Maternal and personal information mediates the use of social cues about predation risk

Laurane Winandy[1,2], Lucie Di Gesu[1], Marion Lemoine[1], Staffan Jacob[2], José Martin[3], Christine Ducamp[1], Michèle Huet[2], Delphine Legrand[2] and Julien Cote[1]

[1] CNRS, Université Toulouse III Paul Sabatier, ENFA; UMR5174 EDB (Laboratoire Évolution & Diversité Biologique), Toulouse, France

[2] CNRS, UMR5321, Station d'Écologie Théorique et Expérimentale, Moulis, France

[3] Department of Evolutionary Ecology, Museo Nacional de Ciencias Naturales, CSIC, José Gutiérrez Abascal 2, 28006, Madrid, Spain.

Abstract

Organisms can gain information about predation risks from their parents, their own personal

experience and their conspecifics, and adjust their behavior to alleviate these risks. These

different sources of information can, however, provide conflicting information due to spatial

and temporal variation of the environment. This raises the question of how these cues are

integrated to produce adaptive antipredator behavior. We investigated how common lizards

(*Zootoca vivipara*) adjust the use of conspecifics cues about predation risk depending on

whether the information is maternally- or personally-acquired. We experimentally manipulated

the presence of predator scent in gestating mothers and their offspring in a full-crossed design.

We then tested the consequences for social information use by monitoring offspring social

response to conspecifics previously exposed to predator cues or not. Lizards were more

attracted to the scent of conspecifics having experienced predation cues when they had

themselves no personal information about predation risk. In contrast, they were more repulsed

by conspecific scent when they had personally obtained information about predation risk.

However, the addition of maternal information about predation risk cancelled out this

interactive effect between personal and social information: lizards were slightly more attracted

to conspecific scent when these two sources of information about predation risk were in

agreement. A chemical analysis of lizard scent revealed that exposure to predator cues modified

the chemical composition of lizard scents, a change that might underlie lizards' use of social

information. Our results highlight the importance of considering multiple sources of

information while studying anti-predator defenses.

INTRODUCTION

Prey frequently respond to the risk of predation via plastic physiological, morphological and/or behavioural changes, with strong implications for individual fitness (Lima 2002; Benard 2004). The most common antipredator behaviours include active escape, reduction of activity, shelter use or grouping behaviour (Krause et al. 2002; Lima 2002; Winandy et al. 2015). Although these behavioural defences are expected to enhance survival, they may also be costly (Lind and Cresswell 2005). For example, reducing activity or increasing the time spent in refuge alleviates the risk of being detected by a predator but also decreases foraging and mating opportunities. Consequently, individuals should experience energy allocation trade-offs between predator avoidance and other essential activities (Lima 1998). Organisms should therefore benefit from obtaining information about predation risk to maximize their benefit-cost ratio of antipredator behaviors.

Prey may rely on a variety of cues from different sources to assess predation risk. Throughout their life, individuals gain information by personal experience, which implies observation, detection and/or direct non-lethal encounter with predators. Individuals can also gain information from parental cues carried over to the next generation (*i.e.*, transgenerational effects). In particular, if mothers have reliable information about the risk of predation that their offspring are likely to encounter in the future, they can shape their offsprings' phenotype to be better defended against predator (Sheriff and Love 2013; Sheriff et al. 2017). For example, offspring produced by mother exposed to predation risk can exhibit morphological defense (e.g. the helmet morph in *Daphnia*, Agrawal et al. 1999; the greater wing length in great tits, Coslovsky and Richner 2011); an increase growth rate (Donelan and Trussell 2018a; Donelan and Trussell 2018b); more active and bold personalities (Donelan and Trussell 2015)). Such adaptive maternal stress may occur for example when the circulating maternal glucocorticoid hormones during pregnancy is linked to a relevant ecological stressor leading to programing

74 the stress axis of offspring in order to prepare them to cope, reproduce and survive in an

75 environment where the ecological stressor is frequently encountered (Love and William 2008;

76 Sheriff et al. 2010; Love et al. 2013; Sheriff et al. 2017; Potticary and Duckworth 2020). For

77 example, in common lizards, high maternal levels of corticosterone influence juvenile activity,

78 basking and dispersal behavior (Belliure et al. 2004; Meylan et al. 2002; Meylan and Clobert

79 2005).

80   While personal and parental information are well-studied for predation risk, organisms

81 can also gather information that is socially transmitted by conspecifics (*i.e.*, social information;

82 Danchin et al. 2004; Dall et al. 2005; Blanchet et al. 2010). Social information can either rely

83 on intentionally produced signals (*e.g.*, alarm calls), or on behavioral and chemical cues

84 produced inadvertently by individuals (Danchin et al. 2004).

85   In natural populations, the sources of information can contradict each other because of

86 the spatial and temporal variation of environmental conditions. Organisms therefore have to

87 decide on whether to respond to the information received. The reliability of some sources over

88 others usually depends on the predictive accuracy of cues informing about the current and future

89 environments. For example, social information being generally recognized as less reliable than

90 personal information, individuals might favor personal information over social when sources

91 are in conflict. Alternatively, because predation risk can fluctuate in time and space, individuals

92 might trust conspecifics information about a threat over their own information about safety

93 (Crane and Ferrari 2015). A general assumption is that the addition of consistent sources of

94 information should increase the predictive accuracy of information, and result in a linear

95 relationship between the number of coherent sources and the adaptiveness of the phenotype

96 (Leimar and McNamara 2015). Yet, accumulating coherent sources of information may not be

97 required when a single source of information is sufficient to go beyond a threshold and elicit a

98 response (Buoro et al. 2012). This could particularly be the case when dealing with life

99   threatening information such as the presence of predators; prey should overestimate the degree

100   of risk (Johnson et al. 2013) and respond to predatory cues even if they come from only a single

101   source (Blanchet et al. 2010). While theoretical studies provided several models of cues

102   integration (Stamps and Krishnan 2014; Dall et al. 2015; Leimar and McNamara 2015),

103   experimental studies that examine how prey integrates information from multiple sources in

104   order to make behavioural decisions are still rare (Beaty et al. 2016; Donelan and Trussell

105   2018a; Stein et al. 2018). A more general evolutionary understanding of information use in anti-

106   predator defense requires that we understand how individuals integrate transgenerational cues

107   informing them about the past environment with immediate environmental cues (personally- or

108   socially-acquired) to produce adaptive phenotypes (Leimar and McNamara 2015; McNamara

109   et al. 2016).

110   Here, we experimentally tested whether personal and transgenerational information

111   influence the use of social information about predation risk in the common lizard *Zootoca*

112   *vivipara*, a small lacertid widespread in Eurasia. To do so, we used a full-crossed design in

113   which maternal information was manipulated by maintaining gestating females with or without

114   olfactory cues from a predator (snake), and personal information was manipulated by raising

115   the offspring from these females with or without predator cues. We manipulated predation risk

116   with olfactory cues rather than with actual predators because lizards are able to innately detect

117   chemicals left on the substrate by a snake predator (Van Damme et al. 1995). Further, snake

118   cues gained personally or through maternal effects effectively elicit lizard antipredator

119   responses including morphological (*e.g.*, tail length), behavioral (*e.g.*, activity, basking) and life

120   history strategies (*e.g.*, dispersal, mate choice) (Van Damme et al. 1995; Downes and Shine

121   1999; Bestion et al. 2014; Teyssier et al. 2014; Ortega et al. 2017). We then assessed the use of

122   social information about predation risk through the level of attraction to conspecific scents. This

123   assay has been routinely used in common lizards to assess individual attraction towards

124 conspecific cues depending on cues such as donors' relatedness (Léna et al. 1998; Léna et al.

125 2000), past experience of competition (Aragón et al. 2006; Aragon et al. 2006), and more

126 generally the individual social strategy with respect to population density (Cote and Clobert

127 2007; Cote et al. 2008; Le Galliard et al. 2015; Mell et al. 2016). We used the scent of

128 conspecifics either previously exposed to predator cues or not, and tested the attraction to these

129 conspecific cues (*i.e.*, sociability) of focal individuals at the subadult stage (*i.e.,* one year old).

130 To go deeper into the molecular mechanisms responsible for social information, we tested

131 whether exposure to predator cues modified lizard scent. When an organism is disturbed or

132 stressed, but not captured by a predator, it can indeed release chemical cues (Chivers and Smith

133 1998), as shown in lacertids (Aragón et al. 2008). These modified scents can act as disturbance

134 cues warning nearby conspecifics of the risk of predation (Chivers et al. 2012; Bairos-Novak et

135 al. 2019; Bairos-Novak et al. 2019).

136   While previous studies have shown that common lizards use social information to make

137 behavioral decisions (*e.g.*, Aragon 2006; Cote & Clobert, 2007, 2010), it is unknown how

138 maternal and personal information may modulate the use of conspecific cues about predation

139 risks. We could broadly expect that either all sources of information (*i.e.*, maternally, personally

140 or socially-acquired) influence lizard's responses in an additive way, or that more reliable

141 sources of information elicit a threshold response. Since personal and maternal information are

142 usually more reliable than social information, we predict that social information about predation

143 risk would matter more when maternal and personal cues about predation risk are lacking, or

144 when they provide conflicting information.

MATERIALS AND METHODS

Maternal and personal information

147   We manipulated the perceived predation risk by exposing lizards to predator cues over

148 two generations. This experiment was approved by the ethical committee and the French

6

149 government: APAFIS#19524-2019022816109633 v2. Fifty-four gestating females were

150 captured during spring 2014 from 4 natural populations in the Cévennes mountains (Lozère,

151 France, Licence no.2010-189-16 DREAL), and brought back to the lab in the CNRS Station

152 d'Ecologie Théorique et Expérimentale (Moulis, France). While we did not know the previous

153 experience of females with predators, snakes were observed in only 2 of the 4 populations

154 during the last 20 years of monitoring (pers. comm. Jean Clobert). We therefore equally

155 distributed females from each population and from populations with and without observed

156 snakes between the two treatments (populations with snakes: 16 females and their 44 juveniles

157 in the predation risk treatment and 16 females and 42 juveniles in the control treatment,

158 populations without snakes: 10 females and 24 juveniles in the predation risk treatment and 12

159 females and 27 juveniles in the control treatment). We maintained females in 24 outdoor tanks

160 (1100 L; diameter: 1.70 m , 2 females in each tank, except 1 tank of each treatment with 3

161 females) containing 20 cm of soil litter, dense vegetation, one dish for water and a weekly

162 addition of crickets, *Acheta domestica*. We provided refuges by adding several 5cl falcon tube

163 in the litter, three half flower pots and two perforated bricks. A basking area was available in

164 the center of the tanks, using a few rocks and three logs. These housing conditions were highly

165 suitable for lizards, as shown in previous experiments (Bestion et al. 2014; Teyssier et al. 2014).

166 Gestation usually lasts 2-3 months depending on air temperature. During the last month of

167 gestation, we manipulated maternal information by exposing the females to predator or control

168 scent (see below for the detail description of the procedure). Before the first parturition, females

169 were brought to the lab in 35 x 18 x 22 cm individual terraria filled with 5cm substrate,

170 providing two shelters (on and under the ground) and a water bowl. A light bulb (25 W) and an

171 UV lamp provided respectively a heat source and light from 9 AM to noon and from 2 PM to 5

172 PM. In addition, each terraria were water sprayed three times a day. Food was provided daily

173 with two crickets per lizard. Since the lizard populations used in this study are viviparous, we

174 separated all newborns from their mother just after parturition. In total, we raised 137 juveniles

that we marked by toe clipping (approved by the ethical committee and the French government: APAFIS#15897-2018070615164391 v3) and sexed by counting the number of ventral scales (Massot et al. 1992). Each clutch, whose mother was either exposed or unexposed to predator scents, was equally split between the two treatments for personal information. Using this full-crossed design (Figure 1), we exposed two generations of lizards to predator cues: offspring unexposed from mother unexposed (P-M-, n=39; P for personal information and M for maternal information), offspring unexposed from mother exposed (P-M+, n=36), offspring exposed from mother unexposed (P+M-, n=30) and offspring exposed from mother exposed (P+M+, n=32). Offspring were raised in 24 outdoor tanks (in the same maintenance conditions as described before). We randomly distributed the juveniles into 12 tanks of a control treatment and 12 tanks of a predation treatment (5 to 7 individuals in each tank), checking there were no difference in body size or body mass between treatments (body size: $t = -1.127$, $P = 0.261$; body mass: $t = -0.344$, $P = 0.731$). The density and sex-ratio were similar between treatments (generalized linear model with a Poisson distribution and a log link, number of lizards: P- = 6.00 ± 0.21, P+ = 5.92 ± 0.19, $P = 0.93$; number of females (with number of lizards as a covariate): P- = 0.55 ± 0.02, P+ = 0.52 ± 0.02, $P = 0.78$). Offspring personal exposure was manipulated twice: just after birth at the juvenile stage (in summer 2014) and one year later at the subadult stage (in summer 2015).

Predation risk treatments

We used the cues of a natural predator the green whip snake, *Hierophis viridiflavus*. Common lizards have an innate recognition of snakes as a threat and their highly developed tongue-vomeronasal system allows them to detect chemicals that are left on the substrate by the snake predator. Lizard responses to snake scents strongly decreases the chance of capture (Downes 2002). Common lizards live in dense vegetation and their population density is much

200 higher than that of snakes. Direct encounters with snake are therefore rare but highly lethal.

201 This innate aversion of lizard to predatory scents is thus subjected to minor ontogenetic changes

202 and is stable over long periods of time without an encounter with a snake (Van Damme et al.

203 1995; Bestion et al. 2014).

204   We kept the green whip snake in a terrarium providing a water bowl, a shelter and a

205 light bulb for basking. To collect snake odours, we placed calcite tiles (3 x 3 x 0.6 cm) in the

206 snake cage for three days and gently rubbed, using rubber gloves, on the snake body before use.

207 We used identical tiles (i.e. blank tiles), kept in a separate room, for the control treatment

208 without snake scent. We placed fives tiles in each outdoor home tank, blank tiles for the control

209 tanks and tiles with cues for the predation tanks. Every three days for four weeks, we exchanged

210 old tiles of both treatments for new ones before olfactory cues could vanish in the outdoor tanks.

211 This same predator exposure protocol was used for all sources of information: the maternal

212 exposure in Mai 2014, the offspring exposure in August 2014 at juvenile stage and in August

213 2015 at subadult stage. While we did not use any physical encounters to maintain the potential

214 anti-predatory response, one month of exposure to predatory cues is not enough to trigger

215 habituation (Downes 2001; Downes 2002). Moreover, we did not use the scent of the same

216 snake for exposure at the juvenile and subadult stages. This scent novelty that should maintain

217 lizard responsiveness. Previous studies show that both within and between-generation

218 responses are induced by predator olfactory cues manipulated over a month (Shine and Downes

219 1999; Bestion et al. 2014), which makes this procedure, along with ethical considerations, the

220 most suitable option.

221

222 **Social information and attraction to conspecific cues**

223   Social information about predation was provided after the second exposure to predation

224 cues at the subadult stage (in late summer 2015). We assessed individual social response to the

cues of conspecifics that were previously exposed to predator cues (S+) or not (S-). Following the full crossed-design experiment (Figure 1), half of the lizards from each treatment (*i.e.,* P-M-, P-M+, P+M- and P+M+) were exposed to S+ and the other half were exposed to S-. To do so, we collected pooled scents from the lizards maintained in each of the 24 tanks just after the predation treatment at the subadult stage (August 2015). These 24 groups (12 from the control treatment and 12 from the predation treatment) were housed separately in large terraria (35 x 18 x 22 cm) covered by paper towel during one week. Twenty-four pieces of paper containing the feces of each group were then used during the social attraction test. Each tested lizard was exposed to one of the 24 different scents, always avoiding the scent of their own group to exclude the possibility that lizards were exposed to their own feces or to feces from a conspecific that they already knew. Lizards were cleaned using an antiparasite solution (©frontline) before being released in the terraria and could therefore not bear predator cues from tiles on them. We collected the papers devoid of conspecific scent from vacant terraria maintained in the same conditions as our inhabited terraria.

We tested social attraction with a choice assay between two compartments with or without scents of conspecifics. This type of assay is commonly used in common lizards and other lizard species to quantify individuals' social strategies (Cote and Clobert 2007; Cote et al. 2008; Rodríguez-Prieto et al. 2011; Teyssier et al. 2014; Le Galliard et al. 2015; Mell et al. 2016). In reptiles, lizards' scents convey various types of information about the donor (Martín & Lopez, 2010, 2014). Therefore, the assay allowed us to measure attraction to conspecific cues depending on donors' characteristics (*i.e.*, social information, Léna et al. 1998; Léna et al. 2000; Aragón et al. 2006). We used glass terraria ($34 \times 17 \times 25$ cm) divided in three compartments: a shelter without conspecific scents was put at one end of the terrarium and a shelter with conspecific scents was put at the other end of the terrarium. We placed each lizard in the central compartment (devoid of shelter and scent) for four hours and we started the assay by removing the walls separating the compartments. After 10 min of acclimation to the two shelters, we

10

251 recorded for another 10 min the time spent in each compartment and on/under each shelter to

252 estimate social tendency. Video were analyzed using "The Observer" software, allowing the

253 exact measurement of the time in each location. The observer was blind to the treatment of

254 individuals.

255 **Analysis of scent chemical composition**

256 We analyzed the chemical composition of scent samples collected in the 24 terraria in

257 the same manner as those used for the social attraction test (12 from the control treatment and

258 12 from the predation treatment). This means that for each group, the sample was made of

259 several pieces of paper towel with feces and was composed of a mix of individual scents. We

260 collected feces instead of femoral secretions because feces are also commonly used in lacertid

261 lizard to simulate olfactory responses (Aragón et al. 2000, López et al. 1998, Moreira et al.

262 2008) and chemical communication based on femoral secretions is relatively less important in

263 this species (Gabirot et al. 2008). Samples were collected using surgical pliers cleaned with

264 alcohol and rinsed with sterile water between each population. Samples of paper towel and soil

265 from vacant terraria were also collected as controls. Samples were disposed in glass vials and

266 kept at -80°C until analyses.

267 Chemical compounds were analyzed using solid phase microextraction (SPME) with a

268 Stableflex fiber (50/30μm DVB/CAR/PDMS, Supelco, Sigma-Aldrich, Bellefonte, PA, USA).

269 Samples were placed at 50°C for 20min, and the fiber was then exposed to the headspace of the

270 glass vials (without touching the towel) for 20min. Absorbed chemicals were then analyzed on

271 a mass spectrometer quadrupole detector (ISQ QD) coupled to a Trace 1300 gas

272 chromatography (Thermo Fisher Scientific Inc) with a capillary column (Restek RTX-5MS 30

273 m x 0.25 mm, 0.25 lm film thickness, 5% diphenyl and 95% dimethylpolysiloxane) and a

274 splitless injector (300 °C). Ionization was performed by electron impact (70 eV, source

275 temperature 250 °C). Helium was the carrier gas (1.2 ml/ min). The oven temperature was

276   initiated at 40 °C for 1 min, and then programmed to increase 10 °C/min to 300 °C and held at

277   300°C for 5 min. The scan range of the mass spectrometer was 60 to 500 m/z. Blanks were

278   regularly interspersed throughout the sample analyses. After removing the compounds found in

279   paper towel and soil (*i.e.,* control sample without feces), we obtained 62 different peaks (*i.e*.,

280   compounds). The relative abundance of compound refers to the relative areas of the selected

281   peaks that were restandardized to 100%. Tentative compound identification was performed

282   based on mass spectral fragmentation patterns and comparison with the NIST mass spectral

283   library using Xcalibur software.

284

285   **Statistical analysis**

286   To summarize the data collected during the social attraction test, we performed a

287   Principal Component Analysis (PCA) using the time spent in each compartment (*i.e.,* with or

288   without conspecific scents, excluding the central compartment) and the time spent on, and under

289   each shelter. These data were scaled to unit variance before the analysis. The PC1 axis explained

290   39% of the variance and had an eigenvalue of 2.32. It was positively correlated to behaviors in

291   the compartment without scent (PC loadings: 0.94 for the total time spent in the compartment

292   without scent and 0.6 for the time spent under the shelter) and negatively correlated to behaviors

293   in the compartment with conspecific scent (PC loadings: -0.92 for the total time spend in the

294   compartment with scent and -0.44 for the time spend under the shelter). To make interpretation

295   easier, we multiplied scores by -1. Higher scores on the PC1 axis then corresponded to higher

296   attraction to conspecific scent (*i.e.,* higher sociability).

297   Afterward, we used linear mixed models to assess the effect of maternal, personal and

298   social information about predation (single effects and interactions between these three factors)

299   on social attraction. We added sex and body size (snout-vent length) as covariates as they can

influence sociability (Michelangeli, Chapple, & Wong, 2016), and mother identity and tank

group as random intercepts. Sex and body size did not affect the use of conspecific cues ($P >$

0.11 for simple effects and interactions with the three sources of information) and were

therefore removed from the model. We then used likelihood ratio tests to estimate the

significance of factors and interactions in the model and provided summary of parameter

estimates and confidence interval (95%). To test the additive effects of information sources

about predation risk on social attraction, we ran a linear regression by scoring the number of

sources as follow: 0 when there were neither personal nor conspecific cues about risk, 1 when

there were either a personal information or conspecific cue about risk and 2 when there were

both personal information or conspecific cue about risk. Compliance with requirement of the

fitted linear model were checked using Shapiro-Wilk normality test on the model residuals

assessing social attraction (W = 0.988, P = 0.29).

We assessed the effect of predation risk on lizard chemical profile. We first analyzed

the number of compounds present in each of the 24 chemical profiles (each tank) using a GLM

assuming a Poisson error distribution and a log link. We then perform analysis on the

occurrences (presence/absence) of chemical compounds that convey threshold information. We

identified differences in the occurrence of compounds between treatments using a discriminant

analysis (LDA) effect size (LEfSe) on the 62 initial compounds using the Galaxy platform

(http://huttenhower.sph.harvard.edu/galaxy/) with a 0.05 p-value threshold and a LDA score >2

(supplementary table 1). As a cross-validation, we also ran a similarity percentage analysis on

the occurrence of the 62 compounds (supplementary table 2) and considered the compounds

identified as different in both LDA and similarity analysis as important. We then summarized

the occurrence of the 62 compounds using a LDA and a MCA (i.e. Multiple Correspondence

Analysis). The two methods are complementary as the LDA summarizes differences in

chemical profiles between treatments in a single variable and the MCA summarize chemical

profiles regardless of the treatments. The contribution of each compound to the first axis of a

13

LDA was examined using linear models with LDA axis as a dependent variable and the occurrence of the compound as an explanatory variable (supplementary table 3). For the MCA, we kept the first two axes (*i.e.,* MC1 and MC2) as they explained respectively 12.62% and 10.80% of the variance and had an eigenvalue of 0.12 and 0.11, respectively. The contribution (in %) of each compound to the first two axis of the MCA is in Supplementary table 4.

We used the occurrences above rather than the relative abundances because a high proportion of relative abundances were equal to 0 which complicated the transformation needed for the PCA and LDA. However, the analysis using relative abundances largely supported the results based on the occurrence data (see supplementary material). The LDA analysis using galaxy identified the same compounds (supplementary table 5) and the LDA axis on abundances was highly correlated to the LDA axis on occurrences (Estimate: 0.99, SE= 0.04, R^2 =0.96, *P* < 0.0001). The contribution of each compound to the first axis of a LDA was examined using Spearman rank correlations (supplementary table 6). For the PCA, we kept the first two axes (*i.e.,* PC1 and PC2) as they explained respectively 13.97% and 11.36% of the variance and had an eigenvalue of 8.66 and 7.04, respectively. The component loadings of the relative abundance of chemical compounds can be found in supplementary table 7.

A final post-hoc analysis investigated whether the identified differences in chemical profiles between exposed and unexposed donors are responsible for the effect of predation risk on the use of conspecific cues. We compared effects sizes of the predation risk treatment of cues donors (i.e. the social information as reported in Table 1) and of the chemical profiles on social attraction. Similar or higher effect sizes would suggest that the descriptor may convey the social information about predation risk, while lower effect sizes would suggest additional unidentified information carriers. To do so, we ran the same linear model with maternal, personal and social treatments on lizard sociability (as in Table 1), but replacing the social information treatment by the descriptors of the cues used for the social information assay

351 (supplementary table 8). The descriptors were the number of compounds, the two MCA axes,

352 the LDA axis and the occurrence of compounds that differed between predation and control

353 treatment. We extracted effect sizes (standardized beta coefficients) and compared it to the

354 effect for the predation risk treatments of cues donors in interaction with maternal and personal

355 treatments. Note that caution about conclusion should be exercised, as only an experimental

356 manipulation of chemical profiles would permit us to test directly the role of chemical profile.

357 Finally, we performed the same post-hoc analysis using the descriptors of compound

358 abundance: the LDA axis of the abundance, the two PCA axis and the abundance of compounds

359 that differed between predation and control treatment (supplementary table 9). We provided p-

360 values in supplementary tables 8 and 9 for information purposes. Only the effects sizes should

361 be interpreted, as they are not influenced by the post-hoc multiple testing.

362   Analyses were performed in R 3.5.1 (www.r-project.org) using FactoMinR (Lê et al.

363 2008), ggplot2 (Wickham et al. 2016), lme4 (Bates et al. 2007), sjstats (Lüdecke and Lüdecke

364 2017), MASS (Ripley et al. 2013), and vegan (Oksanen et al. 2007) packages.

RESULTS

Effect of sources of information on sociability

367   Personal and maternal information interacted to shape the use of social information

368 about predation risk (Table 1). We found a significant interaction between personal and social

369 information on lizards' sociability, but only when mothers were not exposed to predator cues

370 (Table 2, Figure 2a). In this case, lizards with personal information about predation risk were

371 repulsed by the scent of conspecifics exposed to predator cues ($\chi^2_1 = 50.579$, $P < 0.001$), while

372 naïve lizards tended to be attracted by these conspecifics scents ($\chi^2_1 = 3.147$, $P = 0.076$).

373 Maternal exposure to predation risk canceled out this interaction between personal and social

374 information (Table 2): sociability tended to increase with the number of sources of information

375 about risk (Estimates= 0.442, SE= 0.237, $\chi^2_1 = 3.478$, $P = 0.062$; Table 2, Figure 2b).

15

Effect of predation risk on conspecific scent

The exposure of individuals to predator cues significantly decreased the number of chemical compounds forming lizard scents ($\chi^2_1 = 7.394$, $P = 0.007$, mean ± SE, S+: 16.8 ± 1.2 and S-: 12.6 ± 1.1). The LDA effect size analysis showed that two compounds substantially differed between the profiles of exposed and unexposed lizards (supplementary table 1), which is also confirmed by the similarity percentage analysis (Supplementary Table 2). Other compounds were also identified from the correlations with the LDA axis (Supplementary Table 3) and the similarity percentage analysis (Supplementary Table 2), but it is likely they had a weaker role in the chemical differentiation. The predation treatments had a significant effect on the LDA axis ($F_{1,22} = 106.1$, $P < 0.001$, mean ± SE, P+: -1.251 ± 0.857 and P-: 1.751 ± 0.386), but had no effects on the two MCA axes (MC1: $F_{1,22} = 1.276$, $P = 0.271$ and MC2: $F_{1,22} = 0.902$, $P = 0.353$). The tentative identification of chemical compounds indicated that the two main compounds, Compound_1 (i.e. X154) and Compound_2 (i.e. X167), may be respectively a derivative of Napthalenol and an unsaturated alcohol.

We then investigated whether the descriptors of donors' cues could explain the effect of predation risk of conspecific donors by comparing effect sizes. The effect size of the interaction between personal, maternal and social information is similar to the effect size of the interaction using the LDA first axis, and more particularly using the occurrence of Compound_1 and Compound_2 instead of the social information treatment (Supplementary Table 8, Figure 3).

Overall, the various analyses of the relative abundance of the chemical compounds showed very similar results to the analysis based on their occurrence. Indeed the LDA effect size analysis highlighted the same two compounds (supplementary table 5, supplementary table 6). The post-hoc analyses comparing effect sizes showed that the effect size of the interaction between personal, maternal and social information is similar or slightly lower than the effect size of the interaction using the PC2 and the abundance of Comp_1 and Comp_2 instead of the

401 social information treatment (Supplementary Table 9, Supplementary figure 1).

DISCUSSION

403 We assessed how personally- and maternally-acquired information altered lizards' responses to

404 conspecific cues. We found that personal and maternal information interacted to shape lizard

405 responses to conspecific cues about predation risk. The scent of conspecifics exposed to

406 predation risk attracted more focal lizards when they had no personal information about the

407 risk, while it repulsed them when they also had personal knowledge about the risk. Furthermore,

408 we found that maternal information about predation risk cancelled out this interactive effect

409 between personal and social information, with individuals tending to be more social when

410 sources of information about risk added up.

411   Prey are known to assess the risk of predation when making decisions about how to

412 behave (Lima 2002). Decision making often results in a trade-off between risk and other

413 rewarding activities (*e.g.,* foraging and mating; Kats and Dill 1998). An accurate risk

414 assessment requires reliable information about predation at a given time and location. Such

415 information can be acquired via multi-modal sensory cues including sight, tactile and chemical

416 signals made by conspecifics. In our study, we manipulated the exposure to predation risk using

417 scents of a snake predator because it is known to elicit anti-predator behavior in common lizards

418 through maternal and personal exposure, even one month after exposure (Bestion et al. 2014;

419 Teyssier et al. 2014). Such permanent strong defense behavior without any actual encounter

420 with predators can be explained by the low encounter rate between lizards and snakes in the

421 wild, because of the dense vegetation and the comparatively lowest density of predators. It can

422 further be explained by the high probability the a snake is successful in catching a lizard when

423 an actual attack occurs. We further showed that common lizards can use olfactory cues from

424 conspecifics to assess predation risk, while it was already known that they can perceive different

425 donors' characteristics through scents (*i.e.*, relatedness: Léna et al. 1998; past experiences of

17

426 competition: Aragón et al. 2006; Aragon et al. 2006). Chemical cues released by a conspecific

427 may signal individual stress levels (Douglas III et al. 2018), body condition (Martín and Lopez

428 2010) or health status (Martín et al. 2007) and lizard species are particularly prone to use such

429 signals to assess mating partners or competitors (reviewed in Mason and Parker 2010).

430 Predation risk usually requires chemicals from injured conspecifics (*i.e.,* alarm cues) to elicit

431 behavioral defense in other conspecifics (Crane and Ferrari 2013). However, prey can also

432 release a chemical signal when detecting a predator (*i.e.,* disturbance cues; Chivers and Smith

433 1998; Griffin 2004), or have a modified scent after experiencing predation risk, as found in

434 another lacertid lizard species (Aragón et al. 2008).

435 Individuals may rely on cues intentionally or inadvertently produced by conspecifics,

436 (defined as social information: Danchin et al. 2004; Dall et al. 2005; Blanchet et al. 2010), to

437 cope with limited personal information about challenging environmental conditions. In the

438 context of predation risk, acquiring social cues may be less costly and therefore more adaptive

439 than acquiring the information personally through a direct encounter with a predator (Blanchet

440 et al. 2010). Moreover, no personal information about predation risk can be unreliable because

441 predators circulate in the environments and their actual presence can be highly variable in space

442 and time. A prey may then overestimate the degree of risk (Johnson et al. 2013) and a response

443 to predator cues could be observed even if they came from only a single source (Nesse 2005;

444 Blanchet et al. 2010). However, when an individual eventually encounters a predator, social

445 cues may become less relevant and additional cues about risk may even signal an acute increase

446 in predation risk. In absence of maternal cues, we found that social and personal information

447 about risk increase the attraction towards conspecific scents when these information sources

448 are uncoupled, supposedly because grouping may decrease predation risk (Lima and Dill 1990;

449 Krause et al. 2002). Indeed, an increase in sociability is a common antipredator strategy in lizard

450 that allows for collective vigilance (*i.e.,* increased detection of predators, (Downes and Hoefer

451 2004; Lanham and Bull 2004) and a risk-dilution effect (*i.e.,* a lower probability for a single

452   individual to be captured, Ioannou 2017). However, in the absence of maternal cues, lizard

453   personally-informed about predators avoided the scents of social partners that were also

454   exposed to predator scents. The accumulation of information sources about predator presence,

455   through personal and social information, may indicate a temporally or spatially acute risk of

456   predation. Lizards may therefore avoid the scent of predator-exposed conspecifics because it

457   signals immediate danger, while the scent of unexposed conspecifics is attractive because it

458   might signal safe conditions. The safest strategy could then be to avoid a particular social

459   partner who has recently encountered a predator.

460   Transgenerational information can strongly influence prior expectations about

461   individuals' risk, and, in turn, the use of social information. We found that the exposure of

462   mothers to predation risk during gestation cancelled out the observed interaction between

463   personal and social information and was replaced by a weak but significant additive effect of

464   information sources affecting lizard social responses. The attraction towards conspecific scents

465   increased gradually with the number of sources of information about predation risk from lizards

466   with only maternal information to lizards personally, socially and maternally informed.

467   Additional cues might increase an individual's confidence in the state of the environment,

468   causing a multiplicative effect on their sociality. A higher level of sociability could indeed be

469   an efficient antipredator strategy in a risky environment. While additivity is less expected in

470   discrete traits such as a defensive morphology (McCollum and Van Buskirk 1996; Buoro et al.

471   2012), it is more likely to occur in gradual behavioral traits. Maternal information signals

472   environmental conditions on a larger temporal scale than does personal information. When

473   maternal and offspring information matches, it signals a persistent risk across generations

474   (Sheriff et al. 2017), which can explain the additive effect of information sources. The

475   environmental/maternal-matching hypothesis states that maternal stress can be adaptive if the

476   maternal and offspring environmental conditions match (Sheriff et al. 2017). In our study, when

477 personal and maternal information about risk matched (P+M+), social information was less

478 valuable. Indeed, individuals showed high attraction to conspecific cues whether or not this

479 conspecific was exposed to predation risk, as in a persistent risk of predation, being more

480 sociable could be beneficial. On the contrary, social information had stronger effect when there

481 was no personal and maternal information about risk (P-M-). In this case, individuals were only

482 attracted by social cues of conspecific that had been exposed to predation risk, which mirrors

483 cases where acquiring personal information is costly (Webster and Laland 2008). If social cues

484 were misleading, it would only result in reduced foraging or mating opportunities, while not

485 responding to a relevant danger cue could result in higher mortality risk by predation. Prey

486 might thus benefit from erring on the side of caution (Johnson et al. 2013).

487 Finally, we also attempted an assessment of the molecular mechanisms responsible for

488 social information by collecting feces samples from groups of lizards exposed and unexposed

489 to predation risk to identify potential changes in their chemical scent profiles. In our study,

490 predators never injured lizards, as we never exposed lizards to actual predators, so there were

491 no compounds released upon injury (*i.e.*, damage-release chemical alarm signals; Chivers et al.

492 1996). Despite no physical encounter with predators, as in natural populations, the exposure to

493 predator cues changed the chemical composition of lizard scents collected from feces. We found

494 fewer chemical compounds in the scent of lizards exposed to predation risk compared to

495 unexposed lizards. Our conservative analysis revealed that two compounds were differently

496 expressed between treatments. The tentative identification of the chemical compounds matches

497 expectations since Lacertid lizards usually have alcohols in their secretions, and alcohols can

498 be detected by conspecifics (Martín and López 2014). This modification of scent profile may

499 have provided chemical cues for risks and triggered the observed behavioral response to

500 conspecific scents. We also ran post-hoc analyses replacing the predation risk treatment of

501 donors' scents by a few descriptors summarizing chemical profiles and compared effect sizes.

502 We expected similar or larger effect sizes if chemical profiles were indeed the mechanisms

503 behind social responses to conspecific scents, and this is what we observed for the two

504 compounds differently expressed between treatments. However, caution should be exercised in

505 interpreting this preliminary investigation of chemical profiles and their influences. In depth

506 chemical analysis and manipulative experiments are required to provide a more precise

507 identification of chemical cues, and to ascertain their influences on lizard's behavior.

508 **CONCLUSION**

509 Prey generally have incomplete information about their environment and have to rely on other

510 source of information to assess the risk of predation. In our study, the scents of conspecific

511 exposed to predation risk acted as social information shaping behavioral responses. However,

512 when personal and social information conflicted, which is mostly the rule in stochastic

513 environments, decision making can be hampered. Transgenerational information seemed to

514 alleviate the uncertainty about risk when personal and social information mismatched.

515 Transgenerational cues can provide information on a larger temporal scale and influence the

516 prior expectations of individuals about their environment. Moreover, ancestors' experience is

517 the first possible source of information an individual can get and, therefore, may have large

518 effects on phenotypic outcomes (Dufty Jr et al. 2002; Fawcett and Frankenhuis 2015; English

519 et al. 2016; Donelan and Trussell 2018a). Maternal exposures to predation cues may adaptively

520 prepare the phenotype of offspring for more stressful environmental conditions (Uller 2008;

521 Sheriff and Love 2013; Sheriff et al. 2017) but also induce changes in the developmental

522 trajectory of offspring, leading to direct or delayed effects on individuals from the embryonic

523 stage to adulthood (Love and Williams 2008; Nettle and Bateson 2015). Here we found that

524 maternal stress affected how offspring used the cues from conspecific later in life. While our

525 study raises interesting perspectives on how animals integrate information from a wide variety

526 of sources to make decisions, we believe additional studies on this and other taxa are required

527 to replicate our results and test the generality of our conclusions. Understanding the complex

528 mechanisms involved in the integration of multiple information sources within and among

529 several generation deserves further attention (Sheriff et al. 2017).

530 **REFERENCES**

531 Aragón P, López P, Martín J. 2000. Size-dependent chemosensory responses to familiar and

532 unfamiliar conspecific faecal pellets by the Iberian rock-lizard, *Lacerta monticola*.

533 *Ethology*, *106*(12), 1115-1128.

534 Aragón P, López P, Martín J. 2008. Increased predation risk modifies lizard scent-mark

535 chemicals. J Exp Zool A Ecol Genet Physiol. 309(7):427–433.

536 Aragón P, Massot M, Gasparini J, Clobert J. 2006. Socially acquired information from chemical

537 cues in the common lizard, Lacerta vivipara. Anim Behav. 72(5):965–974.

538 Aragon P, Meylan S, Clobert J. 2006. Dispersal status-dependent response to the social

539 environment in the Common Lizard, Lacerta vivipara. Funct Ecol. 20(5):900–907.

540 Agrawal AA, Laforsch C, Tollrian R. 1999. Transgenerational induction of defences in animals

541 and plants. Nature. 401(6748): 60–63.

542 Bairos-Novak KR, Ferrari MC, Chivers DP. 2019. A novel alarm signal in aquatic prey:

543 Familiar minnows coordinate group defences against predators through chemical

544 disturbance cues. J Anim Ecol.:1281–1290.

545 Bates D, Sarkar D, Bates MD, Matrix L. 2007. The lme4 package. R package version. 2(1):74.

546 Beaty LE, Wormington JD, Kensinger BJ, Bayley KN, Goeppner SR, Gustafson KD, Luttbeg

547 B. 2016. Shaped by the past, acting in the present: transgenerational plasticity of anti-

548 predatory traits. Oikos. 125(11):1570–1576.

549 Belliure J, Meylan S, Clobert J. 2004 Prenatal and postnatal effects of corticosterone on

550 behavior in juveniles of the common lizard, Lacerta vivipara. J Exp Zool Part Comp

551 Exp Biol. 301A: 401–410.

Benard MF. 2004. Predator-induced phenotypic plasticity in organisms with complex life histories. Annu Rev Ecol Evol Syst. 35:651–673.

Bestion E, Teyssier A, Aubret F, Clobert J, Cote J. 2014. Maternal exposure to predator scents: offspring phenotypic adjustment and dispersal. Proc R Soc B. 281(1792):20140701.

Blanchet S, Clobert J, Danchin É. 2010. The role of public information in ecology and conservation: an emphasis on inadvertent social information. Ann N Y Acad Sci. 1195(1):149–168.

Buoro M, Gimenez O, Prévost E. 2012. Assessing adaptive phenotypic plasticity by means of conditional strategies from empirical data: the latent environmental threshold model. Evolution: International Journal of Organic Evolution. 66(4):996–1009.

Chivers DP, Brown GE, Ferrari MC. 2012. The evolution of alarm substances and disturbance cues in aquatic animals. Chemical ecology in aquatic systems:127–139.

Chivers DP, Kiesecker JM, Anderson MT, Wildy EL, Blaustein AR. 1996. Avoidance response of a terrestrial salamander (*Ambystoma macrodactylum*) to chemical alarm cues. J Chem Ecol. 22(9): 1709-1716.

Chivers DP, Smith RJF. 1998. Chemical alarm signalling in aquatic predator-prey systems: a review and prospectus. Ecoscience. 5(3):338–352.

Coslovsky M, Richner H. 2011. Predation risk affects offspring growth via maternal effects. Funct. Ecol. 25, 878–888.

Cote J, Boudsocq S, Clobert J. 2008. Density, social information, and space use in the common lizard (Lacerta vivipara). Behav Ecol. 19(1):163–168.

Cote J, Clobert J. 2007. Social information and emigration: lessons from immigrants. Ecol lett. 10(5):411–417.

Crane AL, Ferrari MC. 2013. Social learning of predation risk: a review and prospectus. Social learning theory: phylogenetic considerations across animal, plant, and microbial taxa.:53–82.

578   Crane AL, Ferrari MC. 2015. Minnows trust conspecifics more than themselves when faced

579   with conflicting information about predation risk. Anim Behav. 100:184–190.

580   Dall SR, Giraldeau L-A, Olsson O, McNamara JM, Stephens DW. 2005. Information and its

581   use by animals in evolutionary ecology. Trends Ecol Evol. 20(4):187–193.

582   Dall SR, McNamara JM, Leimar O. 2015. Genes as cues: phenotypic integration of genetic and

583   epigenetic information from a Darwinian perspective. Trends Ecol Evol. 30(6):327–

584   333.

585   Danchin E, Giraldeau L-A, Valone TJ, Wagner RH. 2004. Public information: from nosy

586   neighbors to cultural evolution. Science. 305(5683):487–491.

587   Donelan SC, Trussell GC. 2015. Parental effects enhance risk tolerance and performance in

588   offspring. Ecology. 96(8):2049–2055.

589   Donelan SC, Trussell GC. 2018a. Parental and embryonic experiences with predation risk affect

590   prey offspring behaviour and performance. Proc R Soc B. 285(1874):20180034.

591   Donelan SC, Trussell GC. 2018b. Synergistic effects of parental and embryonic exposure to

592   predation risk on prey offspring size at emergence. Ecology. 99(1):68–78.

593   Douglas III HD, Kitaysky AS, Kitaiskaia EV. 2018. Odor is linked to adrenocortical function

594   and male ornament size in a colonial seabird. Behav Ecol. 29(3):736–744.

595   Downes S. 2001. Trading heat and food for safety: costs of predator avoidance in a lizard.

596   Ecology. 82(10):2870–2881.

597   Downes S, Hoefer AM. 2004. Antipredatory behaviour in lizards: interactions between group

598   size and predation risk. Anim Behav. 67(3):485–492.

599   Downes SJ. 2002. Does responsiveness to predator scents affect lizard survivorship? Behav

600   Ecol Sociobiol. 52(1):38–42.

601   Downes SJ, Shine R. 1999. Do incubation-induced changes in a lizard's phenotype influence

602   its vulnerability to predators? Oecologia. 120(1):9–18.

603   Dufty Jr AM, Clobert J, Møller AP. 2002. Hormones, developmental plasticity and adaptation.

Trends Ecol Evol. 17(4):190–196.

English S, Fawcett TW, Higginson AD, Trimmer PC, Uller T. 2016. Adaptive use of information during growth can explain long-term effects of early life experiences. The Am Nat. 187(5):620–632.

Fawcett TW, Frankenhuis WE. 2015. Adaptive explanations for sensitive windows in development. Front in Zool. 12(S1):S3.

Gabirot M, Lopez P, Martin J, De Fraipont M, Heulin B, Sinervo B, Clobert J. 2008. Chemical composition of femoral secretions of oviparous and viviparous types of male common lizards *Lacerta vivipara*. Biochem Syst Ecol. 36(7): 539–544.

Griffin A. 2004. Social learning about predators: a review and prospectus. Anim Learn Behav. 32(1):131–140.

Ioannou C. 2017. Grouping and predation. Encyclopedia of evolutionary psychological science.:1–6.

Johnson DD, Blumstein DT, Fowler JH, Haselton MG. 2013. The evolution of error: Error management, cognitive constraints, and adaptive decision-making biases. Trends Ecol Evol. 28(8):474–481.

Kats LB, Dill LM. 1998. The scent of death: chemosensory assessment of predation risk by prey animals. Ecoscience. 5(3):361–394.

Krause J, Ruxton GD, Ruxton GD, Ruxton IG. 2002. Living in groups. Oxford University Press.

Lanham EJ, Bull CM. 2004. Enhanced vigilance in groups in Egernia stokesii, a lizard with stable social aggregations. J Zool. 263(1):95–99.

Le Galliard J, Paquet M, Mugabo M. 2015. An experimental test of density-dependent selection on temperament traits of activity, boldness and sociability. J Evol Biol. 28(5):1144–1155.

Lê S, Josse J, Husson F. 2008. FactoMineR: an R package for multivariate analysis. J Stat Softw. 25(1):1–18.

630 Leimar O, McNamara JM. 2015. The evolution of transgenerational integration of information
631   in heterogeneous environments. Am Nat. 185(3):E55–E69.

632 Léna J, De Fraipont M, Clobert J. 2000. Affinity towards maternal odour and offspring dispersal
633   in the common lizard. Ecol Let. 3(4):300–308.

634 Léna J-P, Clobert J, De Fraipont M, Lecomte J, Guyot G. 1998. The relative influence of density
635   and kinship on dispersal in the common lizard. Behav Ecol. 9(5):500–507.

636 Lima SL. 1998. Stress and decision making under the risk of predation: recent developments
637   from behavioral, reproductive, and ecological perspectives. In: Advances in the Study
638   of Behavior. Vol. 27. Elsevier. p. 215–290.

639 Lima SL. 2002. Putting predators back into behavioral predator–prey interactions. Trends Ecol
640   Evol. 17(2):70–75.

641 Lima SL, Dill LM. 1990. Behavioral decisions made under the risk of predation: a review and
642   prospectus. Canadian journal of zoology. 68(4):619–640.

643 Lind J, Cresswell W. 2005. Determining the fitness consequences of antipredation behavior.
644   Behav Ecol. 16(5):945–956.

645 López P, Aragón P, Martin J. 1998. Iberian rock lizards (*Lacerta monticola cyreni*) assess
646   conspecific information using composite signals from faecal pellets. *Ethology*, *104*(10),
647   809-820.

648 Love OP, Williams TD. 2008. The adaptive value of stress-induced phenotypes: effects of
649   maternally derived corticosterone on sex-biased investment, cost of reproduction, and
650   maternal fitness. Am Nat. 172(4):E135–E149.

651 Lüdecke D, Lüdecke MD. 2017. Package 'sjstats'.

652 Martín J, Civantos E, Amo L, López P. 2007. Chemical ornaments of male lizards
653   Psammodromus algirus may reveal their parasite load and health state to females. Behav
654   Ecol Sociobiol. 62(2):173–179.

655 Martín J, Lopez P. 2010. Condition-dependent pheromone signaling by male rock lizards: more

oily scents are more attractive. Chem Senses. 35(4):253–262.

Martín J, López P. 2014. Pheromones and chemical communication in lizards. In: Reproductive biology and phylogeny of lizards and tuatara. Rheubert, Justin L., Dustin S. Siegel, and Stanley E. Trauth, eds. CRC Press. p. 43–77.

Mason RT, Parker MR. 2010. Social behavior and pheromonal communication in reptiles. J Comp Physiol A. 196(10):729–749.

Massot M, Lecomte J, Clobert J. 1992. Sex identification in juveniles of Lacerta vivipara. Amphib-Reptil. 13(1):21–25.

McCollum SA, Van Buskirk J. 1996. Costs and benefits of a predator-induced polyphenism in the gray treefrog Hyla chrysoscelis. Evolution. 50(2):583–593.

McNamara JM, Dall SR, Hammerstein P, Leimar O. 2016. Detection vs. selection: integration of genetic, epigenetic and environmental cues in fluctuating environments. Ecol Lett. 19(10):1267–1276.

Mell H, Josserand R, Decencière B, Artacho P, Meylan S, Le Galliard J-F. 2016. Do personalities co-vary with metabolic expenditure and glucocorticoid stress response in adult lizards? Behav ecol and sociobiol. 70(6):951–961.

Meylan S, Belliure J, Clobert J, de Fraipont M. 2002 Stress and body condition as prenatal and postnatal determinants of dispersal in the common lizard (*Lacerta vivipara*). Horm Behav. 42: 319–326.

Meylan S., Clobert J. 2005. Is corticosterone-mediated phenotype development adaptive? Maternal corticosterone treatment enhances survival in male lizards. Horm. Behav. 48: 44–52.

Moreira PL, López P, Martín J. 2008. Discrimination of conspecific faecal chemicals and spatial decisions in juvenile Iberian rock lizards (*Lacerta monticola*). acta ethologica, 11(1): 26–33.Nesse RM. 2005. Natural selection and the regulation of defenses: A signal detection analysis of the smoke detector principle. Evol hum behav. 26(1):88–

682   105.

683   Nettle D, Bateson M. 2015. Adaptive developmental plasticity: what is it, how can we recognize

684   it and when can it evolve? Proc R Soc B. 282(1812):20151005.

685   Oksanen J, Kindt R, Legendre P, O'Hara B, Stevens MHH, Oksanen MJ, Suggests M. 2007.

686   The vegan package. Community ecology package. 10:631–637.

687   Ortega Z, Mencía A, Pérez-Mellado V. 2017. Rapid acquisition of antipredatory responses to

688   new predators by an insular lizard. Behav Ecol and Sociobiol. 71(1):1.

689   Potticary A, Duckworth RA. 2020. Multiple environmental stressors induce an adaptive

690   maternal effect. Am Nat. 196(4): 487-500.

691   Ripley B, Venables B, Bates DM, Hornik K, Gebhardt A, Firth D, Ripley MB. 2013. Package

692   'mass'. *Cran R*, *538*.

693   Rodríguez-Prieto I, Martín J, Fernández-Juricic E. 2011. Individual variation in behavioural

694   plasticity: direct and indirect effects of boldness, exploration and sociability on

695   habituation to predators in lizards. Proc R Soc B. 278(1703):266–273.

696   Sheriff MJ, Bell A, Boonstra R, Dantzer B, Lavergne SG, McGhee KE, MacLeod KJ, Winandy

697   L, Zimmer C, Love OP. 2017. Integrating ecological and evolutionary context in the

698   study of maternal stress. Integr Comp Biol. 57(3):437–449.

699   Sheriff MJ, Krebs CJ, Boonstra R. 2010. The ghosts of predators past: population cycles and

700   the role of maternal effects under fluctuating predation risk. Ecology. 91: 2983–2994.

701   Sheriff MJ, Love OP. 2013. Determining the adaptive potential of maternal stress. Ecol lett.

702   16(2):271–280.

703   Shine R, Downes SJ. 1999. Can pregnant lizards adjust their offspring phenotypes to

704   environmental conditions? Oecologia. 119(1):1–8.

705   Stamps JA, Krishnan V. 2014. Combining information from ancestors and personal experiences

706   to predict individual differences in developmental trajectories. Am Nat. 184(5):647–

707   657.

708   Stein LR, Bukhari SA, Bell AM. 2018. Personal and transgenerational cues are nonadditive at

709   the phenotypic and molecular level. Nature ecology & evolution. 2(8):1306–1311.

710   Teyssier A, Bestion E, Richard M, Cote J. 2014. Partners' personality types and mate

711   preferences: predation risk matters. Behav Ecol. 25(4):723–733.

712   Uller T. 2008. Developmental plasticity and the evolution of parental effects. Trends Ecol Evol.

713   23(8):432–438.

714   Van Damme R, Bauwens D, Thoen C, Vanderstighelen D, Verheyen R. 1995. Responses of

715   naive lizards to predator chemical cues. J Herpetol.:38–43.

716   Webster M, Laland K. 2008. Social learning strategies and predation risk: minnows copy only

717   when using private information would be costly. Proc R Soc B. 275(1653):2869–2876.

718   Wickham H, Chang W, Wickham MH. 2016. Package 'ggplot2'. Create Elegant Data

719   Visualisations Using the Grammar of Graphics Version. 2(1):1–189.

720   Winandy L, Cote J. 2020. Data from: Maternal and personal information mediates the use of

721   social cues about predation risk. Behav Ecol. Dryad, Dataset,

722   https://doi.org/10.5061/dryad.tdz08kpzf

723   Winandy L, Darnet E, Denoël M. 2015. Amphibians forgo aquatic life in response to alien fish

724   introduction. Anim Behav. 109:209–216.

725

726 **TABLE 1** Summary results of LMM model relating the effect of the different sources of

727 information (i.e. maternal, personal and social) and their interaction on lizard attraction to

728 conspecific cues. Significant effects are highlighted in bold.

Paramaters:	Estimates	SE	X^2_1	95% CI	p-value
Source of information					
Maternal	0.472	0.479	2.001	-0.447, 1.391	0.157
Personal	1.297	0.515	1.795	0.303, 2.286	0.180
Social	0.868	0.463	0.420	-0.022, 1.758	0.517
Maternal * Personal	-0.791	0.702	0.379	-2.128, 0.587	0.538
Maternal * Social	-0.500	0.674	0.947	-1.792, 0.797	0.330
Personal * Social	-2.192	0.708	4.709	-3.544, -0.821	**0.030**
Maternal * Personal * Social	2.255	1.020	4.886	0.225, 4.214	**0.027**

729

730

731

732

733

734

735

736

737

738

739 **TABLE 2** Summary results of LMM models relating the effect of personal and social

740 information about predation risk on lizard sociability in presence (M+) and absence (M-) of

741 maternal information about predation. Significant effects are highlighted in bold.

Maternal information	Paramaters: Source of information	Estimates	SE	X^2_1	95% CI	p-value
M-	Personal	1.217	0.546	0.222	0.164, 2.269	0.637
	Social	0.859	0.515	0.025	-0.138, 1.853	0.875
	Personal * Social	-2.121	0.782	7.357	-3.630, -0.613	**0.007**
M+	Personal	0.528	0.463	2.383	-0.367, 1.428	0.123
	Social	0.365	0.445	1.269	-0.491, 1.251	0.260
	Personal * Social	-0.000	0.657	0.000	-1.389, 1.308	0.999

742
743

744 **SUPPLEMENTARY TABLE 1** Linear discriminant analysis on the occurrence of chemical

745 compounds in samples from lizards exposed (P+) and unexposed to predation (P-) using the

746 LEfSe platform (http://huttenhower.sph.harvard.edu/galaxy/).These compounds were selected

747 using linear discriminant scores (LDA > 2.0) and Mann-Whitney test (p_MW = p-value, p <

748 0.05).

Chemical compounds	Occurrence in treatment (%)		LDA effect size (log10)	p-value
	P+	P-		
X154 (Comp_1_Occ)	16.67	66.67	4.4179	**0.026**
X167 (Comp_2_Occ)	8.33	58.33	4.5312	**0.012**
X82	100	91.67	4.5351	**0.012**

749

750

751   **SUPPLEMENTARY TABLE 2** Similarity percentage analysis on the occurrence of chemical

752   compounds in samples from lizards exposed (P+) and unexposed to predation (P-). The

753   contribution of the compound to between-treatments dissimilarity and its standard deviation

754   (SD) are provided. P-values are obtained from a permutation test with 1000 permutations. The

755   compounds with a contribution larger than 0.01 are shown.

Chemical compounds	Compound contribution	SD of the contribution	Occurrence of chemical compounds		p-value
			P+	P-	
X154 (Comp_1_Occ)	0.0214	0.0178	0.1667	0.6667	**0.0060**
X167 (Comp_2_Occ)	0.0198	0.0181	0.0833	0.5833	**0.0030**
X76	0.0175	0.0182	0.3333	0.5000	0.2697
X47	0.0174	0.0181	0.5000	0.8333	0.1968
X109	0.0173	0.0179	0.5000	0.3333	0.6713
X50	0.0171	0.0177	0.3333	0.5000	0.5125
X159	0.0170	0.0176	0.0833	0.5000	0.0400
X80	0.0169	0.0179	0.4167	0.4167	0.9980
X168	0.0168	0.0185	0.4167	0.6667	0.9930
X137	0.0166	0.0183	0.0833	0.3333	0.9970
X152	0.0163	0.0184	0.5833	0.7500	0.6833
X170	0.0156	0.0181	0.3333	0.3333	0.9970
X101	0.0153	0.0178	0.1667	0.4167	0.3137
X106	0.0152	0.0175	0.3333	0.3333	1.0000
X79	0.0151	0.0168	0.2500	0.4167	0.5964
X126	0.0150	0.0173	0.3333	0.3333	0.9970
X66	0.0146	0.0178	0.3333	0.2500	0.9970
X249	0.0142	0.0173	0.3333	0.2500	1.0000
X149	0.0142	0.0172	0.3333	0.2500	0.9990
X145	0.0135	0.0174	0.1667	0.3333	0.2448
X235	0.0127	0.0165	0.1667	0.3333	0.2757
X116	0.0111	0.0160	0.1667	0.2500	0.6034
X21	0.0110	0.0160	0.1667	0.2500	0.4645
X100	0.0105	0.0151	0.1667	0.2500	0.3386

756

757

758   **SUPPLEMENTARY TABLE 3** The part of each compound on the LDA axis was analyzed

759   with a linear model with LDA axis as a dependent variable and the occurrence of the compounds

760   ass an explanatory variable. Significant ones are highlighted in bold.

Compounds	Std coefficients	CI lower	CI upper	t-test	p-value
X10	-0.0549	-1.6208	1.5110	-0.0727	0.9427
X100	0.0246	-1.0412	1.0903	0.0478	0.9623
X101	-0.5980	-1.5129	0.3168	-1.3557	0.1889
X103	0.9287	-0.5825	2.4400	1.2745	0.2158
X104	1.3901	-0.0503	2.8305	2.0014	0.0578
X105	0.0172	-1.5489	1.5832	0.0227	0.9821
X106	-0.0161	-0.9342	0.9021	-0.0363	0.9714
X109	0.3089	-0.5584	1.1762	0.7386	0.4679
X113	-1.3837	-2.5407	-0.2267	-2.4802	**0.0213**
X116	-0.5115	-1.5530	0.5301	-1.0184	0.3196
X12	-1.0491	-3.1649	1.0668	-1.0283	0.3150
X126	0.1074	-0.8096	1.0243	0.2428	0.8104
X130	-1.0517	-3.1673	1.0639	-1.0309	0.3138
X137	-0.1343	-1.0264	0.7579	-0.3121	0.7579
X142	1.1128	-0.3740	2.5996	1.5522	0.1349
X145	-0.3440	-1.3320	0.6440	-0.7221	0.4779
X149	0.4039	-0.5315	1.3393	0.8955	0.3802
X15	0.2747	-1.0285	1.5778	0.4371	0.6663
X152	-0.4032	-1.3039	0.4975	-0.9284	0.3633
X154 comp_1	-0.9819	-1.7450	-0.2187	-2.6683	**0.0140**
X158	-1.3174	-2.4894	-0.1454	-2.3311	**0.0293**
X159	-0.9936	-1.8385	-0.1487	-2.4388	**0.0233**
X164	-1.4314	-2.8639	0.0010	-2.0724	0.0502
X165	-1.2787	-3.3697	0.8123	-1.2682	0.2180
X167 comp_2	-1.2037	-1.9519	-0.4555	-3.3364	**0.0030**
X168	0.2310	-0.6573	1.1192	0.5393	0.5951
X170	0.1876	-0.7268	1.1021	0.4255	0.6746
X173	-1.0790	-2.2977	0.1398	-1.8360	0.0799
X18	-0.3930	-1.6902	0.9042	-0.6283	0.5363
X180	1.5318	-0.5256	3.5893	1.5441	0.1368
X188	-0.8465	-2.3672	0.6741	-1.1545	0.2607
X192	-0.8847	-3.0152	1.2458	-0.8612	0.3984
X198	0.7797	-1.3588	2.9182	0.7562	0.4576
X20	-0.3384	-1.4902	0.8133	-0.6094	0.5485
X21	-0.3416	-1.3967	0.7134	-0.6715	0.5089
X217	-0.8847	-3.0152	1.2458	-0.8612	0.3984
X218	-1.1271	-3.2351	0.9809	-1.1088	0.2795
X235	-0.5819	-1.5478	0.3840	-1.2494	0.2247
X236	-1.1271	-3.2351	0.9809	-1.1088	0.2795

X249	0.2264	-0.7206	1.1734	0.4959	0.6249
X254	-1.1271	-3.2351	0.9809	-1.1088	0.2795
X287	1.0433	-1.0731	3.1597	1.0224	0.3177
X290	1.0433	-1.0731	3.1597	1.0224	0.3177
X38	-1.0491	-3.1649	1.0668	-1.0283	0.3150
X41	-1.0517	-3.1673	1.0639	-1.0309	0.3138
X47	-0.6549	-1.5262	0.2164	-1.5587	0.1333
X5	-1.0491	-3.1649	1.0668	-1.0283	0.3150
X50	-0.3397	-1.2047	0.5253	-0.8144	0.4241
X51	-0.2165	-1.7796	1.3467	-0.2872	0.7766
X6	-1.0491	-3.1649	1.0668	-1.0283	0.3150
X63	0.6205	-1.5282	2.7691	0.5989	0.5554
X66	0.2890	-0.6547	1.2326	0.6351	0.5319
X69	-1.3283	-2.7800	0.1235	-1.8974	0.0710
X70	-1.4324	-3.5038	0.6391	-1.4341	0.1656
X72	0.2352	-1.0694	1.5399	0.3739	0.7121
X76	-0.4189	-1.2771	0.4393	-1.0124	0.3223
X79	-0.4978	-1.3893	0.3936	-1.1582	0.2592
X80	-0.1599	-1.0350	0.7153	-0.3788	0.7084
X81	-1.1271	-3.2351	0.9809	-1.1088	0.2795
X82	1.1938	-0.9070	3.2946	1.1785	0.2512
X93	0.4390	-0.8553	1.7333	0.7034	0.4892

761

762

763

SUPPLEMENTARY TABLE 4 Contributions (in %) of the chemical compound to the first

two axis of the MCA (MC1 and MC2).

Compounds	MC1	MC2	Compounds	MC1	MC2
X10_N	0.08707947	0.00676785	X192_N	0.00118471	0.0001665
X10_Y	0.95787414	0.07444634	X192_Y	0.02724844	0.00382942
X100_N	0.61839521	0.61958591	X198_N	0.06461066	0.00456372
X100_Y	2.3499018	2.35442644	X198_Y	1.48604528	0.1049655
X101_N	0.22311634	1.30143302	X20_N	0.29363092	0.1629909
X101_Y	0.54185396	3.16062306	X20_Y	0.05872618	0.03259818
X103_N	0.056515	0.00701668	X21_N	0.46876316	0.32609739
X103_Y	0.62166501	0.07718348	X21_Y	1.78130002	1.23917008
X104_N	0.17645263	0.00402807	X217_N	0.00118471	0.0001665
X104_Y	1.94097893	0.04430879	X217_Y	0.02724844	0.00382942
X105_N	0.06249526	0.25844474	X218_N	0.02872433	0.00087635
X105_Y	0.6874479	2.84289219	X218_Y	0.66065968	0.02015609
X106_N	0.42805431	0.37976616	X235_N	1.80156004	0.37562457
X106_Y	0.85610862	0.75953231	X235_Y	5.40468012	1.12687372
X109_N	0.04200149	0.89777594	X236_N	0.02872433	0.00087635
X109_Y	0.05880208	1.25688632	X236_Y	0.66065968	0.02015609
X110_Y	6.27E-31	6.28E-31	X249_N	1.4466928	0.04811525
X113_N	0.4497757	0.31876193	X249_Y	3.5133968	0.11685132
X113_Y	3.14842993	2.23133348	X254_N	0.02872433	0.00087635
X116_N	0.77109756	0.42683848	X254_Y	0.66065968	0.02015609
X116_Y	2.93017074	1.62198623	X287_N	0.04602633	0.00108232
X12_N	0.01123698	0.28539565	X287_Y	1.05860561	0.02489335
X12_Y	0.25845049	6.56409996	X290_N	0.04602633	0.00108232
X126_N	0.19141592	0.19835902	X290_Y	1.05860561	0.02489335
X126_Y	0.38283184	0.39671804	X38_N	0.01123698	0.28539565
X130_N	0.01419281	0.00128481	X38_Y	0.25845049	6.56409996
X130_Y	0.32643459	0.02955061	X41_N	0.01419281	0.00128481
X137_N	0.49408083	0.562244	X41_Y	0.32643459	0.02955061
X137_Y	0.2964485	0.3373464	X47_N	0.41674108	0.00247901
X142_N	0.01048617	6.8491E-07	X47_Y	0.20837054	0.00123951
X142_Y	0.11534788	7.534E-06	X5_N	0.01123698	0.28539565
X145_N	1.17781216	0.53612855	X5_Y	0.25845049	6.56409996
X145_Y	3.53343648	1.60838564	X50_N	0.78277465	0.55263318
X149_N	0.4678568	1.43284687	X50_Y	1.09588451	0.77368645
X149_Y	1.13622366	3.47977097	X51_N	0.00685812	0.06098394
X15_N	0.62093225	0.18748768	X51_Y	0.07543933	0.67082337
X15_Y	4.34652574	1.31241374	X6_N	0.01123698	0.28539565
X152_N	0.39781619	0.13244647	X6_Y	0.25845049	6.56409996
X152_Y	0.19890809	0.06622324	X63_N	0.0009896	0.02512299
X154_N	0.62926464	1.18887168	X63_Y	0.02276076	0.57782867
X154_Y	0.88097049	1.66442035	X66_N	0.04275621	1.154135
X158_N	0.01699763	0.30022806	X66_Y	0.10383651	2.80289928

X158_Y	0.11898339	2.10159644	X69_N	0.08117691	0.30164285
X159_N	0.02426734	1.18142499	X69_Y	0.89294599	3.31807137
X159_Y	0.05893497	2.86917497	X70_N	0.14127656	0.14549519
X164_N	0.28453983	0.34604872	X70_Y	3.24936079	3.34638926
X164_Y	3.12993813	3.80653593	X72_N	0.05224178	0.06001557
X165_N	0.02725379	0.00853318	X72_Y	0.36569249	0.42010901
X165_Y	0.62683718	0.19626309	X76_N	1.03119579	0.13375063
X167_N	1.46431053	0.74432017	X76_Y	1.44367411	0.18725088
X167_Y	2.92862107	1.48864034	X79_N	0.47481352	0.00225228
X168_N	3.32261458	0.70066263	X79_Y	0.94962704	0.00450456
X168_Y	5.53769097	1.16777104	X80_N	0.31288219	0.76759627
X170_N	2.70165226	0.72427865	X80_Y	0.43803506	1.07463478
X170_Y	5.40330452	1.44855729	X81_N	0.02872433	0.00087635
X173_N	0.07106418	0.0537883	X81_Y	0.66065968	0.02015609
X173_Y	0.49744925	0.37651812	X82_N	0.68990226	0.69607478
X18_N	0.40058147	0.03872462	X82_Y	0.02999575	0.03026412
X18_Y	2.80407032	0.27107234	X93_N	0.04384443	0.12851646
X180_N	0.0015009	0.04406517	X93_Y	0.306911	0.8996152
X180_Y	0.03452076	1.01349892			
X188_N	2.10212683	0.08341418			
X188_Y	0.19110244	0.00758311			

766

767

768

769 **SUPPLEMENTARY TABLE 5** Linear discriminant analysis on the abundance of chemical

770 compounds in samples from lizards exposed (P+) and unexposed to predation (P-) using the

771 LEfSe platform (http://huttenhower.sph.harvard.edu/galaxy/).These compounds were selected

772 using linear discriminant scores (LDA > 2.0) and Mann-Whitney test (p_MW = p-value, p <

773 0.05).

Chemical compounds	Predation treatment		LDA effect size (log10)	p-value
	P+	P-		
X154 (Comp_1_Ab)	0.0053	0.0197	4.0560	**0.017**
X167 (Comp_2_Ab)	0.0061	0.0161	3.8549	**0.021**

774

775

776 **SUPPLEMENTARY TABLE 6** Spearman coefficient and p-value for the correlations

777 between the first axis of the LDA and the abundance of each compound. Significant ones are

778 highlighted in bold.

Compounds	Spearman	p-value	Compounds	Spearman	p-value
X10	-0.05530165	0.79744512	X188	-0.10697978	0.61880429
X100	0.03061097	0.88708807	X192	-0.22591967	0.28846596
X101	-0.15480506	0.47012651	X198	0.16567443	0.43912168
X103	0.34178232	0.10212057	X20	-0.16209189	0.44921815
X104	0.349035	0.09458715	X21	-0.0599975	0.78063901
X105	0.02085144	0.92295847	X217	-0.22591967	0.28846596
X106	0.16888698	0.43017202	X218	-0.19579705	0.35918525
X109	0.19611882	0.35838041	X235	-0.23776087	0.26325008
X110	0.26347826	0.21267378	X236	-0.19579705	0.35918525
X113	-0.53701651	**0.00681334**	X249	0.10284253	0.6325087
X116	-0.01224439	0.95471671	X254	-0.19579705	0.35918525
X12	-0.16567443	0.43912168	X287	0.22591967	0.28846596
X126	-0.12329786	0.56597757	X290	0.22591967	0.28846596
X130	-0.25604229	0.22718485	X38	-0.16567443	0.43912168
X137	0.09914272	0.64486447	X41	-0.25604229	0.22718485
X142	0.22936586	0.28097636	X47	-0.06688491	0.75616286
X145	-0.0240047	0.91134962	X5	-0.16567443	0.43912168
X149	0.10825529	0.61460371	X50	-0.05388413	0.80253589
X15	0.09530152	0.65778959	X51	0.05167531	0.81048395
X152	0.02790562	0.89701279	X6	-0.16567443	0.43912168
X154 Comp_1	-0.5058312	**0.01167671**	X63	0.07530656	0.72654294
X158	-0.31010812	0.14027926	X66	0.01623829	0.93996884
X159	-0.33450885	0.11011241	X69	-0.34178232	0.10212057
X164	-0.45510537	**0.0254441**	X70	-0.34641016	0.09726418
X165	-0.07530656	0.72654294	X72	0.23749744	0.26379515
X167 Comp_2	-0.6201157	**0.00122749**	X76	-0.11310813	0.5987301
X168	0.20294927	0.34154524	X79	-0.16681475	0.4359336
X170	0.16629669	0.43738043	X80	0.14806	0.4899164
X173	-0.32977352	0.11555654	X81	-0.19579705	0.35918525
X18	-0.12706869	0.55406363	X82	0.28869565	0.17085682
X180	0.31628754	0.132136	X93	0.16639948	0.43709315

779

780 **SUPPLEMENTARY TABLE 7** Component loadings of the relative abundance of chemical

781 compound observed from principal components analyses: Correlations between the 62 different

782 compounds identified in the samples compound and the first two axis of the PCA (PC1 and

783 PC2).

Compounds	PC1	PC2	Compounds	PC1	PC2
X10	0.1959	0.4768	X188	0.6677	0.0001
X100	0.0491	0.5664	X192	0.123	0.2168
X101	-0.381	-0.2837	X198	0.183	0.6085
X103	0.0343	-0.07	X20	0.1801	0.6261
X104	-0.2463	-0.1697	X21	0.2124	0.569
X105	-0.2229	-0.0075	X217	0.123	0.2168
X106	0.7676	-0.2997	X218	0.0189	0.5303
X109	0.7751	-0.4438	X235	0.1235	0.806
X110	0.6277	-0.3355	X236	0.0189	0.5303
X113	-0.2754	0.0022	X249	0.4427	0.504
X116	-0.3169	-0.2341	X254	0.0189	0.5303
X12	0.4433	-0.3345	X287	-0.2208	-0.05
X126	-0.526	-0.0445	X290	-0.2208	-0.05
X130	-0.1643	0.0017	X38	0.4433	-0.3345
X137	0.5267	-0.3332	X41	-0.1643	0.0017
X142	-0.2309	-0.0219	X47	0.5296	-0.1133
X145	-0.352	-0.291	X5	0.4433	-0.3345
X149	0.5456	-0.123	X50	0.5747	-0.1144
X15	0.2367	0.5367	X51	0.1185	0.5611
X152	-0.2564	-0.2697	X6	0.4433	-0.3345
X154	0.0732	0.4958	X63	-0.1231	-0.0353
X158	-0.1944	-0.1423	X66	0.5769	-0.1836
X159	0.317	-0.0973	X69	-0.1761	-0.1599
X164	-0.2274	0.0014	X70	-0.1541	0.0114
X165	-0.1578	-0.0667	X72	0.3652	-0.1774
X167	0.2211	0.6519	X76	0.5691	0.3097
X168	-0.4313	-0.3386	X79	0.5326	-0.3433
X170	-0.4382	-0.3218	X80	0.4533	0.1594
X173	0.0827	0.0813	X81	0.0189	0.5303
X18	0.4734	-0.2247	X82	0.7766	-0.0192
X180	0.3983	-0.1893	X93	-0.3158	-0.05

784

785

786

787 **SUPPLEMENTARY TABLE 8** Effect of the indicators of chemical composition on lizard

788 sociability: the number of compounds, the two axis of the MCA on the abundance (*i.e.,* MC1

789 and MC2) and the LDA first axis of the occurrence. We analyzed the triple interaction with

790 maternal and personal information to extract effects sizes and compare it to the effect size of

791 the treatment. Significance is only reported for information and should not be used to compare

792 the strength of effects.

Indicators of chemical composition	Interactive effect with maternal and personal information		
	sdt. estimate	χ^2_1	p-value
Number of compounds	-0.48	1.619	0.203
MC1 occurrence	-0.15	3.081	0.081
MC2 occurrence	-0.11	1.195	0.274
LDA occurrence	0.19	5.623	0.018
Comp_1_Occ	-0.396	4.001	0.046
Comp_2_Occ	-0.622	9.248	0.002

793

794

795 **SUPPLEMENTARY TABLE 9** Effect of the indicators of chemical composition on lizard

796 sociability: the number of compounds, the two axis of the PCA on the abundance (*i.e.,* PC1 and

797 PC2) and the LDA first axis of the abundance. We analyzed the triple interaction with maternal

798 and personal information to extract effects sizes and compare it to the effect size of the

799 treatment. Significance is only reported for information and should not be used to compare the

800 strength of effects.

801

Indicators of chemical composition	Interactive effect with maternal and personal information		
	sdt. estimate	χ^2_1	p-value
PC1 abundance	-0.250	2.742	0.098
PC2 abundance	-0.484	10.886	0.001
LDA abundance	0.532	3.638	0.056
Comp_1_Ab	-0.820	11.034	0.001
Comp_2_Ab	-0.596	8.125	0.004

802

803

804   **FIGURE 1 Sources of information about predation risk**

805   The predation treatment (light grey and dark red for respectively unexposed and exposed to

806   predation cues) was manipulated in each of the three source of information following a full-

807   crossed experimental design. Half of the gravid mother were exposed to predation risk (*i.e.,*

808   maternal information). After hatching, each clutch was divided in halves and raised with or

809   without predation risk (*i.e.,* personal information) in order to have all combination of treatment

810   between mothers and offspring: offspring unexposed from mother unexposed (P-M-, n=39; P

811   for personal information and M for maternal information), offspring unexposed from mother

812   exposed (P-M+, n=36), offspring exposed from mother unexposed (P+M-, n=30) and offspring

813   exposed from mother exposed (P+M+, n=32). The social information was provided by cues

814   from conspecific (using feces) that were either previously exposed (S+), or unexposed (S-) to

815   predation risk.

816

817   **FIGURE 2 Interactive effect of multiple sources of information about predation risk on**

818   **lizard social attraction**.

819   The variation of social attraction (mean ± SE) according to the interaction between personal

820   and social information depended on the maternal information about predation: a) in the absence

821   of maternal information about predation risk (M-), there is a significant interaction between

822   personal information (P- versus P+) and social information (S-, light grey bars and S+, dark red

823   bars); b) in the presence of maternal information about predation risk (M+), there is a slight

824   increase of sociability when the number of sources of information about the actual risk of

825   predation increased. See results for statistics.

826

827   **FIGURE   3 Interactive effects of the occurrence of chemical composition on lizard**

828   **sociability**

829   Comparison of effect size (95% CI) of the triple interaction between maternal information,

830 personal information and social information (S- *versus* S+) and the triple interaction between

831 maternal information, personal information and the different indicators of chemical

832 composition on lizard sociability. The indicators of chemical composition are the number of

833 compounds, the two axis of the MCA on the occurrence (*i.e.,* MC1 and MC2), the LDA first

834 axis of the occurrence and the occurrence of two compounds: Comp_1_Occ and Comp_2_Occ.

835

836 **SUPPLEMENTARY FIGURE 1 Interactive effects of the abundance of chemical**

837 **composition on lizard sociability**

838 Comparison of effect size (95% CI) of the triple interaction between maternal information,

839 personal information and social information (S- *versus* S+) and the triple interaction between

840 maternal information, personal information and the different indicators of chemical

841 composition on lizard sociability. The indicators of chemical composition are the number of

842 compounds, the two axis of the PCA on the abundance (*i.e.,* PC1 and PC2), the LDA first axis

843 of the abundance and the abundance of two compounds: Comp_1_Ab and Comp_2_Ab.

844