to be able to read social cues and understand their offspring even when their children are not able to properly express themselves; either because they are preverbal or because they are overwhelmed with expressing their thoughts and feelings clearly, especially when they are feeling strong emotions (Borelli et al., 2021; Swain et al., 2014). Therefore, social understanding is vital for parenting (Decety, 2011; Feldman, 2012, 2015).

Many aspects of social understanding rely on people correctly recognising the emotions of their counterparts. This includes comforting someone sad, celebrating with someone happy, offering protection to someone scared or giving space to someone angry. One important source of information to recognise

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someone's emotions are facial expressions. Although there are complex relationships between facial expressions and emotions (Barrett et al., 2019), some emotions are often associated with certain facial expressions. For example, while not everyone happy shows this with a smile, smiles often indicate the person being happy. Recognising typically associated emotions in facial expressions (FER) is especially vital for parents. On the one hand, the correct interpretation of facial expressions typically associated with emotions has been shown to be predictive of prosocial behaviour (Marsh et al., 2007). On the other hand, impairments of this process have consequences: mothers suffering from a depression, and their children have been shown to have a bias towards sadness, suggesting a transgenerational effect possibly leading to increased risk for depression in the child (Kluczniok et al., 2016). Nonetheless, research on how motherhood influences emotion processing and recognition in non-clinical populations is scarce, and most studies focus on infant facial expressions.

Studies investigating how mothers and non-mothers differ in linking a typically associated emotion with infant and child facial expressions have either found no behavioural differences (Matsunaga et al., 2018; Nishitani et al., 2011; Plank et al., 2022a) or increased response times in mothers (Proverbio et al., 2006). Proverbio and colleagues (2006) asked parents and non-parents to judge as accurately and quickly as possible whether an infant facial expression was positive or negative. The age of the parents' oldest child and, therefore, the duration of parenthood is not reported. They investigated response times as well as event-related potentials (ERPs), finding that parents were slower than non-parents and exhibited larger ERPs. Nishitani and colleagues (2011) used functional near-infrared spectroscopy (fNIRS) to investigate neural activity during FER in mothers of children between 9 and 36 months old and matched non-mothers using adult and infant faces as stimuli. They found no behavioural differences between mothers and non-mothers and increased activity in response to infant but not adult stimuli in the mothers in the prefrontal cortex. Matsunaga and colleagues (2018) used morphed pictures of infants and adults to determine sensitivity in a FER task. They found no effect of motherhood on sensitivity; however, since only primiparous mothers of infants less than one year old took part in the study, Matsunaga and colleagues raised the possibility that differences between mothers and non-mothers in emotion recognition might still develop. Plank and colleagues (2022b) compared mothers and non-mothers using a FER task with child (7- to 10-years-old) and adult faces during neuroimaging. Similar to Nishitani et al. (2011), they found no behavioural differences, neither in the FER task nor in a task where participants processed the same facial expressions typically associated with an emotion without being asked to recognise it. Even so, they found differences in child-evoked activation with mothers increasingly activating the precuneus.

These results fail to provide a clear picture of FER in mothers and non-mothers. While most studies report no behavioural differences (Matsunaga et al., 2018; Nishitani et al., 2011; Plank et al., 2022a), one study found increased response times in parents (Proverbio et al., 2006). Unfortunately, the sample size was small (nine fathers and mothers each), they did not report accuracies and there was no control task. It is, therefore, unclear if the slower responses were specific to FER: parenthood is often associated with more stress and less sleep, sometimes leading to parental burnout (Mikolajczak et al., 2019). This could lead to a general increase in response times on any task. In the case of the studies reporting no differences, two studies were designed to increase detection efficiency for neural activation and did not use sensitive behavioural tasks (Plank et al., 2022a). It is, therefore, crucial to compare mothers of children of various ages with non-mothers using FER and a matched control task to shed further light on the interaction of motherhood and FER.

Despite the mixed results reported in the aforementioned studies, there are convincing arguments that motherhood could positively affect FER of children. First, mothers tend to have more experience than non-mothers associating child facial expressions with specific emotions. Since an infant's emotional signals can be ambiguous and, therefore, harder to understand than an adult's (Sullivan & Lewis, 2003), this might give them an important advantage. However, influences based on experiences need time to develop. Second, research has revealed an attentional bias toward infant and child faces in both mothers and non-mothers (Lucion et al., 2017). Thompson-Booth and colleagues showed that facial expressions typically associated with an emotion interfered more strongly with an unrelated task in mothers than non-mothers (Thompson-Booth et al., 2014a; Thompson-Booth et al., 2014b). Furthermore, the difference in interference between mothers and non-mothers was larger for infant faces (6-12 months old) than adult faces. This suggests that mothers focus more strongly on infant facial expressions typically associated with an emotion than non-mothers, even if it is irrelevant for the task. This attentional bias may counteract the difficulty of interpreting more ambiguous facial expressions in infants (Sullivan & Lewis, 2003) and possibly children. It is, therefore, possible that mothers have an advantage compared to non-mothers in FER.

The present study aims to investigate FER of unfamiliar children in mothers and non-mothers using a sensitive task with children between 4 and 15 years old in three age groups (pre-schoolers, middle children and adolescents). We used videos gradually and continuously changing from a facial expression associated with emotional neutrality to expressions typically associated with a specific emotion (FER task). We hypothesised that mothers and non-mothers would differ in the amount of information needed to associate a specific facial expression of an unfamiliar child with a specific emotion than non-mothers. More specifically, we expected that mothers might need less information due to their increased experience and attentional biases towards facial expressions associated with emotions. For the same reason, we hypothesised that mothers would have higher discrimination of typically associated emotions of facial expressions. We expected that mothers and non-mothers would not differ in a control task, where an emotionally neutral face turns into an animal face. Additionally, we explored the effect of typically associated emotion and age group of the child individually and in interaction with motherhood on the amount of information needed, discrimination of emotions and bias towards certain emotions.

Table 1. Group comparisons (mean and standard error) and results of the Bayesian Mann-Whitney-U tests corrected for multiple comparisons.

Measurement	mothers	non-mothers	BF_{10}	W
age	39.85 ± 1.23	36.47 ± 1.46	0.388	407
no. children (0–3)	1.82 ± 0.10	–	–	–
age children (0–28 years)	8.72 ± 0.10	–	–	–
ERQ	39.42 ± 1.07	40.59 ± 1.31	0.131	678
KSE-G	1.62 ± 0.06	1.76 ± 0.06	0.254	704
mood state: online	3.94 ± 0.14	4.06 ± 0.12	0.094	586
mood state: in person	4.21 ± 0.10	4.12 ± 0.10	0.099	516
SES	12.91 ± 0.28	13.34 ± 0.47	0.189	688
SoVT compassion	63.76 ± 2.40	58.35 ± 2.88	0.165	456
SoVT empathy	44.65 ± 2.73	46.11 ± 2.92	0.081	607
TAS	38.09 ± 1.26	38.32 ± 1.15	0.083	562
WAIS®-IV (matrices)	10.71 ± 0.40	9.67 ± 0.48	0.173	480

Note. ERQ = emotion regulation questionnaire; KSE-G = Kurzskala Soziale Erwünschtheit-Gamma (social desirability scale); SES = socioeconomic score; SoVT = socio-affective video task; TAS = Toronto alexithymia scale; WAIS®-IV = Wechsler Adult Intelligence Scale – 4th edition.

Material and methods

In the following sections, we will report all data exclusions, manipulations and measurements collected in this study, following JARS (Appelbaum et al., 2018). We have made all data and scripts available here: https://osf.io/twxsk/. Data were preprocessed using *R 4.1.0* (R Core Team, 2021) and *RStudio 1.4.1106* (RStudio Team, 2020), visualised with the package *ggplot 3.3.3* (Wickham, 2016) and analysed using *JASP 0.16.1* (JASP Team, 2020).

Participants

Participants for this study were recruited online and with flyers. Inclusion criteria for this study were to be female, between 18 and 60 years old, proficient in German, and of good health. Since there are no established ways to determine sample sizes for Bayesian analyses, we based our sample size goal of 32 mothers and 32 non-mothers to investigate the effect of motherhood on prior research (Luo et al., 2011; Matsunaga et al., 2018; Thompson-Booth et al., 2014a; Thompson-Booth et al., 2014b). We tested 74 women, of which five were excluded (three due to a depressive disorder and two due to technical difficulties). Additionally, one mother was excluded due to their child being an adult. Therefore, the final sample slightly exceeded the goal and consisted of 68 women, of which 34 were mothers (*mean* age = 39.9 years) and 34 were non-mothers (*mean* age = 36.5 years). Mothers had at least one child older than 6 months (see Table 1), while non-mothers had no children of any age; however, two non-mothers reported working with children. Mothers and non-mothers did not differ in age, socioeconomic status or intelligence. Participants were informed and had time to ask questions before providing written consent. They were reimbursed for their participation. The study was approved by the Ethics committee of the Charité – Universitätsmedizin Berlin and conducted in accordance with the Declaration of Helsinki.

Experimental procedure

Data collection consisted of an online questionnaire and an in-person testing session. The online questionnaire was hosted with *SoSci* (Leiner, 2019), and participants could complete it from home. Most participants completed the questionnaire prior to the in-person testing; however, one mother's questionnaire is missing. The online questionnaire consisted of questions about socio-demographic status, relationship status, mood state and health as well as questionnaires to measure alexithymia (TAS-20; Popp et al., 2008), emotion regulation (ERQ, Abler & Kessler, 2009) and the tendency for social desirability (KSE-G, Kemper et al., 2012). During the in-person testing, they rated their mood state and completed the matrix reasoning task of the Wechsler Adult Intelligence Scale (WAIS®-IV, Wechsler, 2008), the socio-affective video task (SoVT, Klimecki et al., 2013) as well as two newly developed tasks: a morphing task to measure FER and a picture-based task to measure empathy and compassion. Only the morphing task is the subject of this paper. All tasks were presented on a 15-inch laptop with a resolution of 1920 × 1080 pixels using the software Presentation® (Neurobehavioral Systems). Participants were seated in front of the laptop with approximately 50cm distance between their eyes and the screen. Testing lasted about 60 min with the FER task lasting 10–15 min.

Morphing task

We developed a new FER task based on morphed videos portraying neutral child faces continually and gradually changing into an emotional face (see Figure 1). Similar morphing tasks have been successfully used before, however, using either infant or adult stimuli but never stimuli of children (Domes et al., 2008; Matsunaga et al., 2018; Schwenck et al., 2012). Faces were taken from established databases (NIMH-ChEFS, Egger et al., 2011; DEFSS, Meuwissen et al., 2017; Dartmouth Database, Dalrymple et al., 2013; CAFE Set, LoBue & Thrasher, 2015). We used 48 identities with available facial expressions typically associated with anger, fear, sadness, happiness and emotional neutrality. Pictures were processed in GIMP (Version 2.8.22) to be 640 × 800 pixels, greyscale on a black background and only show faces without hair or ears. These pictures were morphed using WinMorph© (Version 3.01) to create 10-second long videos. The 48 identities were equally divided into three age groups: 4–6 years old (pre-school, *mean* age = 5.06 ± 0.77 years), 7–10 years old (middle children, *mean* age = 8.50 ± 1.15 years) and 11–15 years old (adolescents, *mean* age = 12.88 ± 1.46 years). Each version consisted of 64 morphed videos of interest, showing 8 male and 8 female identities in each of the four emotions. Additionally, participants saw four practice videos to familiarise themselves with the task. Mothers were assigned the age group of their child or one of their children. However, seven mothers whose children were younger than four years were assigned the pre-school group and one mother with a teenager older than 15 years was assigned the adolescent group (pre-school $n = 16$, middle $n = 9$, adolescents $n = 9$). Non-mothers were assigned randomly to one age group (pre-school $n = 13$, middle $n = 11$, adolescents $n = 10$). A Bayesian Contingency table reveals strong evidence *against* any differences between mothers' and non-mothers' assignment to age group ($BF_{10} = 0.16$, see Table S1 in the supplementary materials).

Videos were presented in a pseudo-randomised order so that two or more videos of the same emotion or identity were never consecutively presented. Participants were asked to stop the video as soon as they recognised the emotion with which this facial expression is typically associated. They did

Figure 1. Still images from one of the 10s long videos in the middle age group of the facial emotion recognition task. The emotionally neutral expression gradually and continuously changes into a facial expression associated with anger. Participants are asked to stop the video as soon as they recognise the emotion and then choose the correct emotion from four options (afraid, angry, happy and sad).

not see a still of the full facial expression typically associated with this emotion; therefore, response time for correct items measured how much information a participant needed to correctly associate the emotion with the facial expression typically expressing this emotion. If participants did not stop the video, the response time is coded as the full duration of the video (10 s). After stopping the video, participants had 8 s to choose the emotion typically associated with this facial expression from four options (afraid, angry, happy and sad) using the arrow keys and the space bar to confirm their choice. However, it was also possible for them to opt out because they did not recognise the target emotion. Participants rarely used this option (see Table S2 in the supplementary materials). All participants used their dominant hand to press the keys. Before doing the FER task, participants performed a control (CTR) task where the same neutral face was morphed to animal faces using the same procedure for morphing the neutral to emotional faces. This CTR task was chosen to capture how fast and concentrated participants would react in a task that involves detecting a change in a face without involving facial expressions typically associated with certain emotions. Here, participants were asked to stop the video as soon as they recognised the species and then choose the species from the following options: ape, cat, dog and lion. This CTR task consisted of 16 morphed videos of interest and two practice videos.

Analysis

All analyses are based on the Bayesian framework provided in *JASP* using the default priors (JASP Team, 2020). The Bayes factor BF_{10} encodes the relative likelihood of the data given a model compared to the null model without any of the predictors. We compare all possible combinations of predictors and interactions to the null model. In the case of multiple predictors, we also inspect the inclusion Bayes factor BF_{incl} which encodes the Bayes factor for each predictor across all matched models simultaneously. We use Jeffrey's scheme to label the strength of evidence for or against a specific model: "decisive" for a model more than 100 times more likely, "very strong" for a model between 30 and 100 times more likely, "strong" for a model between 10 and 30 times more likely, "moderate" for a model between 3 and 10 times more likely and "anecdotal" for a model between 1 and 3 times more likely. The multiplicative inverse is used for evidence for the null model (Goss-Sampson, 2020).

Differences between mothers and non-mothers in age, socioeconomic status, intelligence (WAIS®-IV - matrix reasoning task), mood state (both during online and in-person testing), empathy and compassion (SoVT) as well as questionnaire scores (TAS, ERQ, KSE-G) were evaluated using Bayesian Mann–Whitney-U tests with 10,000 random samples and corrected for multiple comparisons using Westfall's method (de Jong, 2019; Westfall et al., 1997). The socioeconomic status score was computed using net equivalent income, education and career (SES, Lampert et al., 2013). A Bayesian contingency table was computed with independent multinomial sampling to investigate possible differences in relationship status.

We used response times of correct responses to measure the amount of information needed to correctly recognise the animals in CTR and the emotion typically associated with a certain facial expression in FER. Additionally, discrimination and bias indices based on Pollak et al. (2000) and Smith et al. (2022) were used to investigate group differences in the FER task. Discrimination and bias indices are based on threshold modelling in signal detection theory. The discrimination index P_r measures the difference between hit rate (HR) and false alarm rate (FAR), quantifying sensitivity to a specific emotion. The bias index B_r measures the amount of certainty needed in favour of a specific emotion. It is calculated with the formula in Equation 1. These indices were not used to investigate effects in the CTR task due to the small number of stimuli per animal.

Equation 1.

$$B_r = \frac{FAR}{1 - P_r}$$

The amount of information needed in the CTR task as measured by response times for correct responses was compared between mothers and non-mothers using a Bayesian ANOVA with the predictor motherhood (yes/no) to test our hypothesis and age group (4-6, 7-10, 11-15) to explore differences between participants assigned to different age groups. For evaluating the FER task, Bayesian repeated measures ANOVAs were used with the following predictors: motherhood (yes or no) to test the hypotheses as well as age group (4-6, 7-10, 11-15) and typically associated emotion (anger, fear, happiness, sadness). Where the best model included the predictor age group or emotion, post hoc tests were computed to determine which levels differed. For these tests, posterior odds were corrected for multiple testing, and individual comparisons are based on a t-test with a Cauchy prior (Westfall et al., 1997).

We performed a Bayesian linear regression using the response times for correct responses in the CTR task, emotion regulation and alexithymia to predict the response times for correct responses in the FER averaged over all emotions. We used an uninformed uniform prior of 12.5% for each possible model.

Results

Sample characteristics

Our samples of mothers and non-mothers were comparable in almost all accompanying measures that we investigated. They did not differ in age, intelligence, socioeconomic status, tendency for socially desirable responses, alexithymia, emotion regulation, empathy or compassion (see Table 1). They also did not differ in their rating of their mood state before they performed the FER task or when they filled out the online questionnaire. However, mothers were more likely to be in a relationship than non-mothers, with 79.41% of non-mothers being single but only 45.46% of mothers ($BF_{10} = 17.14$). Therefore, mothers and non-mothers were comparable in many traits and socioeconomic factors, but they differed in relationship status.

CTR task

Mothers and non-mothers did not differ in the amount of information they needed for a correct response in the CTR task as measured by response times for correct responses (RT; see Figure 2 and Table S3 in the supplementary materials). The Bayesian ANOVA revealed anecdotal evidence *against* the alternative model including the predictor motherhood ($BF_{10} = \mathbf{0.47}$), moderate evidence *against* the model including age group ($BF_{10} = 0.14$), strong evidence *against* the model including both predictors ($BF_{10} = 0.06$) and strong evidence *against* the model including both predictors and the interaction ($BF_{10} = \mathbf{0.05}$). Therefore, mothers and non-mothers performed equally in a comparable recognition task not involving facial expressions typically associated with emotions, and there were no differences between the participants assigned to the different age groups for the FER task. This indicates that any differences found between the groups in the FER task cannot

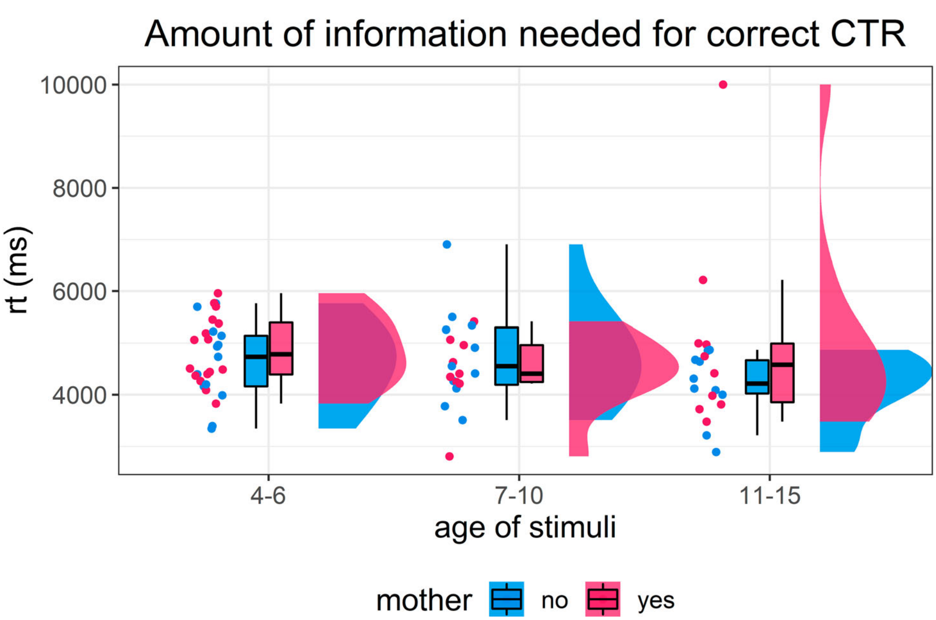

Figure 2. Response times for correct items in the CTR task, capturing the amount of information needed for recognition. Response times are shown separately for mothers and non-mothers as well as age groups to which they were assigned in the FER task. As confirmed by the Bayesian ANOVA, the best model describing the data is the null model suggesting that mothers and non-mothers needed the same amount of information.

be attributed to overall differences in reaction speed, concentration or other processes that are not related to processing and interpreting facial expressions typically associated with emotions.

FER task

The Bayesian repeated measures ANOVA investigated the effect of motherhood (yes or no) on the amount of information needed for a correct response (RT) in the FER task and explored the effect of emotion (afraid, angry, happy and sad), age group (4-6, 7-10, 11–15 years old) and their interactions. It revealed decisive evidence in favour of the model involving all three predictors and the interaction between age group and emotion ($BF_{10} = 1.80E+32$, see Figure 3 and Table S4 in the supplementary material). This model was more than three times as likely as the second-best model which additionally included the interaction between motherhood and age group ($BF_{10} = 5.64 + E31$). This is also reflected in the analysis of effects over matched models with decisive evidence for the inclusion of the predictor emotion and the interaction between emotion and age group, strong evidence in favour of the predictor motherhood and anecdotal evidence in favour of the predictor age group (see Table 2).

Contrary to our hypothesis, mothers needed more information to correctly choose the emotion typically associated with a specific facial expression across all age groups and emotions than non-mothers. Post-hoc comparisons reveal decisive evidence that both mothers and non-mothers needed more information in the youngest age group than the oldest age group (see Table S4 in the supplementary materials). Additionally, there is decisive evidence that both mothers and non-mothers needed the most information when encountering facial expressions

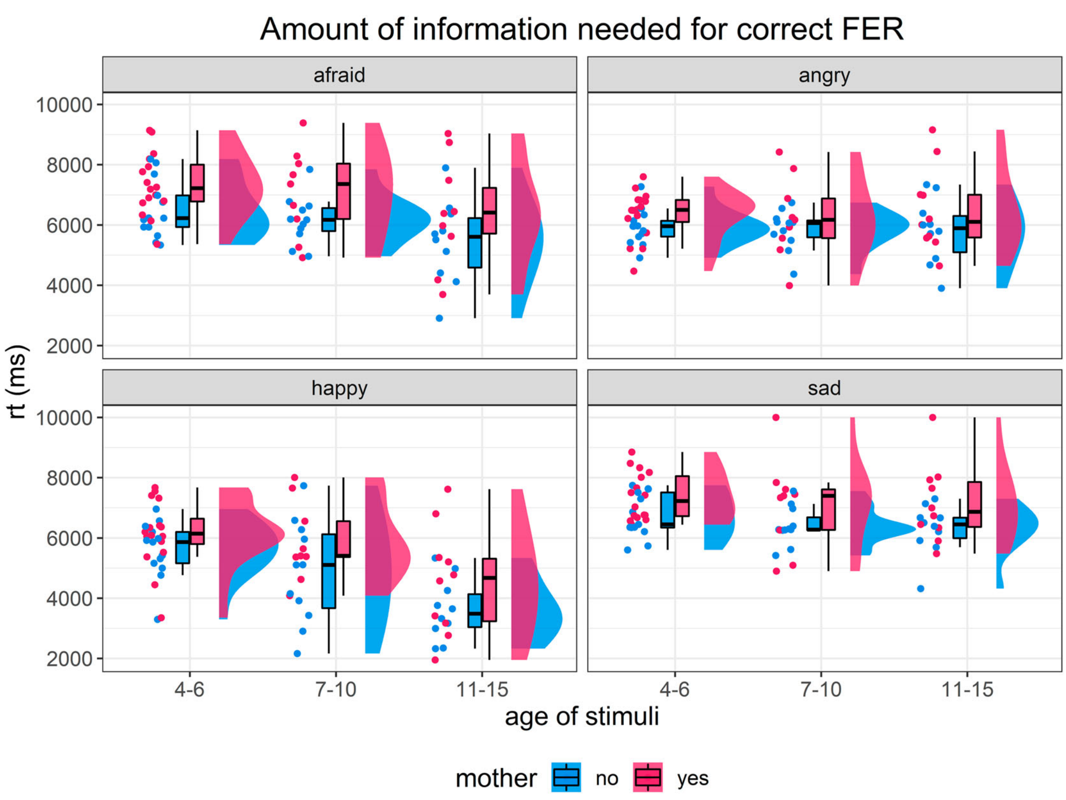

Figure 3. Correct response times per emotion and age group, separately for mothers and non-mothers, in the FER task. Correct response times capture the amount of information needed for recognition of emotions associated with a facial expression. As confirmed by the Bayesian repeated measures ANOVA, the best model describing the data included the predictors emotion, motherhood, age group as well as the interaction between age group and emotion. Mothers needed more information overall and both mothers and non-mothers needed more information in the youngest age group. There were also differences in the amount of information needed between different associated emotions with facial expressions associated with happiness being recognised the fastest.

Table 2. Analysis of predictors of the Bayesian repeated measures ANOVAs investigating differences in amount of information needed for correct responses (RT), discrimination index (P_r) and bias index (B_r).

	P(incl|data)	BF_{incl}	*P*(incl|data)	BF_{incl}	*P*(incl|data)	BF_{incl}
	RT		P_r		B_r	
emotion	7.82E-6	4.43E +25*	1.24E-05	1.45E+18*	0.89	1.83E+11*
age group	5.65E-6	3.04	2.28E-06	0.21	0.08	0.1
mother	0.63	12.08*	0.18	0.26	0.16	0.2
age group * mother	0.23	0.32	0.08	0.37	0.01	0.26
emotion * age group	1.00	1.41E+5*	1.00	4.03E+05*	0.04	0.42
emotion * mother	0.13	0.15	0.06	0.26	0.07	0.45
emotion * age group * mother	0.00	0.03	0.01	0.30	9.87E-05	0.17

Note. Compares models that contain the predictor to equivalent models stripped of the predictor. Analysis suggested by Sebastiaan Mathôt. Asterisks signify predictors with strong to decisive evidence for the inclusion of the predictor into the model.

typically associated with sadness and fear, less for facial expressions typically associated with anger and the least for facial expressions typically associated with happiness (see Table S3 in the supplementary materials). The effect of age group interacted with the effect of the typically associated emotion, with differences between age groups seeming to be the most pronounced in response to facial expressions associated with happiness (see Figure 3).

The same predictors were entered into two additional Bayesian repeated measures ANOVAs to explore participants' choices after stopping the videos, one for discrimination index and one for bias index (see Table 3 and Table S5 and S6 in the supplementary materials). Investigating the discrimination index revealed no difference between mothers and non-mothers. There was decisive evidence in favour of the model including emotion, age group and the interaction of the two compared with the null model (BF_{10} = 1.12E+23). This model performed almost four times as well as the second-best model which additionally included motherhood (BF_{10} = 2.90E+22). Analysis of effects again revealed decisive evidence for the inclusion of the predictor emotion (BF_{incl} = 1.45E+18) and the interaction between age group and emotion (BF_{incl} = 4.03E+5, see Table 2). Post hoc tests revealed decisive evidence for higher discrimination indices for facial expressions typically associated with happiness than any other emotion. Additionally, facial expressions typically associated with anger led to higher discrimination indices than those associated with sadness (moderate evidence).

The model that described the bias indices best included only the predictor emotion (BF_{10} = 1.78E +11). There is decisive evidence in favour of this model compared to the null model, and it performs almost five times as well as the second-best model which additionally includes the predictor motherhood (BF_{10} = 3.59E+10). Analysis of the inclusion of the effects revealed decisive evidence for the predictor emotion (BF_{incl} = 1.83E+11, see Table 2). Post hoc tests revealed decisive evidence for higher bias indices for facial expressions typically associated with happiness than fear and sadness, as well as strong evidence for higher bias indices for facial

Table 3. Average and standard error of discrimination (P_r) and bias indices (B_r), both in percentages, in the FER task for age groups, motherhood and emotions separately.

	4–6		7–10		11–15	
	P_r (%)	B_r (%)	P_r (%)	B_r (%)	P_r (%)	B_r (%)
afraid						
mothers	67 ± 5	23 ± 3	70 ± 5	19 ± 3	85 ± 4	37 ± 11
non-mothers	69 ± 5	24 ± 7	73 ± 5	24 ± 9	84 ± 4	29 ± 8
angry						
mothers	70 ± 2	21 ± 3	81 ± 4	55 ± 10	76 ± 5	25 ± 9
non-mothers	73 ± 5	28 ± 6	74 ± 4	47 ± 10	76 ± 3	40 ± 8
happy						
mothers	88 ± 2	55 ± 10	91 ± 3	71 ± 15	95 ± 1	65 ± 15
non-mothers	89 ± 1	57 ± 9	93 ± 2	36 ± 13	93 ± 1	42 ± 14
sad						
mothers	75 ± 3	11 ± 4	66 ± 5	8 ± 3	70 ± 7	23 ± 9
non-mothers	77 ± 4	17 ± 8	60 ± 5	10 ± 3	54 ± 4	9 ± 4

expressions typically associated with happiness than anger. Additionally, there was decisive evidence for higher bias indices for facial expressions typically associated with anger than sadness, as well as strong evidence for higher bias indices for facial expressions typically associated with fear than sadness.

We repeated the analyses after excluding all mothers whose children were outside of the age range of the stimuli. The evidence strength favouring the above-described predictors in the respective models stays the same (see Table S7-S9 in the supplementary materials).

To sum up, these results indicate that mothers needed more information to assign the correct emotion that is typically associated with a specific facial expression than non-mothers. They did not, however, differ in discrimination or bias indices.

Predicting FER performance

A Bayesian linear regression revealed that the amount of information needed for correct responses in the FER task (RT_{FER}) was only predicted by the amount of information needed in the CTR task (RT_{CTR}) with decisive evidence for this model as compared to the null model (see Table 4). This model was almost twice as likely as the second-best model which additionally included the predictor emotion regulation. The posterior summary confirms this conclusion with very strong evidence in favour of the inclusion of RT_{CTR} (BF_{incl} = **5.58e+3**) and anecdotal evidence against the predictor alexithymia (BF_{incl} = **0.40**) and emotion regulation (BF_{incl} = **0.67**). This indicates that RT_{FER} is not predicted by emotion regulation or alexithymia but can be predicted by RT_{CTR}. A simple linear regression was performed with RT_{CTR} as a predictor for RT_{FER} to derive the regression equation in Equation 2. This adds further evidence that the CTR task relies on similar processes without including emotion processing or associating a specific emotion with a facial expression.

Table 4. Model comparison in the multiple linear regression to predict amount of information needed for correct responses in the FER task using the amount of information needed for correct responses in the control task (RT_{CTR}), emotion regulation and alexithymia.

Models	*P(M| data)*	BF_M	BF_{10}	R^2
null model	5.52E-05	3.86E-04	1	0
RT_{CTR}	0.56	8.89	10137.2	0.3
RT_{CTR} + emotion regulation	0.25	2.38	4604.49	0.32
RT_{CTR} + alexithymia	0.12	0.95	2158.1	0.3
RT_{CTR} + emotion regulation + alexithymia	0.07	0.51	1220.11	0.32
alexithymia	1.71E-05	1.20E-04	0.31	0.01
emotion regulation	1.42E-05	9.98E-05	0.26	0
emotion regulation + alexithymia	6.28E-06	4.40E-05	0.11	0.01

Equation 2.

Regression equation to predict the amount of information needed for correct responses (RT) in the FER task using RT in the CTR task.

$$RT_{FER} = 6178 + 0.542*(RT_{CTR} - 4685)$$

Discussion

This study confirms our hypothesis that there is a difference between mothers and non-mothers in matching facial expressions of an unfamiliar child with a typically associated emotion. Contrary to our expectations, mothers needed *more* information to match the facial expressions with typically associated emotions than non-mothers, while there were no differences in discrimination of and bias towards certain emotions between mothers and non-mothers. The difference in the amount of information needed persisted in the three age groups and was independent of emotion. Regardless of whether a child's facial expression is associated with anger, sadness, fear or happiness, mothers needed more information to match the typically associated emotion correctly than non-mothers. Additionally, both mothers and non-mothers needed less information to match an emotion to adolescent facial expressions than pre-school child facial expressions. This effect of age group was independent of motherhood but interacted with the emotion displayed with more pronounced differences between age groups in facial expressions typically associated with happiness and fear. Therefore, while there were effects of age group and motherhood, there was no interaction between them. Furthermore, the effect of motherhood was inverse to our expectations, with mothers needing more information than non-mothers to correctly match a facial expression to the typically associated emotion.

Mothers needed more information to match a facial expression correctly with a typically associated emotion than non-mothers independent of age group and emotion. Although we hypothesised a difference between mothers and non-mothers in the amount of information needed, we expected mothers to need less information than non-mothers due to their wealth of experience and attentional bias towards infant and child faces (Thompson-Booth et al., 2014a; Thompson-Booth et al., 2014b). However, a similar effect has been reported in a study primarily investigating the effects of parenthood and gender on event-related potentials (ERPs; Proverbio et al., 2006). In this study, increased response times were accompanied by differences in several ERPs, most notably in the N245 and the P3. The N245 has been associated with sensitivity to facial expressions associated with emotions, indicating that parents were more sensitive to the emotions expressed in the infant faces (Streit et al., 2000). Additionally, the authors suggest that the increased P3 in mothers may have the function to induce empathic behaviour and that the slower response time may have been due to the greater emotional impact of the infant facial expressions on parents. Therefore, our study provides further evidence that mothers need more information or time to match facial expressions and typically associated emotions. Furthermore, this finding extends this to child facial expressions in multiple age groups expressing multiple emotions showing that the effect of motherhood is independent of emotion and age group.

Many studies on social understanding indicate that mothers might be more responsive to child facial expressions associated with emotions than non-mothers. The increased attentional bias that Thompson-Booth and colleagues found in mothers as compared to non-mothers may indeed be due to mothers experiencing more distraction by infant and pre-pubescent facial expression associated with an emotion regardless of whether the emotion is relevant to the task (Thompson-Booth et al., 2014a; Thompson-Booth et al., 2014b). We argued that the increased attentional bias could help counteract the increased ambiguity of facial expression associated with emotions in child faces, but the present study does not support this argument. However, increased distraction by child facial expressions associated with an emotion in mothers could have led to the effect observed in this study. Differences between mothers and non-mothers also extend to the neural level, with a study suggesting mothers show a stronger neural response to both adults and children in pain (Plank et al., 2021). In an affective theory of mind task, Plank and colleagues found that mothers exhibited stronger activation in both emotion processing and theory of mind areas than non-mothers in response to both adult and child facial expressions typically associated with emotions (Plank et al., 2022b). These studies could indicate that mothers respond more strongly to emotional stimuli than non-mothers. This increased emotional response could be the reason for the delayed response in this study. Since parenting has a strong emotional component, an increased emotional response might increase mothers' *affective* social understanding, even at the cost of prolonged responses in processes of *cognitive* social understanding. This could lead to more compassion with others feeling anger, sadness or fear as well as compersion with others feeling happiness.

Mothers and non-mothers did not differ in the differentiation of or bias towards any typically associated emotions. This is contrary to our expectation of mothers showing increased discrimination compared to non-mothers. However, it is possible that discrimination or bias would have differed if both groups had had the same amount of information. Since mothers had more information on average but the same level of discrimination, it is possible that their discrimination would have been lower had they had less information. Similar to the amount of information needed, this would have been the exact opposite pattern of what we hypothesised. A follow-up study including a condition where both groups receive the same amount of information could investigate whether mothers would indeed exhibit lower discrimination than non-mothers when receiving the same amount of information.

Our samples of mothers and non-mothers performed equally in a CTR task, where they were asked to recognise animals, needing the same amount of information to recognise the animal. This CTR task was designed to resemble the FER task with an emotionally neutral human face continually and gradually changing into an animal's face. However, it did not include any facial expressions associated with emotions. Therefore, the performance in both tasks depended on general attentive processes, reaction speed, concentration, visual processing, and face perception. Only the FER task included the processing and matching of emotions typically associated with this facial expression. Mothers and non-mothers performed equally on the CTR task, indicating that they do not differ in detecting these continuous and gradual changes in faces.

Additionally, mothers and non-mothers were well-matched in age, intelligence and alexithymia, which have been associated with matching facial expression to emotions (Lambrecht et al., 2012; Lane et al., 1996; Schlegel et al., 2020). A Bayesian linear regression confirmed that the amount of information needed in the CTR task is the only significant predictor of the amount of information needed in the FER task. Therefore, it is unlikely that differences in the FER task between mothers and non-mothers are due to differences in general cognitive capacity or intelligence, task competency, age or alexithymia.

There was no interaction between the effect of motherhood and age group. This indicates that the effect of motherhood on FER is stable over childhood and adolescence. It also suggests that even when features become increasingly adult, the difference in performance between mothers and non-mothers persists. This could be due to the prolonged period of dependence in humans (Feldman, 2015). With parenthood extending into adolescence and early adulthood of the offspring, differences persisting into these age groups are expected. It is possible that this difference between mothers and non-mothers extends to adult faces or that it vanishes for young or older adults.

Both mothers and non-mothers needed less information to match facial expressions of adolescents to typically associated emotions than facial expressions of younger children. This could be due to adolescents' decreased Kindchenschema and increasingly typical, adult features (Luo et al., 2011). Similar to Thompson-Booth and colleagues' data (Thompson-Booth et al., 2014a), pre-school children were treated differently as compared to adolescents. Whereas Thompson-Booth and colleagues observed greater attentional allocation, we observed an increase in the amount of information needed, contrary to our expectations. However, Thompson-Booth and colleagues did not include children between 7 and 10 years old. In our results, the group of 7- to 10-year-old child faces were midway between pre-school and adolescent faces, with no significant difference in the amount of information needed in either of those groups.

There may be different explanations for this effect of age group. First, experience may be a factor here: most adults encounter more adolescent and adult facial expressions associated with an emotion. Experience could also be a driving factor of the own age bias, where people recognise faces better in their own age group (Rhodes & Anastasi, 2012). It is unclear if this bias extends to recognising associated emotions in facial expressions, with some studies reporting own age biases (e.g. Cronin et al., 2019; Hauschild et al., 2020) while others either show no age group differences (e.g. Griffiths et al., 2015; Vetter et al., 2018) or a bias towards an age group regardless of whether it is close to participants' own age (e.g. Ebner et al., 2011; Ebner & Johnson, 2009). However, if experience were a key factor, mothers would have needed less information than non-mothers. Therefore, either experience influenced recognition in different age groups, but a different, independent factor led to the differences between mothers and non-mothers, or experience was not a driving factor in the here-observed results. Second, the differences observed in this study between age groups may be due to differences in how different age groups express a specific emotion in their faces. A recent study showed that facial expressions supposed to portray an emotion were less recognisable for adults when generated by 4- to 6-year-old children than when generated by 7- to 9-year-old children (Fong et al., 2020). Third, child faces may have a stronger emotional impact the younger they are, especially when associated with an emotion. Increased emotional impact could explain increased activity in response to child compared to adult faces associated with an emotion in the bilateral insula in mothers and non-mothers (Plank et al., 2022a). Similar to the effect of motherhood, an increased emotional impact of younger child faces associated with an emotion may have increased *affective* social understanding, even at the cost of prolonged responses in processes of *cognitive* social understanding. Studies incorporating multiple tasks focusing on different processes of face and emotion processing could help disentangle these possibilities.

Three caveats should be kept in mind when interpreting the present results. First, the sample size for the age groups on their own and specifically in interaction with motherhood was rather small. To not further decrease our sample size, we included mothers outside of the strict age ranges since their child used to be in this age group and/or the emotional expression of their children would still be close to the emotional expression of the stimuli used. An analysis excluding mothers whose children were outside of the age range of the stimuli showed the same effects. However, larger samples are needed to determine whether the effect of age groups and the non-existent interaction are generalisable. Second, although women suffering from affective disorders were excluded from the analysis, we did not directly measure depression or stress. Both could be confounding factors and should be considered in future studies. Third, recognising typical emotions associated with facial expressions does not reflect the reality of emotion recognition: emotion expression is not only context-dependent but also multi-faceted (Barrett et al., 2019). When a child is sad, it rarely ever only expresses this with changes in their facial expression. Rather, they express their emotions with their whole body, including posture and vocalisations. This might explain why we found strong effects for emotions in the amount of information needed as well as the discrimination of and bias towards emotion: some emotions, like happiness, may be more strongly associated with facial expressions than others. It is also important to note that it is not only necessary for parents to react to emotions but to anticipate them considering contextual clues. It is, therefore, possible that mothers are used to relying on these contextual cues more heavily than on facial expressions, which would offer an alternative explanation for the results observed in this study.

In the present study, mothers differed from matched non-mothers in the amount of information they needed to match a typical emotion in a FER task with facial expressions of unfamiliar children. Mothers and non-mothers did not differ in the discrimination of or bias towards the typical emotions displayed in the facial expressions. Additionally, both groups performed equally in a control task that required them to recognise animals. The effect of motherhood was independent of the age group of the stimuli and the typically associated emotion. This partially confirms our hypotheses that mothers and non-mothers differ in discrimination and the amount of information needed when matching facial expressions and typically associated emotions. However, we expected mothers to need less information than non-mothers due to attentional biases (Thompson-Booth et al., 2014a; Thompson-Booth et al., 2014b) and their wealth of experience. The increase in the amount of information needed in mothers might be due to their increased emotional response to children in general and child facial expressions typically associated with emotions in particular (Plank et al., 2021; Plank et al., 2022a; Plank et al., 2022b). In addition to a clear effect of motherhood, we found an effect of age group. Adolescent stimuli were easier to interpret for both mothers and non-mothers than pre-school children. A possible explanation is their increasingly adult features. This effect interacted with the emotion expressed, with the greatest difference in the amount of information needed for facial expressions typically associated with happiness followed by those associated with fear. Further research is needed to examine possible causes of the increase of information needed in mothers, including differences in emotional response as well as whether the effect extends to adult faces.

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No potential conflict of interest was reported by the author(s).

Data availability statement

The data that support the findings of this study are openly available in OSF at https://osf.io/twxsk/, reference number doi:10.17605/OSF.IO/TWXSK.

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