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

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10

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23

24 **Abstract**

25 Organisms can gain information about predation risks from their parents, their own personal
26 experience and their conspecifics, and adjust their behavior to alleviate these risks. These
27 different sources of information can, however, provide conflicting information due to spatial
28 and temporal variation of the environment. This raises the question of how these cues are
29 integrated to produce adaptive antipredator behavior. We investigated how common lizards
30 (*Zootoca vivipara*) adjust the use of conspecifics cues about predation risk depending on
31 whether the information is maternally- or personally-acquired. We experimentally
32 manipulated the presence of predator scent in gestating mothers and their offspring in a full-
33 crossed design. We then tested the consequences for social information use by monitoring
34 offspring social response to conspecifics previously exposed to predator cues or not. Lizards
35 were more attracted to the scent of conspecifics having experienced predation cues when they
36 had themselves no personal information about predation risk. In contrast, they were more
37 repulsed by conspecific scent when they had personally obtained information about predation
38 risk. However, the addition of maternal information about predation risk cancelled out this
39 interactive effect between personal and social information: lizards were slightly more
40 attracted to conspecific scent when these two sources of information about predation risk were
41 in agreement. A chemical analysis of lizard scent revealed that exposure to predator cues
42 modified the chemical composition of lizard scents, a change that might underlie lizards' use
43 of social information. Our results highlight the importance of considering multiple sources of
44 information while studying anti-predator defenses.

45 *Key words*

46 Anti-predator behavior, conspecific attraction, disturbance cues, inadvertent social
47 information, maternal stress, private information, transgenerational plasticity

48

49 INTRODUCTION

50 Prey frequently respond to the risk of predation via plastic physiological, morphological
51 and/or behavioural changes, with strong implications for individual fitness (Lima 2002;
52 Benard 2004). The most common antipredator behaviours include active escape, reduction of
53 activity, shelter use or grouping behaviour (Krause et al. 2002; Lima 2002; Winandy et al.
54 2015). Although these behavioural defences are expected to enhance survival, they may also
55 be costly (Lind and Cresswell 2005). For example, reducing activity or increasing the time
56 spent in refuge alleviates the risk of being detected by a predator but also decreases foraging
57 and mating opportunities. Consequently, individuals should experience energy allocation
58 trade-offs between predator avoidance and other essential activities (Lima 1998). Organisms
59 should therefore benefit from obtaining information about predation risk to maximize their
60 benefit-cost ratio of antipredator behaviors.

61 Prey may rely on a variety of cues from different sources to assess predation risk.
62 Throughout their life, individuals gain information by personal experience, which implies
63 observation, detection and/or direct non-lethal encounter with predators. Individuals can also
64 gain information from parental cues carried over to the next generation (*i.e.*, transgenerational
65 effects). In particular, if mothers have reliable information about the risk of predation that
66 their offspring are likely to encounter in the future, they can shape their offsprings' phenotype
67 to be better defended against predator (Sheriff and Love 2013; Sheriff et al. 2017). For
68 example, offspring produced by mother exposed to predation risk can exhibit morphological
69 defense (e.g. the helmet morph in *Daphnia*, Agrawal et al. 1999; the greater wing length in
70 great tits, Coslovsky and Richner 2011); an increase growth rate (Donelan and Trussell
71 2018a; Donelan and Trussell 2018b); more active and bold personalities (Donelan and
72 Trussell 2015)). Such adaptive maternal stress may occur for example when the circulating
73 maternal glucocorticoid hormones during pregnancy is linked to a relevant ecological stressor

74 leading to programming the stress axis of offspring in order to prepare them to cope, reproduce
75 and survive in an environment where the ecological stressor is frequently encountered (Love
76 and William 2008; Sheriff et al. 2010; Love et al. 2013; Sheriff et al. 2017; Potticary and
77 Duckworth 2020). For example, in common lizards, high maternal levels of corticosterone
78 influence juvenile activity, basking and dispersal behavior (Belliure et al. 2004; Meylan et al.
79 2002; Meylan and Clobert 2005).

80 While personal and parental information are well-studied for predation risk,
81 organisms can also gather information that is socially transmitted by conspecifics (*i.e.*, social
82 information; Danchin et al. 2004; Dall et al. 2005; Blanchet et al. 2010). Social information
83 can either rely on intentionally produced signals (*e.g.*, alarm calls), or on behavioral and
84 chemical cues 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
89 future environments. For example, social information being generally recognized as less
90 reliable than personal information, individuals might favor personal information over social
91 when sources are in conflict. Alternatively, because predation risk can fluctuate in time and
92 space, individuals might trust conspecifics information about a threat over their own
93 information about safety (Crane and Ferrari 2015). A general assumption is that the addition
94 of consistent sources of information should increase the predictive accuracy of information,
95 and result in a linear relationship between the number of coherent sources and the
96 adaptiveness of the phenotype (Leimar and McNamara 2015). Yet, accumulating coherent
97 sources of information may not be required when a single source of information is sufficient
98 to go beyond a threshold and elicit a response (Buoro et al. 2012). This could particularly be

99 the case when dealing with life threatening information such as the presence of predators;
100 prey should overestimate the degree of risk (Johnson et al. 2013) and respond to predatory
101 cues even if they come from only a single source (Blanchet et al. 2010). While theoretical
102 studies provided several models of cues integration (Stamps and Krishnan 2014; Dall et al.
103 2015; Leimar and McNamara 2015), experimental studies that examine how prey integrates
104 information from multiple sources in order to make behavioural decisions are still rare (Beaty
105 et al. 2016; Donelan and Trussell 2018a; Stein et al. 2018). A more general evolutionary
106 understanding of information use in anti-predator defense requires that we understand how
107 individuals integrate transgenerational cues informing them about the past environment with
108 immediate environmental cues (personally- or socially-acquired) to produce adaptive
109 phenotypes (Leimar and McNamara 2015; McNamara 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
114 without olfactory cues from a predator (snake), and personal information was manipulated by
115 raising the offspring from these females with or without predator cues. We manipulated
116 predation risk with olfactory cues rather than with actual predators because lizards are able to
117 innately detect chemicals left on the substrate by a snake predator (Van Damme et al. 1995).
118 Further, snake cues gained personally or through maternal effects effectively elicit lizard
119 antipredator responses including morphological (*e.g.*, tail length), behavioral (*e.g.*, activity,
120 basking) and life history strategies (*e.g.*, dispersal, mate choice) (Van Damme et al. 1995;
121 Downes and Shine 1999; Bestion et al. 2014; Teyssier et al. 2014; Ortega et al. 2017). We
122 then assessed the use of social information about predation risk through the level of attraction
123 to conspecific scents. This assay has been routinely used in common lizards to assess

124 individual attraction towards conspecific cues depending on cues such as donors' relatedness
125 (Léna et al. 1998; Léna et al. 2000), past experience of competition (Aragón et al. 2006;
126 Aragon et al. 2006), and more generally the individual social strategy with respect to
127 population density (Cote and Clobert 2007; Cote et al. 2008; Le Galliard et al. 2015; Mell et
128 al. 2016). We used the scent of conspecifics either previously exposed to predator cues or not,
129 and tested the attraction to these conspecific cues (*i.e.*, sociability) of focal individuals at the
130 subadult stage (*i.e.*, one year old). To go deeper into the molecular mechanisms responsible
131 for social information, we tested whether exposure to predator cues modified lizard scent.
132 When an organism is disturbed or stressed, but not captured by a predator, it can indeed
133 release chemical cues (Chivers and Smith 1998), as shown in lacertids (Aragón et al. 2008).
134 These modified scents can act as disturbance cues warning nearby conspecifics of the risk of
135 predation (Chivers et al. 2012; Bairos- Novak et al. 2019; Bairos- Novak et al. 2019).

136 While previous studies have shown that common lizards use social information to
137 make behavioral decisions (*e.g.*, Aragon 2006; Cote & Clobert, 2007, 2010), it is unknown
138 how maternal and personal information may modulate the use of conspecific cues about
139 predation risks. We could broadly expect that either all sources of information (*i.e.*,
140 maternally, personally or socially-acquired) influence lizard's responses in an additive way, or
141 that more reliable sources of information elicit a threshold response. Since personal and
142 maternal information are usually more reliable than social information, we predict that social
143 information about predation risk would matter more when maternal and personal cues about
144 predation risk are lacking, or when they provide conflicting information.

145 **MATERIALS AND METHODS**

146 **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

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
153 previous experience of females with predators, snakes were observed in only 2 of the 4
154 populations during the last 20 years of monitoring (pers. comm. Jean Clobert). We therefore
155 equally distributed females from each population and from populations with and without
156 observed snakes between the two treatments (populations with snakes: 16 females and their
157 44 juveniles in the predation risk treatment and 16 females and 42 juveniles in the control
158 treatment, populations without snakes: 10 females and 24 juveniles in the predation risk
159 treatment and 12 females and 27 juveniles in the control treatment). We maintained females in
160 24 outdoor tanks (1100 L; diameter: 1.70 m , 2 females in each tank, except 1 tank of each
161 treatment with 3 females) containing 20 cm of soil litter, dense vegetation, one dish for water
162 and a weekly addition of crickets, *Acheta domestica*. We provided refuges by adding several
163 5cl falcon tube in the litter, three half flower pots and two perforated bricks. A basking area
164 was available in the center of the tanks, using a few rocks and three logs. These housing
165 conditions were highly suitable for lizards, as shown in previous experiments (Bestion et al.
166 2014; Teyssier et al. 2014). Gestation usually lasts 2-3 months depending on air temperature.
167 During the last month of gestation, we manipulated maternal information by exposing the
168 females to predator or control scent (see below for the detail description of the procedure).
169 Before the first parturition, females were brought to the lab in 35 x 18 x 22 cm individual
170 terraria filled with 5cm substrate, providing two shelters (on and under the ground) and a
171 water bowl. A light bulb (25 W) and an UV lamp provided respectively a heat source and
172 light from 9 AM to noon and from 2 PM to 5 PM. In addition, each terraria were water
173 sprayed three times a day. Food was provided daily with two crickets per lizard. Since the
174 lizard populations used in this study are viviparous, we separated all newborns from their

175 mother just after parturition. In total, we raised 137 juveniles that we marked by toe clipping
176 (approved by the ethical committee and the French government: APAFIS#15897-
177 2018070615164391 v3) and sexed by counting the number of ventral scales (Massot et al.
178 1992). Each clutch, whose mother was either exposed or unexposed to predator scents, was
179 equally split between the two treatments for personal information. Using this full-crossed
180 design (Figure 1), we exposed two generations of lizards to predator cues: offspring
181 unexposed from mother unexposed (P-M-, n=39; P for personal information and M for
182 maternal information), offspring unexposed from mother exposed (P-M+, n=36), offspring
183 exposed from mother unexposed (P+M-, n=30) and offspring exposed from mother exposed
184 (P+M+, n=32). Offspring were raised in 24 outdoor tanks (in the same maintenance
185 conditions as described before). We randomly distributed the juveniles into 12 tanks of a
186 control treatment and 12 tanks of a predation treatment (5 to 7 individuals in each tank),
187 checking there were no difference in body size or body mass between treatments (body size: t
188 = -1.127, $P = 0.261$; body mass: $t = -0.344$, $P = 0.731$). The density and sex-ratio were
189 similar between treatments (generalized linear model with a Poisson distribution and a log
190 link, number of lizards: P- = 6.00 ± 0.21 , P+ = 5.92 ± 0.19 , $P = 0.93$; number of females (with
191 number of lizards as a covariate): P- = 0.55 ± 0.02 , P+ = 0.52 ± 0.02 , $P = 0.78$). Offspring
192 personal exposure was manipulated twice: just after birth at the juvenile stage (in summer
193 2014) and one year later at the subadult stage (in summer 2015).

194

195 **Predation risk treatments**

196 We used the cues of a natural predator the green whip snake, *Hierophis viridiflavus*.
197 Common lizards have an innate recognition of snakes as a threat and their highly developed
198 tongue-vomer nasal system allows them to detect chemicals that are left on the substrate by
199 the snake predator. Lizard responses to snake scents strongly decreases the chance of capture

200 (Downes 2002). Common lizards live in dense vegetation and their population density is
201 much higher than that of snakes. Direct encounters with snake are therefore rare but highly
202 lethal. This innate aversion of lizard to predatory scents is thus subjected to minor ontogenetic
203 changes and is stable over long periods of time without an encounter with a snake (Van
204 Damme et al. 1995; Bestion et al. 2014).

205 We kept the green whip snake in a terrarium providing a water bowl, a shelter and a
206 light bulb for basking. To collect snake odours, we placed calcite tiles (3 x 3 x 0.6 cm) in the
207 snake cage for three days and gently rubbed, using rubber gloves, on the snake body before
208 use. We used identical tiles (i.e. blank tiles), kept in a separate room, for the control treatment
209 without snake scent. We placed fives tiles in each outdoor home tank, blank tiles for the
210 control tanks and tiles with cues for the predation tanks. Every three days for four weeks, we
211 exchanged old tiles of both treatments for new ones before olfactory cues could vanish in the
212 outdoor tanks. This same predator exposure protocol was used for all sources of information:
213 the maternal exposure in Mai 2014, the offspring exposure in August 2014 at juvenile stage
214 and in August 2015 at subadult stage. While we did not use any physical encounters to
215 maintain the potential anti-predatory response, one month of exposure to predatory cues is not
216 enough to trigger habituation (Downes 2001; Downes 2002). Moreover, we did not use the
217 scent of the same snake for exposure at the juvenile and subadult stages. This scent novelty
218 that should maintain lizard responsiveness. Previous studies show that both within and
219 between-generation responses are induced by predator olfactory cues manipulated over a
220 month (Shine and Downes 1999; Bestion et al. 2014), which makes this procedure, along with
221 ethical considerations, the most suitable option.

222

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

224 Social information about predation was provided after the second exposure to
225 predation cues at the subadult stage (in late summer 2015). We assessed individual social
226 response to the cues of conspecifics that were previously exposed to predator cues (S+) or not
227 (S-). Following the full crossed-design experiment (Figure 1), half of the lizards from each
228 treatment (*i.e.*, P-M-, P-M+, P+M- and P+M+) were exposed to S+ and the other half were
229 exposed to S-. To do so, we collected pooled scents from the lizards maintained in each of the
230 24 tanks just after the predation treatment at the subadult stage (August 2015). These 24
231 groups (12 from the control treatment and 12 from the predation treatment) were housed
232 separately in large terraria (35 x 18 x 22 cm) covered by paper towel during one week.
233 Twenty-four pieces of paper containing the feces of each group were then used during the
234 social attraction test. Each tested lizard was exposed to one of the 24 different scents, always
235 avoiding the scent of their own group to exclude the possibility that lizards were exposed to
236 their own feces or to feces from a conspecific that they already knew. Lizards were cleaned
237 using an antiparasite solution (©frontline) before being released in the terraria and could
238 therefore not bear predator cues from tiles on them. We collected the papers devoid of
239 conspecific scent from vacant terraria maintained in the same conditions as our inhabited
240 terraria.

241 We tested social attraction with a choice assay between two compartments with or
242 without scents of conspecifics. This type of assay is commonly used in common lizards and
243 other lizard species to quantify individuals' social strategies (Cote and Clobert 2007; Cote et
244 al. 2008; Rodríguez-Prieto et al. 2011; Teyssier et al. 2014; Le Galliard et al. 2015; Mell et al.
245 2016). In reptiles, lizards' scents convey various types of information about the donor (Martín
246 & Lopez, 2010, 2014). Therefore, the assay allowed us to measure attraction to conspecific
247 cues depending on donors' characteristics (*i.e.*, social information, Léna et al. 1998; Léna et
248 al. 2000; Aragón et al. 2006). We used glass terraria (34 × 17 × 25 cm) divided in three
249 compartments: a shelter without conspecific scents was put at one end of the terrarium and a

250 shelter with conspecific scents was put at the other end of the terrarium. We placed each
251 lizard in the central compartment (devoid of shelter and scent) for four hours and we started
252 the assay by removing the walls separating the compartments. After 10 min of acclimation to
253 the two shelters, we recorded for another 10 min the time spent in each compartment and
254 on/under each shelter to estimate social tendency. Video were analyzed using “The Observer”
255 software, allowing the exact measurement of the time in each location. The observer was
256 blind to the treatment of individuals.

257 **Analysis of scent chemical composition**

258 We analyzed the chemical composition of scent samples collected in the 24 terraria in
259 the same manner as those used for the social attraction test (12 from the control treatment and
260 12 from the predation treatment). This means that for each group, the sample was made of
261 several pieces of paper towel with feces and was composed of a mix of individual scents. We
262 collected feces instead of femoral secretions because feces are also commonly used in lacertid
263 lizard to simulate olfactory responses (Aragón et al. 2000, López et al. 1998, Moreira et al.
264 2008) and chemical communication based on femoral secretions is relatively less important in
265 this species (Gabirot et al. 2008). Samples were collected using surgical pliers cleaned with
266 alcohol and rinsed with sterile water between each population. Samples of paper towel and
267 soil from vacant terraria were also collected as controls. Samples were disposed in glass vials
268 and kept at -80°C until analyses.

269 Chemical compounds were analyzed using solid phase microextraction (SPME) with a
270 Stableflex fiber (50/30µm DVB/CAR/PDMS, Supelco, Sigma-Aldrich, Bellefonte, PA, USA).
271 Samples were placed at 50°C for 20min, and the fiber was then exposed to the headspace of
272 the glass vials (without touching the towel) for 20min. Absorbed chemicals were then
273 analyzed on a mass spectrometer quadrupole detector (ISQ QD) coupled to a Trace 1300 gas
274 chromatography (Thermo Fisher Scientific Inc) with a capillary column (Restek RTX-5MS 30

275 m x 0.25 mm, 0.25 μ m film thickness, 5% diphenyl and 95% dimethylpolysiloxane) and a
276 splitless injector (300 °C). Ionization was performed by electron impact (70 eV, source
277 temperature 250 °C). Helium was the carrier gas (1.2 ml/ min). The oven temperature was
278 initiated at 40 °C for 1 min, and then programmed to increase 10 °C/min to 300 °C and held at
279 300°C for 5 min. The scan range of the mass spectrometer was 60 to 500 m/z. Blanks were
280 regularly interspersed throughout the sample analyses. After removing the compounds found
281 in paper towel and soil (*i.e.*, control sample without feces), we obtained 62 different peaks
282 (*i.e.*, compounds). The relative abundance of compound refers to the relative areas of the
283 selected peaks that were restandardized to 100%. Tentative compound identification was
284 performed based on mass spectral fragmentation patterns and comparison with the NIST mass
285 spectral library using Xcalibur software.

286

287 **Statistical analysis**

288 To summarize the data collected during the social attraction test, we performed a
289 Principal Component Analysis (PCA) using the time spent in each compartment (*i.e.*, with or
290 without conspecific scents, excluding the central compartment) and the time spent on, and
291 under each shelter. These data were scaled to unit variance before the analysis. The PC1 axis
292 explained 39% of the variance and had an eigenvalue of 2.32. It was positively correlated to
293 behaviors in the compartment without scent (PC loadings: 0.94 for the total time spent in the
294 compartment without scent and 0.6 for the time spent under the shelter) and negatively
295 correlated to behaviors in the compartment with conspecific scent (PC loadings: -0.92 for the
296 total time spend in the compartment with scent and -0.44 for the time spend under the shelter).
297 To make interpretation easier, we multiplied scores by -1. Higher scores on the PC1 axis then
298 corresponded to higher attraction to conspecific scent (*i.e.*, higher sociability).

299 Afterward, we used linear mixed models to assess the effect of maternal, personal and
300 social information about predation (single effects and interactions between these three factors)
301 on social attraction. We added sex and body size (snout-vent length) as covariates as they can
302 influence sociability (Michelangeli, Chapple, & Wong, 2016), and mother identity and tank
303 group as random intercepts. Sex and body size did not affect the use of conspecific cues ($P >$
304 0.11 for simple effects and interactions with the three sources of information) and were
305 therefore removed from the model. We then used likelihood ratio tests to estimate the
306 significance of factors and interactions in the model and provided summary of parameter
307 estimates and confidence interval (95%). To test the additive effects of information sources
308 about predation risk on social attraction, we ran a linear regression by scoring the number of
309 sources as follow: 0 when there were neither personal nor conspecific cues about risk, 1 when
310 there were either a personal information or conspecific cue about risk and 2 when there were
311 both personal information or conspecific cue about risk. Compliance with requirement of the
312 fitted linear model were checked using Shapiro-Wilk normality test on the model residuals
313 assessing social attraction ($W = 0.988$, $P = 0.29$).

314 We assessed the effect of predation risk on lizard chemical profile. We first analyzed
315 the number of compounds present in each of the 24 chemical profiles (each tank) using a
316 GLM assuming a Poisson error distribution and a log link. We then perform analysis on the
317 occurrences (presence/absence) of chemical compounds that convey threshold information.
318 We identified differences in the occurrence of compounds between treatments using a
319 discriminant analysis (LDA) effect size (LEfSe) on the 62 initial compounds using the Galaxy
320 platform (<http://huttenhower.sph.harvard.edu/galaxy/>) with a 0.05 p-value threshold and a
321 LDA score >2 (supplementary table 1). As a cross-validation, we also ran a similarity
322 percentage analysis on the occurrence of the 62 compounds (supplementary table 2) and
323 considered the compounds identified as different in both LDA and similarity analysis as
324 important. We then summarized the occurrence of the 62 compounds using a LDA and a

325 MCA (i.e. Multiple Correspondence Analysis). The two methods are complementary as the
326 LDA summarizes differences in chemical profiles between treatments in a single variable and
327 the MCA summarize chemical profiles regardless of the treatments. The contribution of each
328 compound to the first axis of a LDA was examined using linear models with LDA axis as a
329 dependent variable and the occurrence of the compound as an explanatory variable
330 (supplementary table 3). For the MCA, we kept the first two axes (i.e., MC1 and MC2) as
331 they explained respectively 12.62% and 10.80% of the variance and had an eigenvalue of 0.12
332 and 0.11, respectively. The contribution (in %) of each compound to the first two axis of the
333 MCA is in Supplementary table 4.

334 We used the occurrences above rather than the relative abundances because a high
335 proportion of relative abundances were equal to 0 which complicated the transformation
336 needed for the PCA and LDA. However, the analysis using relative abundances largely
337 supported the results based on the occurrence data (see supplementary material). The LDA
338 analysis using galaxy identified the same compounds (supplementary table 5) and the LDA
339 axis on abundances was highly correlated to the LDA axis on occurrences (Estimate: 0.99,
340 SE= 0.04, $R^2 = 0.96$, $P < 0.0001$). The contribution of each compound to the first axis of a
341 LDA was examined using Spearman rank correlations (supplementary table 6). For the PCA,
342 we kept the first two axes (i.e., PC1 and PC2) as they explained respectively 13.97% and
343 11.36% of the variance and had an eigenvalue of 8.66 and 7.04, respectively. The component
344 loadings of the relative abundance of chemical compounds can be found in supplementary
345 table 7.

346 A final post-hoc analysis investigated whether the identified differences in chemical
347 profiles between exposed and unexposed donors are responsible for the effect of predation
348 risk on the use of conspecific cues. We compared effects sizes of the predation risk treatment
349 of cues donors (i.e. the social information as reported in Table 1) and of the chemical profiles

350 on social attraction. Similar or higher effect sizes would suggest that the descriptor may
351 convey the social information about predation risk, while lower effect sizes would suggest
352 additional unidentified information carriers. To do so, we ran the same linear model with
353 maternal, personal and social treatments on lizard sociability (as in Table 1), but replacing the
354 social information treatment by the descriptors of the cues used for the social information
355 assay (supplementary table 8). The descriptors were the number of compounds, the two MCA
356 axes, the LDA axis and the occurrence of compounds that differed between predation and
357 control treatment. We extracted effect sizes (standardized beta coefficients) and compared it
358 to the effect for the predation risk treatments of cues donors in interaction with maternal and
359 personal treatments. Note that caution about conclusion should be exercised, as only an
360 experimental manipulation of chemical profiles would permit us to test directly the role of
361 chemical profile. Finally, we performed the same post-hoc analysis using the descriptors of
362 compound abundance: the LDA axis of the abundance, the two PCA axis and the abundance
363 of compounds that differed between predation and control treatment (supplementary table 9).
364 We provided p-values in supplementary tables 8 and 9 for information purposes. Only the
365 effects sizes should be interpreted, as they are not influenced by the post-hoc multiple testing.

366 Analyses were performed in R 3.5.1 (www.r-project.org) using FactoMinR (Lê et al.
367 2008), ggplot2 (Wickham et al. 2016), lme4 (Bates et al. 2007), sjstats (Lüdecke and Lüdecke
368 2017), MASS (Ripley et al. 2013), and vegan (Oksanen et al. 2007) packages.

369 **RESULTS**

370 **Effect of sources of information on sociability**

371 Personal and maternal information interacted to shape the use of social information
372 about predation risk (Table 1). We found a significant interaction between personal and social
373 information on lizards' sociability, but only when mothers were not exposed to predator cues
374 (Table 2, Figure 2a). In this case, lizards with personal information about predation risk were

375 repulsed by the scent of conspecifics exposed to predator cues ($\chi^2_1 = 50.579$, $P < 0.001$),
376 while naïve lizards tended to be attracted by these conspecifics scents ($\chi^2_1 = 3.147$, $P =$
377 0.076). Maternal exposure to predation risk canceled out this interaction between personal and
378 social information (Table 2): sociability tended to increase with the number of sources of
379 information about risk (Estimates= 0.442, SE= 0.237, $\chi^2_1 = 3.478$, $P = 0.062$; Table 2, Figure
380 2b).

381 **Effect of predation risk on conspecific scent**

382 The exposure of individuals to predator cues significantly decreased the number of chemical
383 compounds forming lizard scents ($\chi^2_1 = 7.394$, $P = 0.007$, mean \pm SE, S+: 16.8 ± 1.2 and S-:
384 12.6 ± 1.1). The LDA effect size analysis showed that two compounds substantially differed
385 between the profiles of exposed and unexposed lizards (supplementary table 1), which is also
386 confirmed by the similarity percentage analysis (Supplementary Table 2). Other compounds
387 were also identified from the correlations with the LDA axis (Supplementary Table 3) and the
388 similarity percentage analysis (Supplementary Table 2), but it is likely they had a weaker role
389 in the chemical differentiation. The predation treatments had a significant effect on the LDA
390 axis ($F_{1,22} = 106.1$, $P < 0.001$, mean \pm SE, P+: -1.251 ± 0.857 and P-: 1.751 ± 0.386), but had
391 no effects on the two MCA axes (MC1: $F_{1,22} = 1.276$, $P = 0.271$ and MC2: $F_{1,22} = 0.902$, $P =$
392 0.353). The tentative identification of chemical compounds indicated that the two main
393 compounds, Compound_1 (i.e. X154) and Compound_2 (i.e. X167), may be respectively a
394 derivative of Naphthalenol and an unsaturated alcohol.

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

400 Table 8, Figure 3).

401 Overall, the various analyses of the relative abundance of the chemical compounds
402 showed very similar results to the analysis based on their occurrence. Indeed the LDA effect
403 size analysis highlighted the same two compounds (supplementary table 5, supplementary
404 table 6). The post-hoc analyses comparing effect sizes showed that the effect size of the
405 interaction between personal, maternal and social information is similar or slightly lower than
406 the effect size of the interaction using the PC2 and the abundance of Comp_1 and Comp_2
407 instead of the social information treatment (Supplementary Table 9, Supplementary figure 1).

408 **DISCUSSION**

409 We assessed how personally- and maternally-acquired information altered lizards' responses
410 to conspecific cues. We found that personal and maternal information interacted to shape
411 lizard responses to conspecific cues about predation risk. The scent of conspecifics exposed to
412 predation risk attracted more focal lizards when they had no personal information about the
413 risk, while it repulsed them when they also had personal knowledge about the risk.
414 Furthermore, we found that maternal information about predation risk cancelled out this
415 interactive effect between personal and social information, with individuals tending to be
416 more social when sources of information about risk added up.

417 Prey are known to assess the risk of predation when making decisions about how to
418 behave (Lima 2002). Decision making often results in a trade-off between risk and other
419 rewarding activities (*e.g.*, foraging and mating; Kats and Dill 1998). An accurate risk
420 assessment requires reliable information about predation at a given time and location. Such
421 information can be acquired via multi-modal sensory cues including sight, tactile and
422 chemical signals made by conspecifics. In our study, we manipulated the exposure to
423 predation risk using scents of a snake predator because it is known to elicit anti-predator
424 behavior in common lizards through maternal and personal exposure, even one month after

425 exposure (Bestion et al. 2014; Teyssier et al. 2014). Such permanent strong defense behavior
426 without any actual encounter with predators can be explained by the low encounter rate
427 between lizards and snakes in the wild, because of the dense vegetation and the comparatively
428 lowest density of predators. It can further be explained by the high probability the a snake is
429 successful in catching a lizard when an actual attack occurs. We further showed that common
430 lizards can use olfactory cues from conspecifics to assess predation risk, while it was already
431 known that they can perceive different donors' characteristics through scents (*i.e.*, relatedness:
432 Léna et al. 1998; past experiences of competition: Aragón et al. 2006; Aragon et al. 2006).
433 Chemical cues released by a conspecific may signal individual stress levels (Douglas III et al.
434 2018), body condition (Martín and Lopez 2010) or health status (Martín et al. 2007) and lizard
435 species are particularly prone to use such signals to assess mating partners or competitors
436 (reviewed in Mason and Parker 2010). Predation risk usually requires chemicals from injured
437 conspecifics (*i.e.*, alarm cues) to elicit behavioral defense in other conspecifics (Crane and
438 Ferrari 2013). However, prey can also release a chemical signal when detecting a predator
439 (*i.e.*, disturbance cues; Chivers and Smith 1998; Griffin 2004), or have a modified scent after
440 experiencing predation risk, as found in another lacertid lizard species (Aragón et al. 2008).

441 Individuals may rely on cues intentionally or inadvertently produced by conspecifics,
442 (defined as social information: Danchin et al. 2004; Dall et al. 2005; Blanchet et al. 2010), to
443 cope with limited personal information about challenging environmental conditions. In the
444 context of predation risk, acquiring social cues may be less costly and therefore more adaptive
445 than acquiring the information personally through a direct encounter with a predator
446 (Blanchet et al. 2010). Moreover, no personal information about predation risk can be
447 unreliable because predators circulate in the environments and their actual presence can be
448 highly variable in space and time. A prey may then overestimate the degree of risk (Johnson
449 et al. 2013) and a response to predator cues could be observed even if they came from only a
450 single source (Nesse 2005; Blanchet et al. 2010). However, when an individual eventually

451 encounters a predator, social cues may become less relevant and additional cues about risk
452 may even signal an acute increase in predation risk. In absence of maternal cues, we found
453 that social and personal information about risk increase the attraction towards conspecific
454 scents when these information sources are uncoupled, supposedly because grouping may
455 decrease predation risk (Lima and Dill 1990; Krause et al. 2002). Indeed, an increase in
456 sociability is a common antipredator strategy in lizard that allows for collective vigilance (*i.e.*,
457 increased detection of predators, (Downes and Hoefer 2004; Lanham and Bull 2004) and a
458 risk-dilution effect (*i.e.*, a lower probability for a single individual to be captured, Ioannou
459 2017). However, in the absence of maternal cues, lizard personally-informed about predators
460 avoided the scents of social partners that were also exposed to predator scents. The
461 accumulation of information sources about predator presence, through personal and social
462 information, may indicate a temporally or spatially acute risk of predation. Lizards may
463 therefore avoid the scent of predator-exposed conspecifics because it signals immediate
464 danger, while the scent of unexposed conspecifics is attractive because it might signal safe
465 conditions. The safest strategy could then be to avoid a particular social partner who has
466 recently encountered a predator.

467 Transgenerational information can strongly influence prior expectations about
468 individuals' risk, and, in turn, the use of social information. We found that the exposure of
469 mothers to predation risk during gestation cancelled out the observed interaction between
470 personal and social information and was replaced by a weak but significant additive effect of
471 information sources affecting lizard social responses. The attraction towards conspecific
472 scents increased gradually with the number of sources of information about predation risk
473 from lizards with only maternal information to lizards personally, socially and maternally
474 informed. Additional cues might increase an individual's confidence in the state of the
475 environment, causing a multiplicative effect on their sociality. A higher level of sociability

476 could indeed be an efficient antipredator strategy in a risky environment. While additivity is
477 less expected in discrete traits such as a defensive morphology (McCollum and Van Buskirk
478 1996; Buoro et al. 2012), it is more likely to occur in gradual behavioral traits. Maternal
479 information signals environmental conditions on a larger temporal scale than does personal
480 information. When maternal and offspring information matches, it signals a persistent risk
481 across generations (Sheriff et al. 2017), which can explain the additive effect of information
482 sources. The environmental/maternal-matching hypothesis states that maternal stress can be
483 adaptive if the maternal and offspring environmental conditions match (Sheriff et al. 2017). In
484 our study, when personal and maternal information about risk matched (P+M+), social
485 information was less valuable. Indeed, individuals showed high attraction to conspecific cues
486 whether or not this conspecific was exposed to predation risk, as in a persistent risk of
487 predation, being more sociable could be beneficial. On the contrary, social information had
488 stronger effect when there was no personal and maternal information about risk (P-M-). In
489 this case, individuals were only attracted by social cues of conspecific that had been exposed
490 to predation risk, which mirrors cases where acquiring personal information is costly
491 (Webster and Laland 2008). If social cues were misleading, it would only result in reduced
492 foraging or mating opportunities, while not responding to a relevant danger cue could result in
493 higher mortality risk by predation. Prey might thus benefit from erring on the side of caution
494 (Johnson et al. 2013).

495 Finally, we also attempted an assessment of the molecular mechanisms responsible for
496 social information by collecting feces samples from groups of lizards exposed and unexposed
497 to predation risk to identify potential changes in their chemical scent profiles. In our study,
498 predators never injured lizards, as we never exposed lizards to actual predators, so there were
499 no compounds released upon injury (*i.e.*, damage-release chemical alarm signals; Chivers et
500 al. 1996). Despite no physical encounter with predators, as in natural populations, the

501 exposure to predator cues changed the chemical composition of lizard scents collected from
502 feces. We found fewer chemical compounds in the scent of lizards exposed to predation risk
503 compared to unexposed lizards. Our conservative analysis revealed that two compounds were
504 differently expressed between treatments. The tentative identification of the chemical
505 compounds matches expectations since Lacertid lizards usually have alcohols in their
506 secretions, and alcohols can be detected by conspecifics (Martín and López 2014). This
507 modification of scent profile may have provided chemical cues for risks and triggered the
508 observed behavioral response to conspecific scents. We also ran post-hoc analyses replacing
509 the predation risk treatment of donors' scents by a few descriptors summarizing chemical
510 profiles and compared effect sizes. We expected similar or larger effect sizes if chemical
511 profiles were indeed the mechanisms behind social responses to conspecific scents, and this is
512 what we observed for the two compounds differently expressed between treatments. However,
513 caution should be exercised in interpreting this preliminary investigation of chemical profiles
514 and their influences. In depth chemical analysis and manipulative experiments are required to
515 provide a more precise identification of chemical cues, and to ascertain their influences on
516 lizard's behavior.

517 **CONCLUSION**

518 Prey generally have incomplete information about their environment and have to rely on other
519 source of information to assess the risk of predation. In our study, the scents of conspecific
520 exposed to predation risk acted as social information shaping behavioral responses. However,
521 when personal and social information conflicted, which is mostly the rule in stochastic
522 environments, decision making can be hampered. Transgenerational information seemed to
523 alleviate the uncertainty about risk when personal and social information mismatched.
524 Transgenerational cues can provide information on a larger temporal scale and influence the
525 prior expectations of individuals about their environment. Moreover, ancestors' experience is

526 the first possible source of information an individual can get and, therefore, may have large
527 effects on phenotypic outcomes (Dufty Jr et al. 2002; Fawcett and Frankenhuis 2015; English
528 et al. 2016; Donelan and Trussell 2018a). Maternal exposures to predation cues may
529 adaptively prepare the phenotype of offspring for more stressful environmental conditions
530 (Uller 2008; Sheriff and Love 2013; Sheriff et al. 2017) but also induce changes in the
531 developmental trajectory of offspring, leading to direct or delayed effects on individuals from
532 the embryonic stage to adulthood (Love and Williams 2008; Nettle and Bateson 2015). Here
533 we found that maternal stress affected how offspring used the cues from conspecific later in
534 life. While our study raises interesting perspectives on how animals integrate information
535 from a wide variety of sources to make decisions, we believe additional studies on this and
536 other taxa are required to replicate our results and test the generality of our conclusions.
537 Understanding the complex mechanisms involved in the integration of multiple information
538 sources within and among several generation deserves further attention (Sheriff et al. 2017).

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737

738 **TABLE 1** Summary results of LMM model relating the effect of the different sources of
 739 information (i.e. maternal, personal and social) and their interaction on lizard attraction to
 740 conspecific cues. Significant effects are highlighted in bold.

Parameters:	Estimates	SE	χ^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

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751 **TABLE 2** Summary results of LMM models relating the effect of personal and social
 752 information about predation risk on lizard sociability in presence (M+) and absence (M-) of
 753 maternal information about predation. Significant effects are highlighted in bold.

Maternal information	Parameters: Source of information	Estimates	SE	χ^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

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756 **SUPPLEMENTARY TABLE 1** Linear discriminant analysis on the occurrence of chemical
 757 compounds in samples from lizards exposed (P+) and unexposed to predation (P-) using the
 758 LEfSe platform (<http://huttenhower.sph.harvard.edu/galaxy/>). These compounds were selected
 759 using linear discriminant scores (LDA > 2.0) and Mann-Whitney test (p_MW = p-value, p <
 760 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

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763 **SUPPLEMENTARY TABLE 2** Similarity percentage analysis on the occurrence of
764 chemical compounds in samples from lizards exposed (P+) and unexposed to predation (P-).
765 The contribution of the compound to between-treatments dissimilarity and its standard
766 deviation (SD) are provided. P-values are obtained from a permutation test with 1000
767 permutations. The 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

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770 **SUPPLEMENTARY TABLE 3** The part of each compound on the LDA axis was analyzed
 771 with a linear model with LDA axis as a dependent variable and the occurrence of the
 772 compounds as 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

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776 **SUPPLEMENTARY TABLE 4** Contributions (in %) of the chemical compound to the first
 777 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			

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781 **SUPPLEMENTARY TABLE 5** Linear discriminant analysis on the abundance of chemical
 782 compounds in samples from lizards exposed (P+) and unexposed to predation (P-) using the
 783 LEfSe platform (<http://huttenhower.sph.harvard.edu/galaxy/>). These compounds were selected
 784 using linear discriminant scores (LDA > 2.0) and Mann-Whitney test (p_MW = p-value, p <
 785 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

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788 **SUPPLEMENTARY TABLE 6** Spearman coefficient and p-value for the correlations
 789 between the first axis of the LDA and the abundance of each compound. Significant ones are
 790 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

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792 **SUPPLEMENTARY TABLE 7** Component loadings of the relative abundance of chemical
793 compound observed from principal components analyses: Correlations between the 62
794 different compounds identified in the samples compound and the first two axis of the PCA
795 (PC1 and 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

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799 **SUPPLEMENTARY TABLE 8** Effect of the indicators of chemical composition on lizard
800 sociability: the number of compounds, the two axis of the MCA on the abundance (*i.e.*, MC1
801 and MC2) and the LDA first axis of the occurrence. We analyzed the triple interaction with
802 maternal and personal information to extract effects sizes and compare it to the effect size of
803 the treatment. Significance is only reported for information and should not be used to compare
804 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

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807 **SUPPLEMENTARY TABLE 9** Effect of the indicators of chemical composition on lizard
808 sociability: the number of compounds, the two axis of the PCA on the abundance (*i.e.*, PC1
809 and PC2) and the LDA first axis of the abundance. We analyzed the triple interaction with
810 maternal and personal information to extract effects sizes and compare it to the effect size of
811 the treatment. Significance is only reported for information and should not be used to compare
812 the strength of effects.

813

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

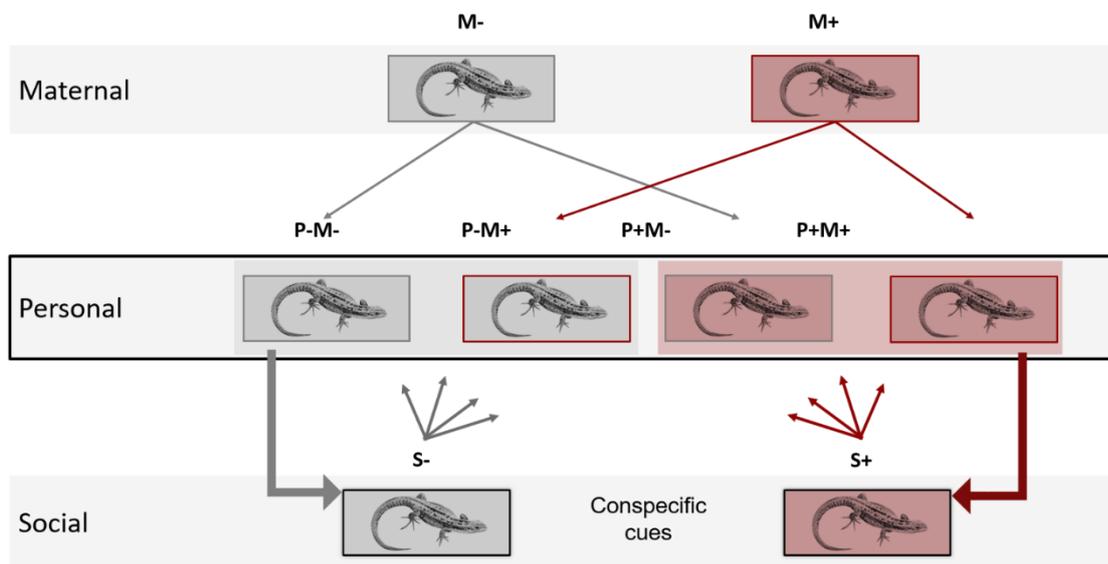
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816 **FIGURE 1 Sources of information about predation risk**

817 The predation treatment (light grey and dark red for respectively unexposed and exposed to
 818 predation cues) was manipulated in each of the three source of information following a full-
 819 crossed experimental design. Half of the gravid mother were exposed to predation risk (*i.e.*,
 820 maternal information). After hatching, each clutch was divided in halves and raised with or
 821 without predation risk (*i.e.*, personal information) in order to have all combination of
 822 treatment between mothers and offspring: offspring unexposed from mother unexposed (P-M-
 823 , n=39; P for personal information and M for maternal information), offspring unexposed
 824 from mother exposed (P-M+, n=36), offspring exposed from mother unexposed (P+M-, n=30)
 825 and offspring exposed from mother exposed (P+M+, n=32). The social information was
 826 provided by cues from conspecific (using feces) that were either previously exposed (S+), or
 827 unexposed (S-) to predation risk.

SOURCE OF INFORMATION

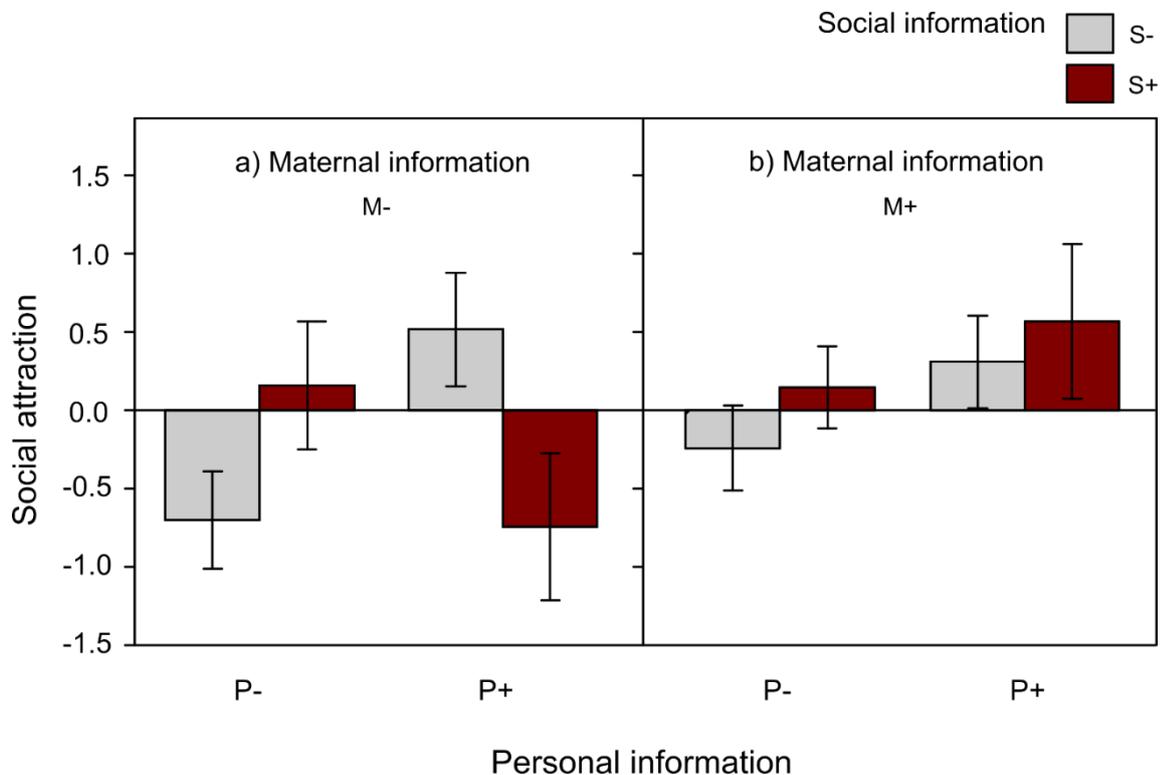


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830 **FIGURE 2 Interactive effect of multiple sources of information about predation risk on**
831 **lizard social attraction.**

832 The variation of social attraction (mean \pm SE) according to the interaction between personal
833 and social information depended on the maternal information about predation: a) in the
834 absence of maternal information about predation risk (M-), there is a significant interaction
835 between personal information (P- versus P+) and social information (S-, light grey bars and
836 S+, dark red bars); b) in the presence of maternal information about predation risk (M+), there
837 is a slight increase of sociability when the number of sources of information about the actual
838 risk of predation increased. See results for statistics.

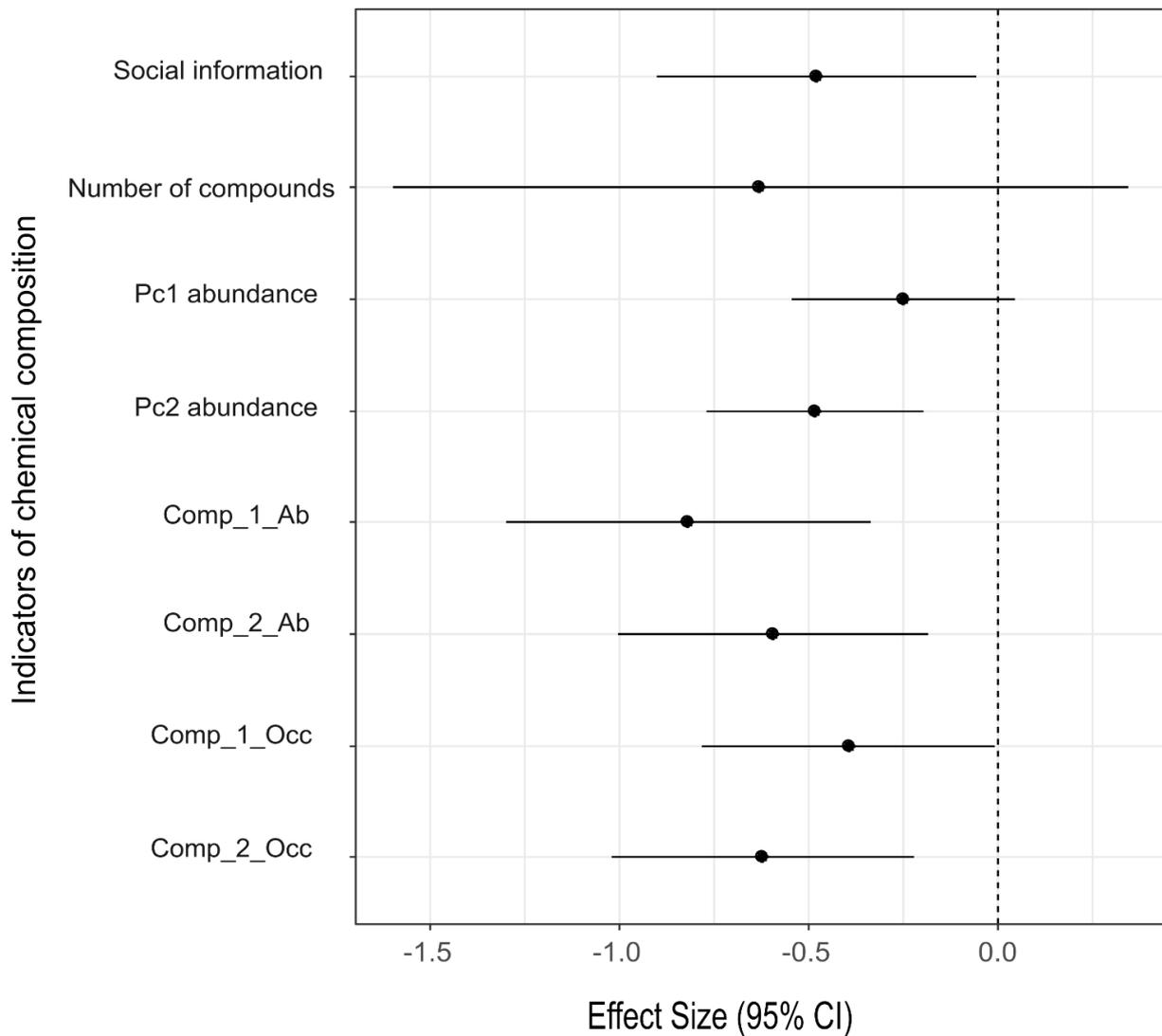


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841 **FIGURE 3 Interactive effects of the occurrence of chemical composition on lizard**
842 **sociability**

843 Comparison of effect size (95% CI) of the triple interaction between maternal information,
844 personal information and social information (S- versus S+) and the triple interaction between
845 maternal information, personal information and the different indicators of chemical
846 composition on lizard sociability. The indicators of chemical composition are the number of
847 compounds, the two axis of the MCA on the occurrence (*i.e.*, MC1 and MC2), the LDA first
848 axis of the occurrence and the occurrence of two compounds: Comp_1_Occ and
849 Comp_2_Occ.

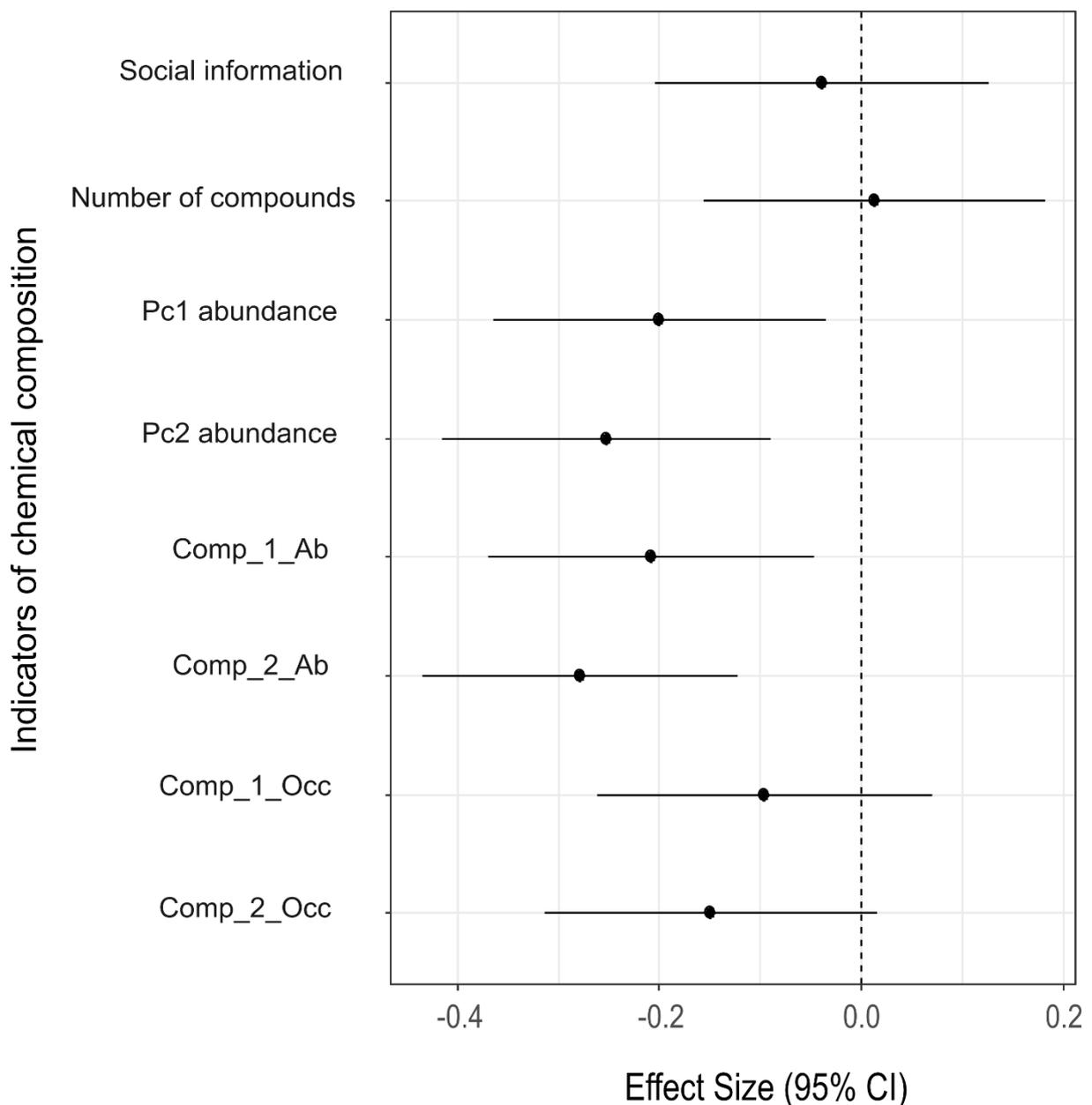


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851

852 **SUPPLEMENTARY FIGURE 1 Interactive effects of the abundance of chemical**
853 **composition on lizard sociability**

854 Comparison of effect size (95% CI) of the triple interaction between maternal information,
855 personal information and social information (S- versus S+) and the triple interaction between
856 maternal information, personal information and the different indicators of chemical
857 composition on lizard sociability. The indicators of chemical composition are the number of
858 compounds, the two axis of the PCA on the abundance (*i.e.*, PC1 and PC2), the LDA first axis
859 of the abundance and the abundance of two compounds: Comp_1_Ab and Comp_2_Ab.



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