Developmental Science

Received: 2 March 2016 | Accepted: 18 August 2016

DOI: 10.1111/desc.12507

PAPER

WILEY Developmental Science

When preschoolers follow their eyes and older children follow their noses: visuo-olfactory social affective matching in childhood

Annachiara Cavazzana[1,2] | Christiane Wesarg[1] | Julia Parish-Morris[3] | Johan N. Lundström[1,4,5] | Valentina Parma[1,3,4,6]

[1]Monell Chemical Senses Center, Philadelphia, PA, USA

[2]Department of General Psychology, University of Padova, Padova, Italy

[3]Center for Autism Research, Children's Hospital of Philadelphia, Philadelphia, PA, USA

[4]Department of Clinical Neuroscience, Karolinska Institutet, Stockholm, Sweden

[5]Department of Psychology, University of Pennsylvania, Philadelphia, PA, USA

[6]SISSA, Neuroscience Area, Trieste, Italy

Correspondence
Valentina Parma, SISSA, Neuroscience Area, Via Bonomea, 265, Trieste (TS), Italy.
Email: vparma@sissa.it

Funding information
National Science Foundation, Grant/Award Number: 1113648; Alice Wallenberg Foundation; Living Knut, Grant/Award Number: 2012.0141

Abstract

Recognition of emotional facial expressions is a crucial skill for adaptive behavior that most often occurs in a multi-sensory context. Affective matching tasks have been used across development to investigate how people integrate facial information with other senses. Given the relative affective strength of olfaction and its relevance in mediating social information since birth, we assessed olfactory–visual matching abilities in a group of 140 children between the ages of 3 and 11 years old. We presented one of three odor primes (rose, fish and no-odor, rated as pleasant or unpleasant by individual children) before a facial choice task (happy vs. disgusted face). Children were instructed to select one of two faces. As expected, children of all ages tended to choose happy faces. Children younger than 5 years of age were biased towards choosing the happy face, irrespective of the odor smelled. After age 5, an affective matching strategy guided children's choices. Smelling a pleasant odor predicted the choice of happy faces, whereas smelling the unpleasant or fish odor predicted the choice of disgusted faces. The present study fills a gap in the developmental literature on olfactory-visual affective strategies that affect decision-making, and represents an important step towards understanding the underlying developmental processes that shape the typical social mind.

RESEARCH HIGHLIGHTS

- Children younger than age 5 do not use visuo-olfactory affective matching strategies.
- Children older than 5 use visuo-olfactory affective matching strategies.
- Happy faces are preferentially chosen when no odor is available.

1 | INTRODUCTION

Face processing is a basic dimension of social communication that is relevant throughout development (McClure, 2000). Numerous studies suggest that humans are responsive to face-like stimuli soon after birth, likely by virtue of the biological and social relevance of faces to infant survival (Serrano, Iglesias, & Loeches, 1992; Young-Browne, Rosenfeld, & Horowitz, 1997). Although the development of face processing has often been studied within a visual context (Haxby, Hoffman, & Gobbini, 2000; Leppänen & Nelson, 2009), human faces are rarely encountered in sensory isolation; rather, they are embedded in a multi-sensory environment. 'Talking faces', for example, provide both audio and visual information that, when integrated, may support or hinder face processing.

Experimental approaches to investigate how multi-sensory processing develops include *intermodal* tasks, in which participants are provided with information presented simultaneously in different modalities (e.g., auditory and visual; for a review, see Grossman, 2010) or *affective matching tasks*, wherein two sensory stimuli are presented sequentially (e.g., Grossman, Striano, & Friederici, 2006). In affective matching tasks, the valence of the first stimulus or *prime* (e.g., a vocalization) may influence the affective evaluation of the second stimulus (e.g., a face). Interestingly, the ability to integrate face–voice interactions emerges early in development, by approximately 4 months of age (for a review, see Campanella & Belin, 2007), and is modulated by affective congruency (de Gelder & Vroomen, 2000; Grossmann et al., 2006; Kahana-Kalman & Walker-Andrews, 2001; Otte, Donkers, Braeken, & van den Bergh, 2015; Soken & Pick, 1992). Congruency facilitates processing; if both stimuli tap the same emotional valence (e.g., angry voice and angry face), they are processed faster and more accurately than stimuli with incompatible valence (e.g., happy voice and angry face). Such cross-modal facilitation is maintained, and further refined, into adulthood (de Gelder & Vroomen, 2000; Ethofer et al., 2006; Massaro & Egan, 1996), suggesting a developmental continuity in affective matching. From an evolutionary perspective, being able to quickly and accurately determine the valence of objects and situations allows for rapid implementation of strategies to avoid negative stimuli (and approach positive stimuli), which ultimately promotes survival (Tooby & Cosmides, 1990). Emotionally relevant stimuli are especially powerful, as they modulate attentional processes and enhance perception (Pourtois, Schettino, & Vuilleumier, 2013; Vuilleumier, 2005).

Prior research on cross-modal affective matching is dominated by audiovisual paradigms. However, complex social communication cannot be reduced to simple interactions between vision and audition (Semin & de Groot, 2013). Embracing a developmental perspective, we argue that the sense of smell can contribute uniquely to our understanding of affective matching in social contexts. Indeed, olfaction develops before birth (Schaal, Marlier, & Soussignan, 1998), shows pre- and postnatal continuity (Schaal et al., 2000), mediates socially relevant information across development (Parma et al., 2016), and can elicit intense affective experiences (Seubert, Regenbogen, Habel, & Lundström, 2016) via tight connections with the emotion centers of the brain (i.e., the limbic regions; Gottfried, 2006; Lundström, Boesveldt, & Albrecht, 2011). Given this link between odor and emotion, odors have been used as affective primes (Smeets & Dijksterhuis, 2014). For example, Hermans and colleagues found that presenting adults with pleasant (good-smelling) or unpleasant (bad-smelling) odors modulated the speed at which subsequent words were identified as positive or negative (Hermans, Baeyens, & Eelen, 1998). Participants were particularly sensitive to cross-modal congruency; they identified 'positive' words more quickly when primed by an odor that they also perceived as pleasant, and were slower to categorize positive words when primed by an odor they perceived as unpleasant. In this way, the valence of a prime in one modality (olfaction) influenced processing speed in another modality (vision) and this depended on congruency (faster when congruent, slower when incongruent).

Valence has been argued to be the principal dimension underlying the human olfactory experience (Richardson & Zucco, 1989). It is therefore unsurprising that olfactory-mediated affective experiences lead to downstream effects in a variety of decision-making and behavioral domains (for a review, see Sela & Sobel, 2010). For example, shoppers spend more money when the air is filled with a pleasant ambient odor than when the air is unscented (Chebat, Morrin, & Chebat, 2009). A reverse effect can also be observed where a disgusting smell can lead to negative decisions and judgments, such as inspiring dislike for members of minority groups (Inbar, Pizarro, & Bloom, 2012). In the realm of face processing, Demattè and colleagues (Demattè, Österbauer, & Spence, 2007) found that participants rated male faces as being less attractive in the presence of an unpleasant odor than when the same faces were presented with a pleasant odor or clean air. Such a result is maintained also beyond binary choices, as Seubert and colleagues demonstrated (Seubert, Gregory, Chamberland, Dessirier, & Lundström, 2014). Indeed, modulations of odor valence are associated with linear effects on judgments of facial attractiveness.

Taken together, these findings suggest that pleasant and unpleasant odors elicit affective reactions, and that these reactions influence people's decisions and modulate their approach or avoidance responses to different stimuli. In particular, face processing appears to be sensitive to olfactory context (Leleu et al., 2015; Leppänen & Hietanen, 2003; Seubert, Kellerman et al., 2010; Seubert, Loughead et al., 2010), in line with their shared ability to convey relevant emotional information (Kensinger, 2004). However, it is still unclear how the link between olfaction and its affective influences develops and the role it plays in cross-modal affective matching in childhood, particularly in the realm of face processing.

Research on olfaction and face processing in early development paints an even more complicated picture. In a recent study of 3-, 5-, and 7-month-olds, Godard et al. (Godard, Baudouin, Schaal, & Durand, 2016) assessed how odors of different valences (pleasant, unpleasant, and no-odor) affected infants' visual choice for dynamic expressive faces (happy vs. disgust). Although the authors found a clear congruency effect in 3-month-olds (e.g., the pleasant odor of strawberry increased infants' looking time for happy faces), the effect vanished in 5- and 7-month-olds. The authors suggested that this unexpected discontinuity was due to a trade-off in sensory development; as the visual modality gained prominence and became an important source of sensory input, it replaced infants' initial reliance on olfaction. The developmental trajectory of multi-modal visuo-affective matching beyond infancy is, however, not known. Although preschool and school-aged children have a well-developed sense of smell and regularly attend to olfactory stimuli in everyday life (Ferdenzi, Coureaud, Camos, & Schaal, 2008; Schaal, 1988), little is known regarding how olfactory information is integrated into the multi-sensory experiences of children in this age range. Furthermore, research on the affective dimension of olfaction in relation to other senses in preschool and school-aged children is almost nonexistent. To our knowledge, only one study has explored whether the positive or negative valence of visual cues modulates odor perception in older children [aged 6–10 years (Hvastja & Zanuttini, 1989)]. Results showed that judgments about odor pleasantness were influenced by the valence of associated visual cues in 6- to 8-year-olds, in that odors presented with a pleasant visual object during encoding were perceived as more pleasant.

There is a dearth of research exploring how children use perceptual and affective information in decision-making. This is a problem made even more urgent by the fact that preschool and school-aged children are entering a phase of life when decisions are embedded in an increasingly complex social world (Garon & Moore, 2004) rife with potential decisions. In the present study, we aim to fill this gap in the literature by exploring visuo-olfactory affective matching in a large sample of children aged 3 to 11 years. We presented children with one of three odors: rose, fish, and no-odor, and asked them to choose a face from one of two expressions shown side-by-side; either happy or disgusted. At the end of the session, we asked them to categorize each odor as pleasant, unpleasant, or neutral. In light of contrasting findings from the adult and infant literatures described above, we postulated two alternative hypotheses about children's behavior in this paradigm. First, the presence of an odor, *irrespective of its valence*, may facilitate the choice of the negative stimulus (i.e., the disgusted face). This hypothesis is based on the results obtained from adult samples, which suggest that the odor-dependent modulation toward disgusted facial expressions is independent of odor valence (Seubert, Kellerman et al., 2010; Seubert, Loughead et al., 2010). In other words, irrespective of the emotional quality of the olfactory prime, the presence of an odorant would improve the recognition of the disgusted faces. This hypothesis stems from the argument that olfaction and disgust are preferentially associated (e.g., Rozin & Fallon, 1987), leading to the advantage in the processing of the visual information signaling possible contamination (disgusted face) as compared to other emotionally relevant information (here, happy face; compatible with Seubert, Kellerman et al., 2010; Seubert, Loughead et al., 2010). Such prioritization would suggest the presence of an evolutionary mechanism based on vigilance (Hudson & Jellema, 2011), serving the detection of contaminants with a bias towards the production of false alarms (i.e., detect contaminants when not present) rather than omissions (i.e., failure to detect contaminants when present; Rozin & Fallon, 1987).

Second, if children are able to integrate affective and perceptual information, their choice may be driven by an affective matching strategy, such that pleasant and unpleasant odors will facilitate the selection of affectively congruent face targets (i.e., good smell = happy face; bad smell = disgusted face). This hypothesis is consistent with evidence presented by Leppänen and Hietanen (Leppänen & Hietanen, 2003).

Our second aim was to explore developmental trajectories, with the goal of determining how visuo-olfactory affective matching strategies change as a function of age. In light of prior research on the development of cross-modal integration skills (Gori, Del Viva, Sandini, & Burr, 2008; Nardini, Bedford, & Mareschal, 2010; Nardini, Jones, Bedford, & Braddick, 2008), we expected that older children (8–11 years) would use affective matching strategies. They should select the face showing the affect that is emotionally compatible with the valence of the odor prime. Conversely, we expected that younger children's choices might reflect their difficulty in integrating cross-modal affective information (Gori et al., 2008; Nardini et al., 2008; Nardini et al., 2010), and would therefore not demonstrate a clear affective matching. Rather, if preschoolers employ a strategy that does not rely on integrating cross-modal information, we should find a consistent bias toward choosing one of the two faces in the *no-odor condition*. Given research suggesting that children of this age are highly susceptible to a social desirability response bias (Paulhus, 1984; Paulhus & Reid, 1991), we hypothesized an imbalance in favor of choosing happy faces.

2 | METHODS

2.1 | Participants

A total of 182 participants took part in the study. Participants were recruited from visitors to the Please Touch Museum of Philadelphia and prior to testing, all parents or legal guardians provided written informed consent and all children provided their verbal assent to participation. Participants were informed that they could discontinue the study at any time and upon completion of the experimental tasks, each child received stickers as a token of appreciation for their effort. Personal information (i.e., child's date of birth, sex, ethnicity, race, handedness, health status, and self-proclaimed integrity of their sense of smell) were obtained via parental/legal guardian (caregiver) report. A total of 42 participants were excluded for the following reasons: (i) incomplete measures due to lack of time, motivation or task comprehension (*N* = 14, 6 females; age: mean 4.86 years, *SD*: 1.78); (ii) current medication intake (*N* = 12, 11 females; age: mean 5.82 years, *SD*: 1.31); (iii) diseases commonly linked to olfactory dysfunction (*N* = 8, 3 females; age: mean 6.05 years, *SD*: 2.10); (iv) psychiatric diagnoses (*N* = 5, 1 female; age: mean 6.08 years, *SD*: 1.86); (v) lack of fluency in the English language (1 female, age: 6.10 years); (vi) technical complications (*N* = 2, 1 female; age: mean 7.86 years, *SD*: 1.20). Our final sample of 140 participants included 48 boys and 92 girls, aged 3.04 to 10.85 years old (Mean = 6.06, *SD* = 1.66). In all, 26.4% of the sample was Hispanic or Latino, 57.1% was White and 87.9% of the sample was right-handed. Please refer to Table 1 for detailed information about age and ethnicity.

All aspects of the study were approved by the local Institutional Review Board and are compliant with the Declaration of Helsinki.

2.2 | Stimuli

2.2.1 | Odor stimuli

Olfactory stimuli were selected from the Sniffin' Sticks Identification test (Burghart Instruments, Wedel, Germany), a standardized test to evaluate olfactory performance in children and adults (Hummel, Kobal, Gudziol, & Mackay-Sim, 2007). Odors of varying valence (pleasant, unpleasant) and no-odor ('blank') were presented via three specially designed felt-tip pens. A pilot study on a representative population (*N* = 31, 15 females, age: mean: 6.5; *SD*: 0.73) identified rose as a pleasant odor, fish as an unpleasant odor, and a blank pen with no-odor as neutral. Odor order was randomized and counterbalanced across participants.

2.2.2 | Visual stimuli

Color photographs of young Caucasian faces (10 women, 10 men) were selected from the Karolinska Directed Emotional Faces standardized database (KDEF; Lundqvist, Flykt, & Öhman, 1998). Happy and Disgusted from the same individual were included once each during the experimental task. We chose Disgust rather than other

TABLE 1 Participants' demographic information. Significant *p*-values are reported in bold

		N	%	Overall X-squared (*df*)	*p*-value	Significant contrasts
Gender	F	92	65.7	14.362 (1)	.0002	a
	M	48	34.3			
Ethnicity	Hispanic or Latino	23	16.4	100.77 (2)	<.0001	a,c
	Not Hispanic or Latino	103	73.6			
	Declined to answer	14	10			
Race	American Indian or Alaska Native	0	0	233.08 (6)	<.0001	a,c,d,e,g,i,j,l,m,n,o,p,s,t
	Asian	11	7.9			
	Native Hawaiian or Other Pacific Islander	1	0.7			
	Black or African American	17	12.1			
	White	80	57.1			
	Other	22	15.7			
	Declined to answer	9	6.5			
Handedness	Right	123	87.9	290.57 (3)	<.0001	a,b,c,d,e
	Left	13	9.3			
	Ambidextrous	4	2.8			
	Declined to answer	0	0			
Total		140	100			

Note: e.g., a = 1st level vs. 2nd level; b = 1st level vs. 3rd level; etc.

negative emotions (e.g., fear) because its features are generally associated with smell (e.g., the wrinkled nose; Rozin, Lowery, & Ebert, 1994). All faces were captured using a straight viewing angle. The original KDEF stimuli were cropped with Adobe 10.1.12 to remove distracting details such as hair, neck, and background, which focuses visual attention on emotional expressions (e.g., Chien, Wang, Chen, Chen, & Chen, 2014). Each face was framed by an oval-shaped window (7.3 cm wide, 10.16 cm tall) through which only the forehead, eyes, nose, cheeks, mouth, and chin were visible.

2.3 | Setting and procedures

The study was run in a dedicated section of a large, well-ventilated room set aside for child development research. Following verbal assent, each child was asked to complete the affective matching task. An experimenter gave the children instructions, then evaluated whether they understood the task during a short training session (two trials). In addition, the experimenter monitored the child's level of compliance and engagement throughout the 10-minute experimental session. Participants were asked to look at a black cross in the center of an iPad screen from a distance of approximately 30 cm. Subsequently, a green cross appeared for 3 seconds, during which the experimenter delivered the olfactory stimulation by placing an odor pen approximately 2 cm under the participant's nose. At the end of the odor delivery, two faces belonging to a single identity (one face showing a Happy expression and one showing a Disgusted expression) were displayed simultaneously, side-by-side on the screen for 5 seconds (Figure 1). Each child was asked to 'pick one face', by pointing to it. These instructions were intentionally vague, and thus avoided biasing children's attention toward either the olfactory or the expressive component of the stimulation. The inter-trial interval was jittered to reduce attentional effects (range: 1.7–2.3 seconds). Based on a previous pilot study evaluating how many repetitions children of age 3 could accurately perform before habituating to olfactory stimuli, our task included 18 randomized trials, equally divided among pleasant, unpleasant, and no-odor ('blank') primes (six times each).

2.3.1 | Pleasantness ratings and identification of odors

Immediately following the affective matching task, children were asked to complete a 3-point rating scale on which they indicated the pleasantness of each of the odor primes (rose, fish, and blank). The left end of the scale showed a cartoon face with a disgusted expression, the right end showed a cartoon face with a happy expression, and the middle of the scale showed a neutral cartoon face. General olfactory skills were measured using an 11-item modified version of the Identification subtest of the Sniffin' Sticks Test (Schriever et al., 2014).

2.4 | Dependent variables and statistical analysis

Our primary dependent variable was the number of times that participants chose Happy vs. Disgusted faces. To control for a possible position bias (e.g., right-handed children might point more often to the face on the right side of the screen), we calculated *position compatibility*. This variable compared the position of the chosen face to the handedness of the participant. The same strategy was applied to evaluate the likelihood of a gender bias, for which we included a variable

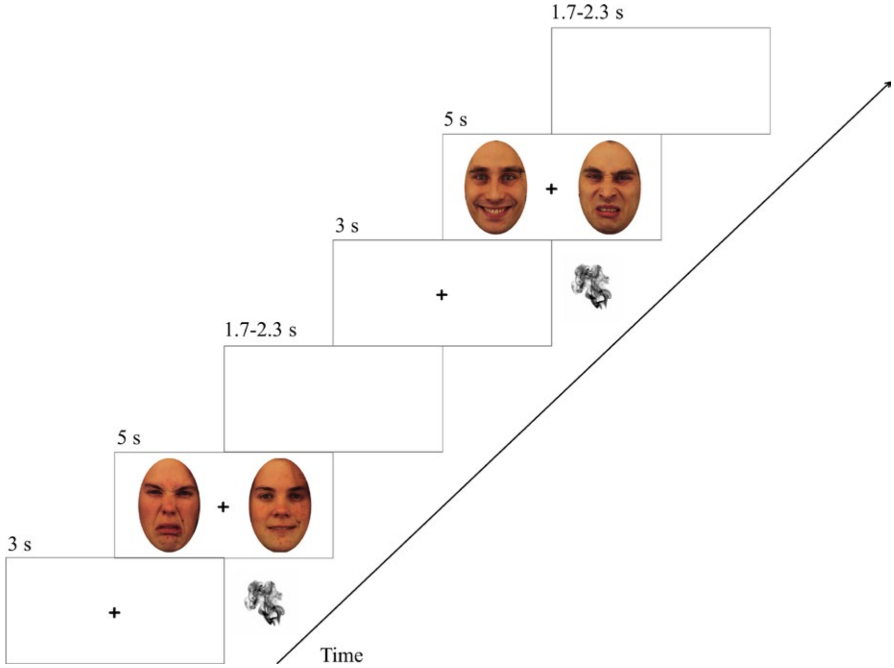

FIGURE 1 Schematic example of the experimental procedure. An odor was presented for 3 seconds, while a fixation cross appeared at the center of the screen. Subsequently, two, side-by-side facial stimuli were presented for 5 seconds and followed by a blank screen

representing the decision strategy for faces of the same gender as the participant. Data analysis was performed in R, version 0.99.484. Chi-square goodness-of-fit tests were used to compare frequencies within and across groups. Linear regression was used to determine whether and how age predicted olfactory identification skills. Estimates of the choice between Happy and Disgusted faces were based on an adaptive Gaussian Hermite approximation of the likelihood with 10 integration points. To avoid a warning of non-convergence, an optimizer (bobyqa) was chosen. Throughout, an alpha level of 0.05 was considered significant, and all statistical tests were two-tailed.

3 | RESULTS

3.1 | Olfactory skills increase with age

The mean odor identification score of the entire sample was 6.11 (*SD*: 2.15, range: 2–10), confirming acceptable odor identification skills overall (higher scores correspond to a better odor identification skill). A multiple linear regression established that age was a significant predictor of odor identification skills, $F(1, 2506) = 588.42$, $p < .0001$, accounting for 18.98% of the explained variability in odor identification score. The regression equation was: odor identification score = 2.68 + 0.57 (Age). Thus, older children correctly identified a significantly higher number of odors than younger children. There were no significant performance differences by gender, ethnic background, or racial group.

3.2 | Visuo-olfactory affective matching is reliably present after age 5

We ran an omnibus mixed effects binomial logistic regression to determine whether age, gender, odor identity, odor valence, general odor identification skills, position compatibility, and gender compatibility would influence the likelihood that participants chose a happy or a disgusted face. To assess the relationship between odor valence and age, the interaction term Age*Odor Valence was included in the binary logistic regression. We hypothesized that the valence of the odor presented directly before the face selection task would bias children to choose the affectively congruent face. Odor identity, odor valence, and general odor identification skills emerged as significant predictor variables (see Table 2). The likelihood of choosing a disgusted face increased incrementally as a function of exposure to the fish odor, and by the presence of whichever odor was considered unpleasant. The interaction between age and odor valence was also significant (Table 2). To visualize yearly changes in the likelihood of choosing a happy face based on odor valence attributed to the odor prime, we split age into 8 bins (aged 3–11 years; Figure 2). The youngest children in our sample did not use an affective matching strategy, consistently choosing happy faces regardless of the valence of the odor prime. After age 5, in contrast, the presence of an odor considered unpleasant began to increase the likelihood of choosing disgusted faces over happy faces (Figure 2). With increasing age, children appeared to rely more heavily on an affective matching strategy to guide decision-making. When the odor was evaluated as neutral, the unpleasant valence trended toward predicting disgusted faces ($p = .085$). Overall, children chose the happy faces.

In order to clarify individual predictors of these age-related differences, we categorized children as Younger (3–4.99 years) or Older (5–11 years). We then applied separate regression models to each age group. In the Younger group (Table 3), the gender compatibility variable was the only significant predictor of face choice: $\chi^2_{2508} = 2.27$, $p = .023$. Our sample included a large proportion of females, who more often chose female faces. In addition, we found evidence of a positivity bias: younger children tended to choose happy faces regardless of the valence or identity of the odor that preceded their choice. For the

TABLE 2 Binomial logistic regression predictors for the whole sample. Significant *p*-values are reported in bold

						95% CI	
	β	*SE*	*z*-value	*p*-value	*βexp*	Lower	Upper
Intercept	0.137	0.408	0.337	.736	0.019	−0.662	0.936
Age	0.008	0.050	0.157	.875	0.000	−0.091	0.107
Gender (F)	0.002	0.129	0.012	.991	0.000	−0.252	0.255
Odor Identity (Fish)	−0.767	0.126	−6.068	**.000**	0.588	−1.014	−0.519
Odor Identity (Rose)	0.107	0.119	0.906	.365	0.012	−0.125	0.340
Odor Valence (Unpleasant)	1.031	0.458	2.249	**.025**	1.063	0.132	1.930
Odor Valence (Pleasant)	0.623	0.151	4.119	**.000**	0.388	0.327	0.920
Odor Identification score	0.094	0.031	3.037	**.002**	0.009	0.033	0.155
Face Position (Right)	−0.049	0.096	−0.517	.605	0.002	−0.237	0.138
Gender Compatibility (F)	0.133	0.093	1.427	.154	0.018	−0.050	0.315
Odor Valence (Unpleasant)*Age	−0.290	0.069	−4.222	**.000**	0.084	−0.424	−0.155

Older group (Table 4), the odor 'Fish' (χ^2_{2508} = −7.13, p < .0001), the valence (pleasant: χ^2_{2508} = 4.05, p < .0001; unpleasant: χ^2_{2508} = −5.51, p < .0001) and general odor identification skill (χ^2_{2508} = 3.34, p = .001) predictor variables were significant. As expected, and in line with the affective matching hypothesis, the likelihood of choosing a disgusted face increased with exposure to the fish odor, and in the presence of whichever odor was considered unpleasant. Similarly, when presented with an odor considered pleasant, children were more likely to choose happy faces. In addition, the probability of choosing the happy face increased as a function of odor identification skill.

3.3 | Odors acquire adult-like valence beginning around age 5

To investigate how children evaluated the different odor conditions used in our study (rose, fish, no-odor), we performed a chi-square analysis on valence ratings. Across the sample as a whole, we found significant differences by odor: χ^2_{418} = 36.27, p = .014. Looking at Pearson residuals, when the blank was rated as neutral and the fish as unpleasant, significantly more children rated the rose as pleasant (Figure 3a). Considering the age two groups separately, there were no significant differences in frequency distribution for the Younger group (χ^2_{121} = 9.15, p = .69, Figure 3b) or Older group (χ^2_{295} = 29.67, p = .075, Figure 3c). However, it is worth noting that, unlike children in the Younger group, who seemed to find it difficult to categorize the blank as neutral and tended to consider both the rose and the fish odor to be pleasant stimuli (Figure 3b), the Older group showed a tendency to consider the fish odor unpleasant, the rose odor pleasant, and the blank odor neutral (Figure 3c).

4 | DISCUSSION

In this study, we investigated the development of visuo-olfactory affective matching strategies using social stimuli in a large sample of preschool and school-aged children. As expected, we found that children were able to integrate affective and multi-modal perceptual information to guide their decision-making, such that exposure

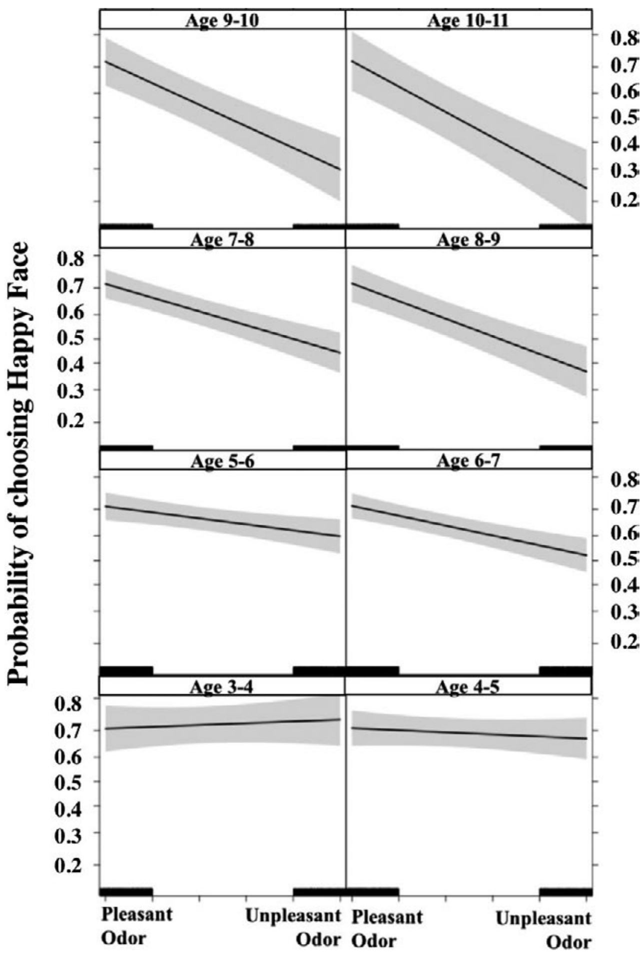

FIGURE 2 Graphs representing the relationship between odor valence (a. unpleasant; b. pleasant) and age. Age range was split into 8 categories representing approximately 1-year bins

TABLE 3 Binomial logistic regression predictors for the Younger Group. Significant *p*-values are reported in bold

						95% CI	
	β	*SE*	*z*-value	*p*-value	*βexp*	Lower	Upper
Intercept	−2.84	2.19	−1.30	.194	0.059	−7.127	1.450
Age	0.90	0.47	1.92	.055	2.461	−0.020	1.821
Gender (F)	0.64	0.57	1.12	.263	1.894	−0.479	1.756
Odor Identity (Fish)	−0.40	0.24	−1.65	.099	0.673	−0.868	0.075
Odor Identity (Rose)	0.17	0.23	0.77	.442	1.189	−0.269	0.616
Odor Valence (Unpleasant)	−0.42	0.79	−0.53	.598	0.659	−1.965	1.132
Odor Valence (Pleasant)	−0.17	0.79	−0.21	.832	0.846	−1.714	1.379
Odor Identification score	0.02	0.10	0.19	.848	1.019	−0.170	0.207
Face Position (Right)	−0.50	0.20	−2.54	**.011**	0.608	−0.882	−0.114
Gender Compatibility (F)	0.41	0.18	2.27	**.023**	1.504	0.056	0.760

TABLE 4 Binomial logistic regression predictors for the Older Group. Significant *p*-values are reported in bold

						95% CI	
	β	*SE*	*z*-value	*p*-value	*βexp*	Lower	Upper
Intercept	0.24	0.47	0.50	.617	1.265	−0.686	1.156
Age	−0.02	0.06	−0.36	.718	0.978	−0.144	0.099
Gender (F)	−0.06	0.16	−0.38	.707	0.940	−0.385	0.261
Odor Identity (Fish)	−1.14	0.16	−7.13	**< .0001**	0.319	−1.457	−0.829
Odor Identity (Rose)	0.05	0.15	0.37	.712	1.056	−0.234	0.342
Odor Valence (Unpleasant)	−0.98	0.18	−5.51	**< .0001**	0.374	−1.332	−0.633
Odor Valence (Pleasant)	0.66	0.16	4.05	**< .0001**	1.935	0.341	0.980
Odor Identification score	0.13	0.04	3.34	**.001**	1.144	0.056	0.214
Face Position (Right)	−0.03	0.12	−0.26	.799	0.970	−0.261	0.201
Gender Compatibility (F)	0.03	0.12	0.29	.774	1.034	−0.194	0.261

to pleasant and unpleasant odors facilitated the selection of affectively congruent face targets. Upon closer examination, we found that children older than age 5 responded to pleasant odors by consistently choosing happy faces over disgusted faces, and likewise chose disgusted faces over happy faces in the context of an unpleasant odor. This pattern is consistent with the affective matching hypothesis.

As predicted, children younger than age 5 did not demonstrate affective matching. One possible explanation for this finding is that younger children did not attend to the odor prime (for a review regarding the development of attention, see Plude, Enns, & Brodeur, 1994). However, this is unlikely because children were alerted to the 'odor smelling' phase in two ways: first, a visual cue appeared on the iPad screen, and second, an experimenter positioned a pen directly below their nose. Alternatively, it is possible that younger children's failure to engage in affective matching stems from difficulties with visuo-olfactory integration. This position is supported by recent investigations into vision, audition, and touch, which demonstrate that children only master multi-modal integration fully at the relatively advanced age of approximately 8 years (Gori et al., 2008; Nardini et al., 2008; Nardini et al., 2010; Barutchu, Crewther, & Crewther, 2009). Our interpretation may seem to contradict recent evidence that 3-month-olds integrate visuo-olfactory cues (Godard et al., 2016), but there is one important methodological difference between our study and that of Goddard and colleagues: the use of pointing vs. looking time to assess choice. Multi-sensory integration processing follows a 'motor hierarchy' (for a review, see Burr & Gori, 2012). For example, integration that relies on orienting reflexes (e.g., reflexive eye and hand movements) develops quite early (Bahrick & Lickliter, 2004; Godard et al., 2016; Kuhl & Meltzoff, 1982; Sann & Streri, 2007), while other forms of integration that rely on non-reflexive, explicit motor responses continue to develop throughout childhood (Gori et al., 2008; Nardini et al., 2008; Nardini et al., 2010). To test the developmental trajectory of explicit, non-reflexive visuo-olfactory affective matching, we measured a goal-directed motor response (e.g., pointing). As in the case of other modalities including vision, audition, and touch, the development of olfaction progresses along a motor trajectory of multi-sensory integration – but, in contrast to the other senses explored thus far, it seems to appear earlier in development.

Another possible explanation for the lack of affective matching by preschool children might be related to context incompatibility. In our

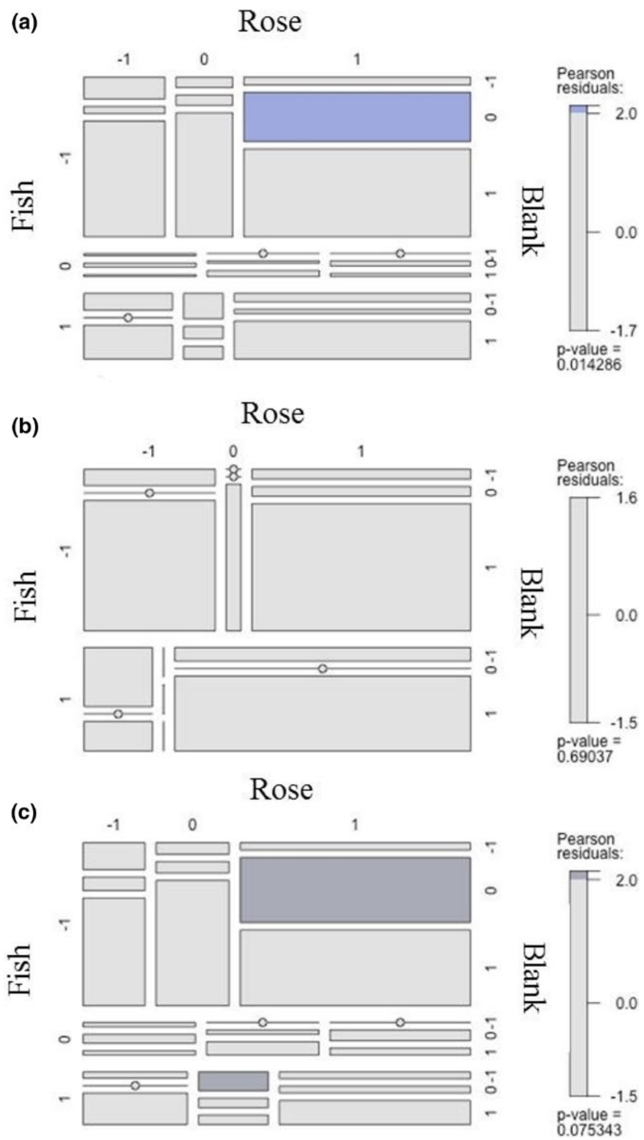

FIGURE 3 Mosaic distribution representing the frequencies of choice when considering the whole sample (a), Younger (b) and Older children (c). The relative frequency is proportionally distributed within rectangles, and dashes represent the absence of choice for the respective site. As an example, children who selected fish as unpleasant (−1) and blank as neutral (0) were significantly more likely to select rose as pleasant (1; as depicted by the blue rectangle), as compared to all other possible combinations, which would predict a same number of observation per cell (i.e., rectangles for the same dimension)

study, non-social olfactory stimuli preceded a forced decision about social visual stimuli. Common odors, irrespective of their valence, might be seen as stimuli unlikely to be related to faces and therefore not integrated (Ernst, 2007). From a functional perspective, perhaps it is adaptive *not* to integrate this information.

Given that young children did not demonstrate affective matching, we proceeded to analyze their behavior in the 'no-odor' condition to assess whether they held any intrinsic biases toward selecting Happy or Disgusted faces. Here, we found that younger children demonstrated a marked bias towards selecting the Happy face. This finding might be due to over-reliance on positive visual information, fostered by a biologically driven preference for positive stimuli. Indeed, studies of emotion recognition in preschool-aged children demonstrate that they first develop the ability to recognize happy faces, and only subsequently do they develop recognition skills that include negative expressions (Boyatzis, Chazan, & Ting, 1993; Camras & Allison, 1985; Widen & Russel, 2003). This bias may reflect a biological drive to approach what is positive (choose the Happy face) and to avoid (by not choosing) the face that reflects the possibility of negative consequences (the Disgusted face).

The social desirability response bias – a normal developmental milestone in childhood (Dadds, Perrin, & Yule, 1998; Reynolds & Richmond, 1978) – provides another explanation for younger children's tendency to choose Happy faces regardless of the odor prime. This bias may have been triggered by the presence of an experimenter near the child and their continuous interaction during the task (Dusek, 1971; Klesges et al., 2004; Stevenson, 1965). However, although the effect of social desirability fades with aging (Reynolds & Richmond, 1978), it still impacts decision-making in 8- to 10-year-old children (Klesges et al., 2004). Thus, although the older subgroup in the present study should have been affected by the social desirability response bias too, we found that affective matching was a more powerful influence.

Starting around 5 years old, visuo-olfactory affective matching influenced children's decisions. Importantly, this strategy was not bound to a specific odor identity (e.g., fish or rose), but rather depended on the odor valence (pleasant or unpleasant, as judged by the child). When an odor (either fish or rose) was considered unpleasant, older children chose the disgusted face more often. Conversely, when different children considered the same odor pleasant (either fish or rose), those children were more likely to choose the happy face. Here, it is worth noting that the blank pen was most often rated as pleasant or unpleasant, rather than neutral. This is consistent with research suggesting that children, especially young children, have difficulty categorizing a neutral stimulus as an ambiguous occurrence (for a review, see Gross & Ballif, 1991). Based on our data, we argue that the superiority of odor valence in driving choice of social affective stimuli might be related to children's ability to integrate multi-sensory cues. Although research on visual, auditory, and tactile stimuli integration suggests that these skills emerge around age 8, the present findings suggest that visuo-olfactory affective matching is efficient after age 5. This might be explained in terms of the close anatomical link between the olfactory system and the limbic centers.

Taken together, our findings suggest that visuo-olfactory affective matching strategies emerge at approximately age 5 when children, rather than just following their eyes, also start following their noses. This developmental pattern is similar to the one described by Hoffner and Badzinki (Hoffner & Badzinski, 1989), who investigated facial expressions and situational cues of emotion. In that study, the authors found that children's reliance on situational cues increased with age: while 3- to 5-year-old children focused almost entirely on facial expressions, older children tended to utilize both facial and situational cues to evaluate others' emotions. The same pattern is reflected in the present research, suggesting that olfactory cues become increasingly effective cues to emotional context across childhood.

In addition to the theoretical relevance of the present data to our understanding of the perceptual affective modulation of choice behavior in children, our findings have broader social and clinical implications. This is the first study to demonstrate that olfaction influences explicit decision-making processes in children as young as 5 years old. Our results might explain why this phenomenon occurs and suggest when to implement educational strategies to counteract perceptual stigmatization – based on smell – that sometimes begins to emerge during the school years.

One potential mechanism underlying the observed age difference in affective matching is Theory of Mind (ToM). A significant body of research indicates a developmental shift in children's abilities to take another person's perspective and empathize, with significant improvements around age 4 to 5 years (Happé, 1995; Wimmer & Perner, 1983). Generally, as children become older, they also become more insightful about their own emotional lives and demonstrate increased understanding of emotions in others (Izard & Harris, 1995). Here, we demonstrate that children 5 and older can match their own affective responses to odor with the emotions expressed on other people's faces – which may hinge on explicit ToM reasoning and empathy. Thus, improved ToM could lead children to engage in affective matching. On the other hand, young children were potentially unable to relate their own internal affective experiences with odors to the visually presented faces. However, such observations remain speculative in light of the fact that we did not assess ToM in our sample.

Considering the power of olfaction to spark affective responses, it might well be that olfactory stimuli will be able to facilitate the use of affective matching strategies over other types of cross-modal interactions. For example, individuals with autism spectrum disorders, who have been argued to have ToM deficits, are able to use olfactory stimulation to facilitate imitation of affectively compatible actions (Parma, Bulgheroni, Trindelli, & Castiello, 2013). To further explore visuo-olfactory affective matching in preschoolers, future investigations should use implicit measures to assess choice. Exploring implicit responses will take into account the developmental trajectory of neuromotor maturation and may reveal abilities that are not evident when explicit measures are used (for a review, see Lock & Berger, 1990). In particular, the addition of eye tracking measures to the present task may uncover subtle differences in visual attention that are not captured by behavioral tasks. Similarly, the implementation of facial electromyography may elucidate the role of automatic mimicry on affective matching.

In conclusion, the current findings demonstrate that pleasant and unpleasant odors can bias children's decision-making such that they choose congruent social affective visual stimuli, a phenomenon that emerges around 5 years of age. This research represents an important step towards understanding the underlying processes that shape both the typical and less typical social mind.

ACKNOWLEDGEMENTS

We would like to thank Ms Kristen Gregory and Ms Smiljana Mutic for assistance with data collection. Support for the realization of this research was provided by the National Science Foundation (1113648), awarded to the Please Touch Museum and the Monell Chemical Senses Center, The Knut and Alice Wallenberg Foundation, Grant/Award Number: 2012-0141, awarded to JNL, the Louise Slade Fellowship to VP, and the RISE Worldwide fellowship to CW.

AUTHOR CONTRIBUTIONS

AC collected data, carried out part of the analyses and drafted the paper. CW and JPM collected the data and drafted the paper. JNL supervised the project and drafted the paper. VP conceived and designed the project, carried out part of the analyses, drafted the paper and supervised the project.

REFERENCES

Bahrick, L.E., & Lickliter, R. (2004). Infants' perception of rhythm and tempo in unimodal and multimodal stimulation: A developmental test of the intersensory redundancy hypothesis. *Cognitive, Affective, & Behavioral Neuroscience*, *4*, 137–147.

Barutchu, A., Crewther, D.P., & Crewther, S.G. (2009). The race that precedes coactivation: Development of multisensory facilitation in children. *Developmental Science*, *12*, 464–473.

Boyatzis, C.J., Chazan, E., & Ting, C.Z. (1993). Preschool children's decoding of facial emotions. *Journal of Genetic Psychology*, *154*, 375–382.

Burr, D., & Gori, M. (2012). Multisensory integration develops late in humans. In M.M. Murray & M.T. Wallace (Eds.), *The neural bases of multisensory processes* (pp. 345–362). Boca Raton, FL: CRC Press.

Campanella, S., & Belin, P. (2007). Integrating face and voice in person perception. *Trends in Cognitive Sciences*, *11*, 535–543.

Camras, L.A., & Allison, K. (1985). Children's understanding of emotional facial expressions and verbal labels. *Journal of Nonverbal Behavior*, *9*, 84–94.

Chebat, J.C., Morrin, M., & Chebat, D.R. (2009). Does age attenuate the impact of pleasant ambient scent on consumer response? *Environment and Behavior*, *41*, 258–267.

Chien, S.H.L., Wang, L.H., Chen, C.C., Chen, T.Y., & Chen, H.S. (2014). Autistic children do not exhibit an own-race advantage as compared to typically developing children. *Research in Autism Spectrum Disorders*, *8*, 1544–1551.

Dadds, M.R., Perrin, S., & Yule, W. (1998). Social desirability and self-reported anxiety in children: An analysis of the RCMAS Lie Scale. *Journal of Abnormal Child Psychology*, *26*, 311–317.

De Gelder, B., & Vroomen, J. (2000). The perception of emotions by ear and by eye. *Cognition and Emotion*, *14*, 289–311.

Demattè, M.L., Österbauer, R., & Spence, C. (2007). Olfactory cues modulate facial attractiveness. *Chemical Senses*, *32*, 603–610.

Dusek, J.B. (1971). Experimenter bias in performance in children at a simple motor task. *Developmental Psychology*, *4*, 55–62.

Ernst, M.O. (2007). Learning to integrate arbitrary signals from vision and touch. *Journal of Vision*, *7*, 7.

Ethofer, T., Anders, S., Erb, M., Droll, C., Royen, L., Saur, R., … & Wildgruber, D. (2006). Impact of voice on emotional judgment of faces: An event-related fMRI study. *Human Brain Mapping*, *27*, 707–714.

Ferdenzi, C., Coureaud, G., Camos, V., & Schaal, B. (2008). Human awareness and uses of odor cues in everyday life: Results from a questionnaire study in children. *International Journal of Behavioral Development*, *32*, 422–431.

Garon, N., & Moore, C. (2004). Complex decision-making in early childhood. *Brain and Cognition*, *55*, 158–170.

Godard, O., Baudouin, J.Y., Schaal, B., & Durand, K. (2016). Affective matching of odors and facial expressions in infants: Shifting patterns between 3 and 7 months. *Developmental Science*, *19*, 155–163.

Gori, M., Del Viva, M., Sandini, G., & Burr, D.C. (2008). Young children do not integrate visual and haptic form information. *Current Biology*, *18*, 694–698.

Gottfried, J. (2006). Smell: central nervous processing. *Advances in Oto-Rhino-Laryngology*, *63*, 44–69.

Gross, A.L., & Ballif, B. (1991). Children's understanding of emotion from facial expressions and situations: A review. *Developmental Review*, *11*, 368–398.

Grossmann, T. (2010). The development of emotion perception in face and voice during infancy. *Restorative Neurology and Neuroscience*, *28*, 219–236.

Grossmann, T., Striano, T., & Friederici, A.D. (2006). Crossmodal integration of emotional information from face and voice in the infant brain. *Developmental Science*, *9*, 309–315.

Happé, F.G. (1995). The role of age and verbal ability in the theory of mind task performance of subjects with autism. *Child Development*, *66*, 843–855.

Haxby, J.V., Hoffman, E.A., & Gobbini, M.I. (2000). The distributed human neural system for face perception. *Trends in Cognitive Sciences*, *4*, 223–233.

Hermans, D., Baeyens, F., & Eelen, P. (1998). Odours as affective-processing context for word evaluation: A case of cross-modal affective priming. *Cognition and Emotion*, *12*, 601–613.

Hoffner, C., & Badzinski, D.M. (1989). Children's integration of facial and situational cues to emotion. *Child Development*, *60*, 411–422.

Hudson, M., & Jellema, T. (2011). Resolving ambiguous behavioral intentions by means of involuntary prioritization of gaze processing. *Emotion*, *11*, 681–686.

Hummel, T., Kobal, G., Gudziol, H., & Mackay-Sim, A. (2007). Normative data for the 'Sniffin' Sticks' including tests of odor identification, odor discrimination, and olfactory thresholds: An upgrade based on a group of more than 3,000 subjects. *European Archives of Oto-Rhino-Laryngology*, *264*, 237–243.

Hvastja, L., & Zanuttini, L. (1989). Odour memory and odour hedonics in children. *Perception*, *18*, 391–396.

Inbar, Y., Pizarro, D.A., & Bloom, P. (2012). Disgusting smells cause decreased liking of gay men. *Emotion*, *12*, 23–27.

Izard, C.E., & Harris, P. (1995). Emotional development and developmental psychopathology. In D. Cicchetti & D.J. Cohen (Eds.), *Developmental psychopathology: Vol. 1. Theory and methods* (pp. 467–503). New York: Wiley.

Kahana-Kalman, R., & Walker-Andrews, A.S. (2001). The role of person familiarity in young infants' perception of emotional expressions. *Child Development*, *72*, 352–369.

Kensinger, E.A. (2004). Remembering emotional experiences: The contribution of valence and arousal. *Reviews in the Neurosciences*, *15*, 241–252.

Klesges, L.M., Baranowski, T., Beech, B., Cullen, K., Murray, D.M., Rochon, J., & Pratt, C. (2004). Social desirability bias in self-reported dietary, physical activity and weight concerns measures in 8-to 10-year-old African-American girls: Results from the Girls Health Enrichment Multisite Studies (GEMS). *Preventive Medicine*, *38*, 78–87.

Kuhl, P.K., & Meltzoff, A.N. (1982). The bimodal perception of speech in infancy. *Science*, *218*, 1138–1141.

Leleu, A., Demily, C., Franck, N., Durand, K., Schaal, B., & Baudouin, J.Y. (2015). The odor context facilitates the perception of low-intensity facial expressions of emotion. *PLoS ONE*, *10*, e0138656.

Leppänen, J.M., & Hietanen, J.K. (2003). Affect and face perception: Odors modulate the recognition advantage of happy faces. *Emotion*, *3*, 315–326.

Leppänen, J.M., & Nelson, C.A. (2009). Tuning the developing brain to social signals of emotions. *Nature Reviews Neuroscience*, *10*, 37–47.

Lock, L.K., & Berger, R.A. (1990). Influence of sex, age, and trial blocks on simple reaction times of elementary school children. *Perceptual and Motor Skills*, *71*, 1379–1387.

Lundqvist, D., Flykt, A., & Öhman, A. (1998). *The Karolinska Directed Emotional Faces-KDEF. CD-ROM from Department of Clinical Neuroscience, Psychology section*, Karolinska Institutet, Stockholm, Sweden. ISBN 91-630-7164-9.

Lundström, J.N., Boesveldt, S., & Albrecht, J. (2011). Central processing of the chemical senses: An overview. *ACS Chemical Neuroscience*, *2*, 5–16.

McClure, E.B. (2000). A meta-analytic review of sex differences in facial expression processing and their development in infants, children, and adolescents. *Psychological Bulletin*, *126*, 424–453.

Massaro, D.W., & Egan, P.B. (1996). Perceiving affect from the voice and the face. *Psychonomic Bulletin & Review*, *3*, 215–221.

Nardini, M., Bedford, R., & Mareschal, D. (2010). Fusion of visual cues is not mandatory in children. *Proceedings of the National Academy of Sciences, USA*, *107*, 17041–17046.

Nardini, M., Jones, P., Bedford, R., & Braddick, O. (2008). Development of cue integration in human navigation. *Current Biology*, *18*, 689–693.

Otte, R.A., Donkers, F.C.L., Braeken, M.A.K.A., & Van den Bergh, B.R.H. (2015). Multimodal processing of emotional information in 9-month-old infants I: Emotional faces and voices. *Brain and Cognition*, *95*, 99–106.

Parma, V., Bulgheroni, M., Tirindelli, R., & Castiello, U. (2013). Body odors promote automatic imitation in autism. *Biological Psychiatry*, *74*, 220–226.

Parma, V., Gordon A.R., M., Cecchetto, C., Cavazzana, A., Lundström, J.L., & Olsson, M.J. (2016). Central processing of human body odors. In Andrea Buettener (Ed.), *Handbook of odors*. New York: Springer.

Paulhus, D.L. (1984). Two-component models of socially desirable responding. *Journal of Personality and Social Psychology*, *46*, 598–609.

Paulhus, D.L., & Reid, D.B. (1991). Enhancement and denial in socially desirable responding. *Journal of Personality and Social Psychology*, *60*, 307–317.

Plude, D.J., Enns, J.T., & Brodeur, D. (1994). The development of selective attention: A life-span overview. *Acta Psychologica*, *86*, 227–272.

Pourtois, G., Schettino, A., & Vuilleumier, P. (2013). Brain mechanisms for emotional influences on perception and attention: What is magic and what is not. *Biological Psychology*, *92*, 492–512.

Reynolds, C.R., & Richmond, B.O. (1978). What I think and feel: A revised measure of children's manifest anxiety. *Journal of Abnormal Child Psychology*, *6*, 271–280.

Richardson, J.T., & Zucco, G.M. (1989). Cognition and olfaction: A review. *Psychological Bulletin*, *105*, 352–360.

Rozin, P., & Fallon, A.E. (1987). A perspective on disgust. *Psychological Review*, *94*, 23–41.

Rozin, P., Lowery, L., & Ebert, R. (1994). Varieties of disgust faces and the structure of disgust. *Journal of Personality and Social Psychology*, *66*, 870–881.

Sann, C., & Streri, A. (2007). Perception of object shape and texture in human newborns: Evidence from cross-modal transfer tasks. *Developmental Science*, *10*, 399–410.

Schaal, B. (1988). Olfaction in infants and children: Developmental and functional perspectives. *Chemical Senses*, *13*, 145–190.

Schaal, B., Marlier, L., & Soussignan, R. (1998). Olfactory function in the human fetus: Evidence from selective neonatal responsiveness to the odor of amniotic fluid. *Behavioral Neuroscience*, *112*, 1438–1449.

Schaal, B., Marlier, L., & Soussignan, R. (2000). Human foetuses learn odours from their pregnant mother's diet. *Chemical Senses*, *25*, 729–737.

Schriever, V.A., Mori, E., Petters, W., Boerner, C., Smitka, M., & Hummel, T. (2014). The 'Sniffin'Kids' Test: A 14-item odor identification test for children. *PLoS ONE*, *9*, e101086.

Sela, L., & Sobel, N. (2010). Human olfaction: A constant state of change-blindness. *Experimental Brain Research*, *205*, 13–29.

Semin, G.R., & De Groot, J.H. (2013). The chemical bases of human sociality. *Trends in Cognitive Sciences*, *17*, 427–429.

Serrano, J.M., Iglesias, J., & Loeches, A. (1992). Visual discrimination and recognition of facial expressions of anger, fear, and surprise in 4- to 6-month-old infants. *Developmental Psychobiology*, *25*, 411–425.

Seubert, J., Gregory, K.M., Chamberland, J., Dessirier, J.M., & Lundström, J.N. (2014). Odor valence linearly modulates attractiveness, but not age assessment, of invariant facial features in a memory-based rating task. *PLoS ONE*, *9*, e98347.

Seubert, J., Kellermann, T., Loughead, J., Boers, F., Brensinger, C., Schneider, F., & Habel, U. (2010). Processing of disgusted faces is facilitated by odor primes: A functional MRI study. *NeuroImage*, *53*, 746–756.

Seubert, J., Loughead, J., Kellermann, T., Boers, F., Brensinger, C.M., & Habel, U. (2010). Multisensory integration of emotionally valenced olfactory–visual information in patients with schizophrenia and healthy controls. *Journal of Psychiatry & Neuroscience*, *35*, 185–194.

Seubert, J., Regenbogen, C., Habel, U., & Lundström, J.L. (2016). Behavioral and neural determinants of odor valence perception. In Andrea Buettener (Ed.), *Handbook of odors*. New York: Springer.

Smeets, M.A.M., & Dijksterhuis, G.B. (2014). Smelly primes – when olfactory primes do or do not work. *Frontiers in Psychology*, *5*, 96.

Soken, N.H., & Pick, A.D. (1992). Intermodal perception of happy and angry expressive behaviors by seven-month-old infants. *Child Development*, *63*, 787–795.

Stevenson, H.W. (1965). Social reinforcement of children's behavior. *Advances in Child Development and Behavior*, *2*, 97–126.

Tooby, J., & Cosmides, L. (1990). The past explains the present: Emotional adaptations and the structure of ancestral environments. *Ethology and Sociobiology*, *11*, 375–424.

Vuilleumier, P. (2005). How brains beware: Neural mechanisms of emotional attention. *Trends in Cognitive Sciences*, *9*, 585–594.

Widen, S.C., & Russell, J.A. (2003). A closer look at preschoolers' freely produced labels for facial expressions. *Developmental Psychology*, *39*, 114–128.

Wimmer, H., & Perner, J. (1983). Beliefs about beliefs: Representation and constraining function of wrong beliefs in young children's understanding of deception. *Cognition*, *13*, 103–128.

Young-Browne, G., Rosenfeld, H.M., & Horowitz, F.D. (1977). Infant discrimination of facial expressions. *Child Development*, *48*, 555–562.