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Learning blossoms: Caregiver-infant interactions in an outdoor garden setting

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Abstract

Plants provide unique opportunities for learning by engaging all human senses. Recent laboratory studies have shown that infants use a combination of behavioural avoidance and social learning strategies to safely learn about plant properties from adults. Here we investigate how infants and their caregivers interact with plants in an outdoor garden as a first step towards examining the operation of these social learning processes in naturalistic settings. We focus on two specific aspects of spontaneous infant-caregiver interactions with plants: olfactory and touch behaviours. Additionally, we look at whether infants' and caregivers' prior knowledge of the plants in our study influences infants' behaviour. Our results showed a multifaceted connection between infants' and caregivers' previous experience with the plants and their olfactory and touch behaviours. First, infants tended to touch and smell the plants after their caregivers did, and this appeared to be independent of whether infants had seen the plant before. Second, infants systematically engaged in some of the same types of olfactory and touch behaviours their caregiver displayed towards plants. Finally, infants whose caregivers were given more information about the plants in the study showed fewer touch behaviours, but no difference in olfactory behaviours. These findings bolster the previous laboratory studies of plant learning early in life, highlighting the importance of olfactory behaviours, and underscoring the benefits of using ecological observations to explore unique aspects of human development.

Article Info

Keywords: Social learning, Spontaneous caregiver-infant interactions, Plants, Olfaction, Naturalistic setting

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1. Introduction

Nature is a privileged context for human learning (Longbottom & Slaughter, 2016). It provides unique possibilities for the spontaneous observation and exploration of odours, materials, textures and shapes. Research examining the health and educational benefits of children's contact with nature indicates that natural outdoor environments present significant benefits for children's cognitive and emotional development (Chawla, 2015; Gill, 2014; Maller & Townsend, 2006). Outdoor schooling and educational programs, such as forest schools and garden-based childcare facilities, are rapidly increasing in popularity in western societies, offering young children hands-on opportunities to learn through closer contact with naturalistic entities (Meyer, Müller, & Macoun, 2017). However, such experiences are not limited to outdoor educational programs. Plants and animals are part of children's everyday experience in a range of different contexts, and with different degrees of involvement for the child: They often become objects of curiosity, stimulating discussions or eager requests for explanations when children encounter them with an adult. Plants, in particular, have intrinsic properties that engage the entire human sensory system. They offer strong, intriguing scents to be smelled and delightful, eye-catching colours and shapes to be seen. They present a variety of textures, from hairy stems to fluffy corollas and rough or soft leaves, that provide a wide array of tactile sensations. Last but not least, some plants offer tasty fruits that can be eaten when ripe. Plants, therefore, provide rich multifaceted learning opportunities for children.

Recent laboratory studies have uncovered behavioural avoidance and social learning strategies for safely acquiring information about plants in infancy (see Wertz, 2019 for a review), but very little is known about how those strategies play out in real-world environments. This is likely to be a fruitful area of inquiry because the rich sensorial experience offered by plants presents unique opportunities for investigating what and how children learn about nature. Here we present a study that investigates social learning opportunities afforded by plants, by looking at caregiver-child interactions while exploring plants together in an outdoor garden setting. We focused on two specific aspects of caregiver-child behaviours when interacting with plants: olfactory and touch behaviours. Our aim was to observe whether and how these sensory behaviours were employed by participants as part of the shared learning opportunities plants provide.

1.1. Development of biological knowledge in infancy and early childhood

Decades of research on children's intuitive or folk biological knowledge has shown that young children possess an impressive array of knowledge about the natural world (e.g., Carey, 1985; Hatano & Inagaki, 2002; Medin & Atran, 1999; Ross, Medin, Coley, & Atran, 2003). For example, infants can readily distinguish between animate and inanimate entities (Fouquet, Megalakaki, & Labrell, 2017; Trauble & Pauen, 2011) and attribute biological properties to animals (Setoh, Wu, Baillargeon, & Gelman, 2013). Infants are especially attentive to ancestrally-recurrent threats such as snakes and spiders (LoBue, Rakison, & DeLoache, 2010). Recent work has shown that infants have a variety of expectations about plants: they initially treat plants as potentially dangerous, being reluctant to touch plants (Elsner & Wertz, 2019; Wertz & Wynn, 2014b; Włodarczyk, Elsner, Schmitterer, & Wertz, 2018; Włodarczyk, Rioux, & Wertz, 2020), looking to adults before touching plants (Elsner & Wertz, 2019), and minimising physical contact with plants after touching them (Włodarczyk et al., 2018, 2020). Infants selectively learn about plant safety (Włodarczyk et al., 2020) and edibility (Wertz & Wynn, 2014a) from adults, and systematically generalise learned information to similar-looking plants (Wertz & Wynn, 2019).

Young children understand that plants grow (Inagaki & Hatano, 1996), can heal themselves after being damaged (Backscheider, Shatz, & Gelman, 1993) and can die (Nguyen & Gelman, 2002). Aspects of plant knowledge appear to emerge later than knowledge about animals. For example, while young children understand that both plants and animals grow, explicit understanding of animal growth appears to emerge earlier (around 3 years of age; Herrmann, French, DeHart, & Rosengren, 2013) than understanding of the more complicated growth cycle of plants (i.e., seed, plant, flower, fruit), which does not appear until four and a half years of age (Hickling & Gelman, 1995). There has also been a long-standing focus on whether plants are seen as "alive" (e.g., Carey, 1985; ojalehto, Medin, & García, 2017). Children generally do not explicitly include plants in this category until middle childhood, although the emergence of such judgements seems to depend on how children understand the word "alive" (Anggoro, Waxman, & Medin, 2008). Nevertheless, from a young child's point of view, plants may seem to be "special things", presenting unique characteristics that make them halfway between inanimate objects and living entities (Fouquet & Megalakaki, 2013). Importantly, the kinds of information children would have needed to learn about plants over evolutionary time cannot safely or efficiently be learned without the help of others (Oña, Oña & Wertz, 2019, Wertz, 2019). For example, in order to survive in a hunter-gatherer world, children must learn which plants can be eaten, which ones are toxic, and master complex food preparation and artefact building techniques (Hardy & Kubiak-Martens, 2016; Wertz & Moya, 2019). All of this means that caregivers play an essential role in providing important information about plants, even to the youngest children, to support the development of plant knowledge.

1.2. Social learning practices in naturalistic settings

An important way in which infants and young children build their understanding of the surrounding world is through social learning, that is, by gleaning information with and from others (Bruner, 1959; Markova & Legerstee, 2006; Reddy, 2008; Vygotsky, 1978). Social learning is a key feature of children's development, which becomes increasingly refined as their knowledge and social experiences become more sophisticated over time (Koenig & Sabbagh, 2013; Legare & Harris, 2016). Accordingly, a large body of empirical research has provided evidence for the beneficial role of information provided by caregivers in children's learning (e.g., Coleman, Brown, & Rivkin, 1997; Lombrozo, 2016), especially within the domain of biological knowledge (Keil, Levin, Richman, & Gutheil, 1999; Legare & Gelman, 2008). Rudimentary knowledge structures naturally develop over the course of early childhood as children have daily experiences with plants and animals either directly (Geerdts, Van de Walle, & LoBue, 2015; Prokop, Prokop, & Tunnicliffe, 2008), or indirectly, through conversations and activities with parents (Crowley et al., 2001; Rigney & Callanan, 2011).

Social learning is especially important for acquiring information about plants because learning on one's own about which plants are safe to handle or consume can lead to serious negative consequences, such as poisoning or injury from dangerous plant structures like thorns or stinging hairs (e.g., Oña et al., 2019; Wertz & Wynn, 2014b; Włodarczyk et al., 2018). Indeed, the existing studies on infants' responses to plants support the theoretical predictions that knowledge about plants is generally acquired through social learning. When plants are first presented to infants in a laboratory setting, they look to adults more frequently and for longer periods of time than when control stimuli are presented (Elsner & Wertz, 2019). Importantly, this increase in social looking occurs *before* infants touch the plants, allowing infants to observe social signals from adults prior to making contact with potentially harmful plants. Infants also use adults' behaviour as a guide for their own interactions with plants. They approach plants more rapidly after watching an adult touch them, while their approach of control stimuli remains unchanged (Włodarczyk et al., 2020). After observing an adult tasting part of a plant and an artefact, infants selectively learn that the plant, but not the artefact, is edible (Wertz & Wynn, 2014a), and they can also generalise an instance of social learning to plants that share features like leaf shape and fruit colour (Gerdemann and Wertz, 2021; Wertz & Wynn, 2019). Taken together, these results strongly suggest that social learning plays a key role in acquiring information about plants in early life.

Socialisation practices like social learning rely on interactions that are intrinsically multimodal in nature, particularly in infancy; that is, they are actions built through multiple sources—gestural, vocal, sensory—that infants directly experience through observation, and often re-production (e.g., by imitating an adult's action). Imitation is one aspect of social learning that is a powerful tool for supporting the transmission of information. Gestural imitation, for instance, has been extensively studied as a precursor of language learning (Bates & Dick, 2002; Volterra, Caselli, Capirci, & Pizzuto, 2005) and a well-established body of literature indicates that imitation is a social response (Legerstee, 1991) and a natural, culturally-shaped pedagogical tool for knowledge transfer (Gergely & Csibra, 2006). Imitation has been shown to be critical to social learning in two particular ways: (1) supporting infants' gaining understanding from adults' about (often puzzling) observed events and behaviours (Tomasello & Camaioni, 1997; Uzgiris, 1981) and (2) coordinating an affectively-loaded mutual attention to a common focus with another person (Reddy, 2008). The pedagogical value of imitation is culturally-shaped and sensitive to infants' early social experiences. That is, understanding and reproducing an action first performed by an adult is most pedagogically effective when that action is relevant and meaningful for the infant in terms of social and cultural practices (Reddy, 2008; Shneidman, Gaskins, & Woodward, 2015)

Imitation, however, is only one of the many, possible tools for infants to learn from and with others. Other aspects of infant-caregiver interactions, such as joint attention and infant-direct speech (Farroni, Csibra, Simion, & Johnson, 2002), also play an essential role in child-directed, pedagogical contexts, as well as daily spontaneous social interactions. Reciprocal eye-contact, bodily posture (Nomikou, Rohlfing, & Szufnarowska, 2013), and child-directed communication help to engage, focus, and maintain infants' attention to relevant information provided by adults (Shneidman & Woodward, 2016), as well as to the ongoing activity (Rossmanith, Costall, Reichelt, López, & Reddy, 2014).

Social learning is an integral component of infants' everyday lives. An increasing body of research in developmental psychology has focused on early social interactions in everyday situations, such as changing a nappy (Nomikou & Rohlfing, 2011), play and teasing exchanges (Fantasia, Fasulo, Costall, & López, 2014; Reddy & Mireault, 2015), shared book reading (Rossmanith et al., 2014), as being paramount in early social learning processes. Infants who are engaged in these routine shared activities are not merely passive imitators of adults' behaviours, but active participants who can take on different roles within the social learning situation, complementing and enriching a caregiver's action. In sum, interactions between infants and their caregivers in everyday contexts provides fertile ground for multifaceted, multimodal social learning about the entities and situations they encounter.

1.3. The role of olfaction and touch in naturalistic learning

Sensory properties play an important role in naturalistic social learning situations. In everyday life, infants and young children explore the world using their five senses, but most developmental studies tend to focus extensively (and almost exclusively) on the role of visual and linguistic communication in social learning situations early in life (e.g. gaze following and alternation, Kaye & Fogel, 1980; Markova & Legerstee, 2006; joint attention, Racine & Carpendale, 2007; and labelling, Markman, 1991; Nazzi & Gopnik, 2001; Pauen, Birgit, Hoehl, & Bechtel, 2015). As little attention has been paid to how knowledge transmission might occur in other modalities, in this study we focused on two sensory modalities that infants and their caregivers can use to explore plants in outdoor garden settings: olfaction and touch.

Olfactory behaviours have received little attention in developmental research, alhtough they are critically important. Olfaction is a part of practically every aspect of a person's daily life (McGann, 2017) as humans can distinguish trillions of different odours (Bushdid, Magnasco, Vosshall, & Keller, 2014). Indeed, the perception and discrimination of odours is central to how we relate to and gain knowledge about the surrounding world and is the result of a complex integrated system including neural operations, body experience, and environmental affordances (Cerulo, 2018). In combination with other sensory modalities, experience with specific odours in infancy can canalise lifelong perceptual abilities (Schaal, 2017) and promote early experiences of social learning (Durand, Baudouin, Lewkowicz, Goubet, & Schaal, 2013). Thus, by bringing attention to scents, caregivers may shape the way young children approach and engage with plants. Research suggests that the olfactory system plays an important role in human memory processes and, in turn, learning (Herz, 2012; for a complete review see Sullivan, Wilson, Ravel, & Mouly, 2014). These findings are supported by neurobiological research that has identified distinct functional-structural associations for semantic odour memory (Herz, Eliassen, Beland, & Souza, 2004; Seubert et al., 2020). Exploring the olfactory properties of plants may thus facilitate memory and learning processes.

Touch is another critically important sensory route for engaging with the world. Nonverbal communication is the foundation of social interactions before children develop sufficient linguistic abilities and touch provides a way to convey information and emotion (Goodwin, 2017). Touch is ontogenetically the earliest and most developed sensory modality in humans. Before birth (Cascio, Moore, & McGlone, 2019; Reissland & Austen, 2018) and throughout the first year of life, touch plays a crucial role in social cognition (Crucianelli & Filippetti, 2020), attachment, bonding, intimacy, learning, communication, and compliance in humans (Field, 2005; Hertenstein, Keltner, App, Bulleit, & Jaskolka, 2006), and the formation of intersubjective relationships through embodied means throughout the lifespan (Goodwin, 2017). Tactile exploration, alongside visual sensory cues, is a basic but essential sensorimotor resource employed by infants to discover themselves (e.g. though proprioceptive haptic experiences of touching their body parts (Rossmanith & Reddy, 2016), explore objects (Adolph & Berger, 2010) and the environment (Lederman & Klatzky, 2009). In particular, active manual exploration is often promoted in early learning and socialisation practices (Carlson & Sullivan, 1999), particularly in Western cultures (Little, Carver, & Legare, 2016).

Touch plays a particularly important role in infants' exploratory behaviours towards plants. Plants can be dangerous in ways that are not always easy to see (e.g., even beautiful, delicate looking plants like oleander can be highly toxic). Therefore, Wertz and colleagues proposed that infants may possess a behavioural avoidance strategy that would protect them from plant dangers by avoiding contact with plants until there is a social signal that a particular plant is safe. Accordingly, recent laboratory research has shown that infants are initially reluctant to touch plants and touch them less frequently than manmade artefacts and naturally occurring entities like shells and stones (e.g., Elsner & Wertz, 2019; Wertz & Wynn, 2014b; Włodarczyk et al., 2018). Infants' reluctance to touch plants diminishes after they see an adult touch the plant first (Włodarczyk et al., 2020) demonstrating the important role of touch in social learning processes about plants. However, to our knowledge no research has investigated how children and their caregivers' approach plants in a naturalistic setting. Therefore, in order to identify specific behaviours of interest prior to this study, we first conducted a pilot study of 18- to 36-month-olds and their caregivers to observe a small number of dyads in an outdoor garden ($N = 10$). Based on the literature and previous laboratory studies, we anticipated that touch behaviours would play an informative role in caregiver-child interactions with plants. Olfactory behaviours, such as smelling a plant directly or sniffing a piece of a plant held in the caregivers' hand, also emerged as an important component of caregiver-child interactions while exploring plants. That is, very often caregivers approached plants by smelling them and encouraging their child to do so as well, often by offering pieces of the plants held in their hands to sniff. These kinds of olfactory behaviours were particularly pronounced in dyads in which the child was in the end of the second year of life, between 18–24 months of age. We then designed the study reported here to investigate these preliminary observations in-depth.

1.4. The current study

Our aim in the current study was to investigate how infants and their caregivers approach plants, and in particular how touch and olfactory experiences are used during spontaneous interactions over plants, in a semi-structured outdoor garden setting. We adopted this more ecologically-valid approach (compared to a laboratory setting) to observe types of behaviours that occur in spontaneous interactions between an infant and caregiver in everyday outdoor settings, such as gardens and parks. In this way, our investigation can add important, novel dimensions to our understanding of caregiver-infant interactions and the social learning processes resulting from them. Building on the previous laboratory studies and our preliminary pilot study, we narrowed our focus to two types of spontaneous behaviours: touch behaviours and olfactory behaviours of infants and their caregivers. We examined the following hypotheses:

a) Prior experience with some plants may reduce children's initial reluctance to touch that plant. Specifically, we predicted that infants should be more likely to touch a selected plant before their caregiver if they had already seen it in another context.
b) Caregiver's behaviours towards plants may prompt similar behaviours in infants. We expect similarities between olfactory and touch behaviours of the caregivers and those of the infants.
c) The amount of information caregivers know about a plant may influence the frequency and duration of infants' touching and olfactory behaviours. Specifically, we predicted that infants in a High Information Condition (HIC) would spend more time touching and smelling the plants compared to infants in a Low Information Condition (LIC).

2. Method

2.1. Participants

Forty-nine infants between 18 and 23 months of age (Mean age = 21 months, 16 days; age range: 18 months, 0 days – 23 months, 30 days; 23 boys and 26 girls) participated in the study together with one caregiver (12 fathers and 37 mothers). The sample size was set according to previous infant studies on plant-relevant behaviours (e.g., Wertz & Wynn, 2014a; Włodarczyk et al., 2018). Three additional dyads were tested but had to be excluded from the final data set due to infant fussiness during the session. The age and sex of the children were balanced across the two study conditions (see Section 2.2 below). Participants were recruited from Berlin, Germany, and told that we were interested in how children would approach plants in an outdoor garden setting and learn about plants from their caregivers. Each participating dyad received 10 Euro and a certificate of participation.

2.2. Study design

The study sessions took place in the garden of the Max Planck Institute for Human Development in Berlin. Infant-caregiver dyads were video-recorded while interacting with five selected plants for approximately two minutes per plant. We used a between-subjects design to examine whether having more information about the plants would influence how the dyads behave, and each dyad was randomly assigned to either a high information or low information condition. A few days prior to the scheduled study appointment, dyads assigned to the High Information Condition (HIC) received an email containing a booklet of information about the plants they would encounter during the study and were asked to read it before the study session. This information included the plants' name, growing environment (e.g., "*Sage is native to the Mediterranean region*"; "*Oregano is native to warm-temperate climates in Europe, North Africa and Asia*"), edibility ("*The fennel bulb is a versatile vegetable*"), and common uses (e.g., *"Lavender is mostly used to make essential oils",* see Supplementary Material for the full Plant Information Booklet). Dyads in the Low Information Condition (LIC) were given no specific information about the plants except for each plant's name immediately prior to the start of the study. The entire outdoor session lasted approximately one hour in total and each interaction phase (see Section 2.3.1 below) was video-recorded. In order to measure the dyads' past experience with the plants selected for the study, at the beginning of the study session, caregivers in both the HIC and LIC received a short booklet (see *Target Plant Questionnaire* in the Supplementary Material) containing pictures of each selected plant along with its name and several questions (in German). These questions asked about the child's prior experience with the plant (*"Has your child seen this plant before?"*) and potential risk in contacting the plant (*"Is your child allergic to this plant?"*), as well as the caregiver's own knowledge about the plants (*"Have you seen this plant before?", "What do you know about this plant?"*). Additionally, caregivers completed a questionnaire (adapted from Wertz & Wynn, 2014a, 2014b) assessing their child's prior experiences with plants in different contexts (the Plant Experience Questionnaire; Rioux & Wertz, 2021).

2.3. Setting and procedure

Two researchers facilitated each study session: one was in charge of running the session (R1) and the other was the camera person (R2). Prior to the starting of the session, R2 put marker sticks in the ground close to each selected plant to make them easy to locate. Then, in a shady and quiet area of the garden, R2 set up a play picnic set, with a blanket and some wooden toys. When participants arrived for their session, they were taken outside to the garden area by R1, and invited to participate in a pretend picnic. This warm-up phase familiarised the child with the setting and the researchers. After a few minutes of joint play, R1 explained the study to the caregiver and asked him/her to fill in the written consent forms, the Target Plant Questionnaire and the Plant Experience Questionnaire.

Prior to the beginning of the session, R1 checked the caregivers' answers to the questions regarding potential allergies to any of the selected plants. If a child had been allergic to one of the plants that plant would have been skipped, however this situation never arose during the study. Participants in the HIC were provided with a printed copy of the same Plant Information Booklet they received via email and given a few minutes to read it again. Participants in the LIC were not provided with any additional information about the selected plants. Finally, R1 explained to the caregiver that she or he should introduce each plant to the infant as she or he would normally do in a garden or park. No specific behaviours with the plant were encouraged or forbidden. Caregivers were asked to try to focus specifically on the selected plants and not the surroundings.

As the session started, R1 accompanied the dyad to the first selected plant. R2 turned on the handheld camera and then gave a starting signal for R1 to introduce participants to the first plant. R1 did this by saying "*Here we have arrived at the first plant*. *This is [plant name]*", in German ("*Hier sind wir bei der ersten Pflanze angekommen. Das ist [Salbei]*") and then walking a few meters away, leaving the caregiver and infant to interact freely with the plant for approximately two minutes. After this time period, E1 moved closer to the participants and invited them to move on to the next plant. R2 repositioned the backup camera (see Section 2.3.3 below), and the same procedure was repeated again for each of the remaining plants. The study procedure was identical in both the HIC and LIC. The presentation order of the selected plants in each session was counterbalanced across participants. After the dyad visited all five plants, participants returned to the picnic blanket where they filled out consent forms concerning video use and inclusion in our participant database and received the compensation for their participation (Fig. 1).

2.3.1. Study phases

We defined a phase as the time period during which participating dyads interacted with one of our study plants; each dyad completed five phases lasting approximately two minutes each ($M\text{length}$: 105.84 s; min.: 10.5 s, max.: 202.5 s; SD: 29.20 s). Whilst E1 used a stopwatch to time each phase, there was some variation in phase length due to the free-form nature of the infant-caregiver interactions and our efforts to keep the participants as comfortable as possible. To account for those differences, the data were adjusted prior to analysis. For the duration measures the values were divided by total phase length and for the frequency measures the values were divided by total phase length and multiplied by 60 to yield a touches per minute rate for each phase.

2.3.2. Plant selection and information

The five plants selected for the study were sage, lavender, oregano, fennel, and oak tree (see Fig. 2). These plants were chosen for their safety, availability and ease of access in the garden, and degree of (possible) familiarity to the children and caregivers.

Fig. 1. a) 19-month-old infant and caregiver interacting with lavender; b) Caregiver smelling sage with her 18-month-old; c) Caregiver offering a piece of lavender to her 20-month-old.

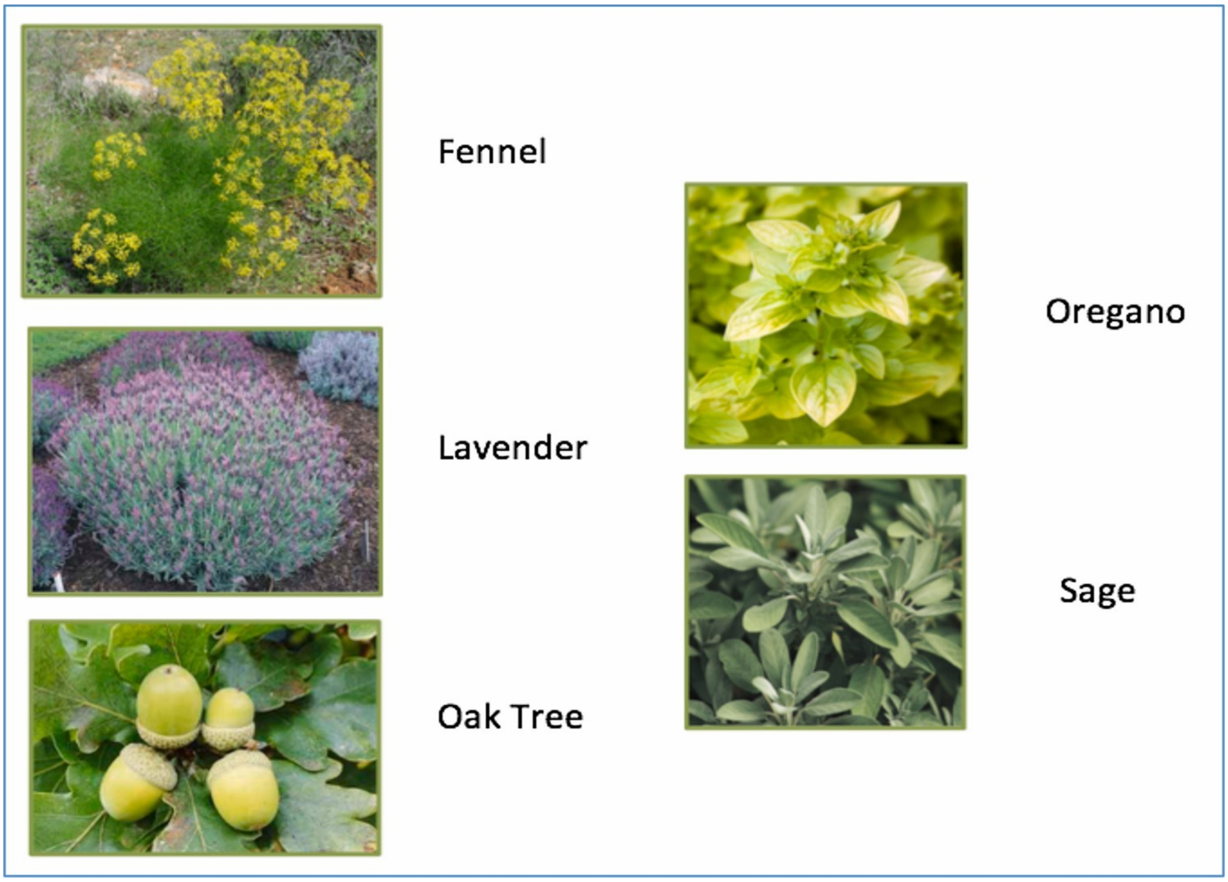

Fig. 2. Pictures of the selected plants as they were presented to participants in the Target Plant Questionnaire.

Furthermore, the researchers met with the individuals responsible for the garden to make sure that the area surrounding the selected plants contained no harmful plants that could pose risks for children (e.g., toxic or thorny plants), as it was expected that the participants could come into contact with the surrounding plants during the session. As an additional safety measure, the potentially harmful plants in the garden were highlighted on a printed map that was shown to the caregivers before the test session.

2.3.3. Video and audio recording

Two cameras were used to record the infant-caregiver dyad during the testing session: a handheld Panasonic high-definition video camera (HDC-HS700) and a tripod mounted GoPro action camera (Hero 4). The Panasonic footage served as the main video data that was used for behavioural coding, while the GoPro served as a backup data source. R2 stayed about a meter away from the participants while filming with the handheld, while the GoPro was situated approximately 3–5 meters away from the participants so that it would not attract attention.

Table 1
Coded behavioural categories and their frequency of occurrence in infants and caregivers.

Behaviour	Description	% occurrence in infants[1]	% occurrence in caregivers[1]
Touch			
Simple touch	One or more fingers or palm of the hand in contact with any part of the selected plant without a specific movement.	76 %	67 %
Pinching	Pressing one or more fingers together on the selected plant, with no additional movement	13 %	28 %
Picking up/ off	Using one or two hands to pick off pieces either directly from the selected plant or off the ground (e.g., one of its flowers or leaves that had fallen on the ground)	11 %	5 %
Olfactory			
Smell other	Smelling a piece of selected plant in someone else's hand or smelling plant residue on someone else's hand or finger(s).	55 %	8 %
Smell self	Smelling a piece of selected plant in own hand or smelling plant residue on own hand.	41 %	86 %
Smell direct	Smelling the selected plant directly without first holding or picking a piece of it up.	4 %	6 %

Note:[1] Percentages represent how frequently each subcategory of coded behaviour occurred within the Touch and Olfactory categories respectively for the entire sample.

2.4. Coding

In the current study, we focused on olfactory behaviours and touch behaviours (see Table 1). These behaviours were systematically identified and described in the pilot study as first pass. In the main study, the behaviours were coded using a coding and data visualisation software (Datavyu v1.3.7). Infant and caregiver touch and olfactory behaviours were coded separately and independently using the same coding scheme (see Table 1 for brief descriptions and the Coding Scheme in the Supplementary Material for the full descriptions of the coded behaviours). This approach allowed us to capture different behaviours occurring simultaneously. For example, if an infant touched and smelled a plant at the same time, both behaviours would be entered into the coding software for that time period. Furthermore, the hand the infant or caregiver used (left or right) to perform our behaviours of interest were noted in the coding scheme. Here again, this was done to capture simultaneously occurring actions (e.g., simple touch with the left hand while pinching with the right; see Table 1). In the analyses, however, we did not distinguish between left and right hand when they performed the same type of action at the same time; in that case they were instead treated as single instances of touch and olfactory behaviours. For example, if an infant touched a plant in the same way with both the left and right hand simultaneously, that would count as one occurrence of touch behaviour. Instead, if the touching was sequential (first touch with the right hand and then with the left hand), this was counted as two distinct touch behaviours. Finally, our behaviours of interest were coded with reference to their recipient (i.e., the other participant or a plant). For example, an action including *touch* was coded either as “touching the plant directly” or as “touching a piece of the plant in the other’s hand”.

2.4.1. Reliability

Two independent primary coders, blind to the study hypotheses, coded each behaviour category separately (touch and olfaction) for both children and caregivers, and two secondary independent coders coded a randomly selected 25 % of the same data in order to assess inter-rater reliability. Coder agreement was high for all categories: caregiver touch (left hand: $\kappa = 0.901$, $p < .001$; right hand: $\kappa = 0.895$, $p < .001$), infant touch (left hand: $\kappa = 0.835$, $p < .001$; right hand: $\kappa = 0.899$, $p < .001$), caregiver olfactory behaviour ($\kappa = 0.950$, $p < .001$) and infant olfactory behaviour ($\kappa = 0.888$, $p < .001$).

3. Analysis approach for our hypotheses

3.1. Hypothesis A

In order to test whether prior experience with selected plants reduces infants’ initial reluctance to touch plants, we analysed which participants touched the selected plants first (First_touch) combined with participants’ responses to the Target Plant Questionnaire about infants’ prior visual experience with those plants (variable Seen_Before, coded as Yes or No). We used GLMM (Baayen, Davidson, & Bates, 2008) with binomial error structure to avoid pseudo-replication by accounting for multiple responses measured for the different individuals and to handle non-normally distributed data. As response variable we used First_touch as binary data (infant or caregiver). We included the variables Plant (5 levels representing the selected plants: Sage, Oak, Lavender, Fennel, Oregano), Seen Before, and Condition as fixed factors. We also included an interaction term for the factors Plant and Seen_Before.

3.2. Hypothesis B

To test whether there is a relationship between caregivers and infants’ behaviours towards plants we analysed participants’ frequency and duration of olfactory and touch behaviours during each session. Additionally, we checked whether those behaviours were influenced by participants’ sex (both caregivers’ and infants’) by using sex as a control variable. We used Generalized Linear Mixed Model (GLMM; Bates et al., 2015) with Poisson (for models B.1, B.3) or Gaussian (for models B.2, B.4) error structure to avoid pseudo-replication by accounting for multiple responses measured for the different individuals and to handle non-normally distributed data. We used infants’ olfactory and touch behaviours as dependent variables and included the same behaviours by caregivers along with the variables: Plant, Seen_Before, and Condition (HIC/LIC) as fixed factors, and sex (Sex_child, Sex_caregiver) as a control variable.

In order to determine if the variables had a significant effect on the response, we used a full-null model comparison lacking the fixed effects test predictors for all models (Forstmeier & Schielzeth, 2011) and conducted a likelihood ratio test (Dobson & Barnett, 2008) by using the R function “Anova”, package “stats” with argument test set to “Chisq”. The p-values for the fixed effects were also based on a likelihood ratio test, comparing the full model with the model reduced by the fixed effect of interest (Dobson & Barnett, 2018) using the R function “drop1” with argument test set to “Chisq”. To allow for an LRT we fitted the LMM using Maximum Likelihood (rather than Restricted Maximum Likelihood; Bolker et al., 2009). We considered p-values ≤ 0.05 to be significant and p-values > 0.05 and < 0.1 as a trend. Collinearity was tested by calculating Variance Inflation Factors (VIF) using a linear model excluding random effects using the R function vif. Collinearity was not an issue in our data (VIF lower than 1.6 for all predictors; Fox & Weisberg, 2018).

3.3. Hypothesis C

We tested whether caregivers’ knowledge about the selected plants (i.e., their assignment to the HIC or LIC) influenced infants’ touch and olfactory behaviours by including Condition as a factor in the models formulated for Hypotheses A and B.

4. Results

4.1. Statistical models

To test our hypotheses, we used Generalized Linear Mixed Models and Linear Mixed Models (LMM and GLMM, Baayen et al., 2008). Prior to fitting all models, we checked the distribution of the covariates as well as the number of responses per level of factor to ensure these were balanced. We fitted the model in R Development Core Team (version 3.5.1, R Core Team, 2017) using the function "glmer" (model A and B) and the function "lmer" (model C) from the R package "lme4" (Bates et al., 2013;). We z-transformed covariates to a mean of zero and standard deviation of one to facilitate the interpretation of the coefficient estimates. Furthermore, to control for pseudo-replication due to repeated sampling from the same child, we included the IDs as random factor into the models (Crawley, 2002). The data consisted of a total of 214 events. For both models used in testing hypotheses A and B, we included sex of the child (Sex_child), sex of the caregiver (Sex_caregiver), age of the child, phase (order), and phase duration as control variables.

4.2. Infants' engagement with plants: frequencies of touch and olfactory behaviours

Before presenting the results of the GLMM, we present a general picture of how infants interacted with the plants and with their caregivers in terms of their touch and olfactory behaviours (Table 1).

Infants touched the plants most frequently by contacting them without a specific gesture (*simple touch)*, and less frequently by pressing the plant's surfaces with their fingers (*pinching*) or picking off any of its parts (*picking off*), either directly from the plant or from the ground. Similar touch behaviours were displayed by the caregivers. Olfactory behaviours emerged as an integral component of both infants' and caregivers' engagement with the plants. Infants showed a marked preference for indirect ways of smelling the plants, that is, they sniffed their caregivers' hands (*smell other*) containing a piece of plant, or their scent of plant residue left behind after the caregiver had rubbed the plant with their fingers. Somewhat less frequently, infants either smelled their own hand after pinching or rubbing a plant, or a piece of plant they held in their hand (*smell self*). Infants quite rarely smelled the plants directly (*smell direct*). Caregivers also rarely smelled the plants directly (*smell direct*), but in contrast to infants, caregivers' most frequent olfactory approach to the plants involved smelling a piece of plant or its residue in their own hand (smell self).

In order to investigate whether infants' previous experience with plants had an impact on their behaviours towards the selected plants in our study, we first analysed the caregivers' responses to the Target Plant Questionnaire. The results revealed that Lavender was the plant most frequently experienced in the past (87.8 % of infants had seen it before), followed by Oak and Sage (both 85.7 %), Oregano (73.5 %) and Fennel (71.4 %). Secondly, we ran a correlational analyses using caregivers' responses to the Plant Experience Questionnaire (PEQ) to look at whether its main factors correlated with the infants' touch and olfactory behaviours (both as frequencies and durations). We found no significant correlations between infants' behaviours in this study and their previous experiences with plants.

4.3. Hypothesis A: the effect of prior experience on infants' approach behaviours towards plants

In order to get a sense of infants' initial approach of the study plants, we began by assessing whether infants or their caregivers touched the plants first. To do this, we ran a binomial test using the first touch event for each phase. We found that caregivers touched the plants first significantly more often than infants did (58 % for caregivers, 42 % for infants; phases total $N = 214$, $p = 0.004$). We next assessed whether the infant or caregiver smelled the plants first by running a binomial test using the first smell event for each phase. From the results, it emerged that caregivers took the initiative in smelling the plants significantly more often than infants did (87 % for caregivers and 13 % for infants; phases tot. $N = 214$, $p = 0.00000001$). Taken together, these results indicate that infants were less likely to approach a plant before their caregiver.

Next, we assessed whether the prior experience of seeing a plant before affected infants' initial approach. For this analysis, we focused on infants' touch behaviours because relatively few infants smelled the plants first. The interaction between Plants and Seen_Before was dropped for all models. The results of the model analysis revealed that there was no significant effect of the variable Seen_Before on the response variable Touch_Plant_Before_Caregiver, thus disconfirming our hypotheses that infants' first touch of our study plants would occur before the caregiver if infants had already seen that plant in the past. Details of the Model A results are reported in Table S1, in the Supplementary Material.

4.4. Hypothesis B: the relationship between caregivers' and infants' olfactory and touch behaviours

The interaction between Plants and Seen_Before for all models (B.1–4) was poor. We continued analysing the models reported below excluding the interaction term. Models and results are included separately for olfactory behaviour frequency, olfactory behaviour duration, touch behaviour frequency, and touch behaviour duration in the Supplementary Material.

4.4.1. Results for Model B.1 (olfactory behaviour frequency)

Overall, the comparison between the full against the null model revealed a clear impact of the fixed effects on the response variable (LRT model with factors vs. model without: $c^2 = 49.026$, $df = 12$, $p < 0.001$). The analyses revealed a significant effect of the caregiver's frequency of olfactory behaviours ($c^2 = 21.06$, $df = 1$, $p < 0.001$) and the type of plant ($c^2 = 52.938$, $df = 4$, $p < 0.001$) on their infant's frequency of smelling plants (Csmell_freq). In other words, a higher frequency of the caregiver's smelling the plants corresponded a higher frequency of the same behaviours in their infant (see Fig. 3). In addition, and not surprisingly, our analyses revealed that infants engaged in olfactory behaviours more frequently with strongly scented plants, such as lavender and sage, compared to all other plants: while oak was smelled significantly less often than the rest of the plants. Details of the Model B.1 are reported in Table S2 in the Supplementary Material.

4.4.2. Results for Model B.2 (olfactory behaviour duration)

The comparison between the full against the null model again revealed a clear impact of the fixed effects on the response variable (LRT model with factors vs. model without: $c^2 = 128.82$, $df = 12$, $p < 0.001$). The analyses revealed no significant effect of the caregiver's duration of olfactory behaviours on the infant's duration of smelling ($c^2 = 0.275$, $df = 1$, $p = 0.6$); but a significant effect of the caregiver's *frequency* on the infant's duration of smelling ($c^2 = 10.629$, $df = 1$, $p = 0.001$), showing a positive relationship between caregiver and infant olfactory behaviours (see Fig. 4). Furthermore, our analyses revealed that the type of plant ($c^2 = 11.768$, $df = 4$, $p = 0.019$) and sex of the infant ($c^2 = 4.259$, $df = 1$, $p = 0.039$) had an effect on infants' duration of smelling plants (Csmell_freq): significant longer durations of olfactory behaviours emerged for lavender compared to oak (but no other contrasts emerged as significant). Overall, boys engaged in olfactory behaviours for significantly shorter bouts than girls. Details of the Model B.2 results are reported in Table S3, in the Supplementary Material.

4.4.3. Results for Model B.3 (touch behaviour frequency)

Here again, the comparison between the full against the null model revealed a clear impact of the fixed effects on the response variable (LRT model with factors vs. model without: $c^2 = 282.2$, $df = 12$, $p < 0.001$). The analyses revealed no significant effect of the caregiver's frequency of touching behaviours on the infant's frequency of touching ($c^2 = 0.468$, $df = 1$, $p = 0.494$). However, there was a significant effect of caregiver's *duration* of touching the plants on the infant's frequency to touch them ($c^2 = 10.818$, $df = 1$, $p = 0.001$), revealing a positive relationship between caregivers' and infants' plant touching behaviours (see Fig. 5). Furthermore, the analyses revealed a significant effect of plant type ($c^2 = 98.54$, $df = 4$, $p < 0.001$) on infants' frequency of touching plants: they touched lavender more frequently than all other plants. Details of the Model B.3 are reported in Table S4, in the Supplementary Material.

4.4.4. Results for Model B.4 (touch behaviour duration)

As before, the comparison between the full against the null model revealed a clear impact of the fixed effects on the response variable (LRT model with factors vs. model without: $c^2 = 36.86$, $df = 12$, $p < 0.001$). In this case, the analysis revealed no significant effect of the caregiver's duration of touching on their infant's duration of touching ($c^2 = 1.00$, $df = 1$, $p = 0.32$). This analysis also revealed significant effects of the sex of the infant ($c^2 = 6.75$, $df = 1$, $p < 0.001$) and the sex of the caregiver ($c^2 = 4.05$, $df = 1$, $p < 0.001$) on touch duration. Female infants, and infants in dyads with male caregivers, touched the plants longer compared to the respective opposite sex. Furthermore, there was a significant effect of plant type ($c^2 = 18.67$, $df = 4$, $p < 0.001$) on infants' duration of touching, resulting in longer durations of touch with lavender compared to all other plants. Details of the Model B.4 are reported in Table S5, in the Supplementary Material.

4.4.5. Summary of Hypothesis B results

Overall, our results confirmed that a significant relationship existed between caregivers' and infants' behaviours towards the

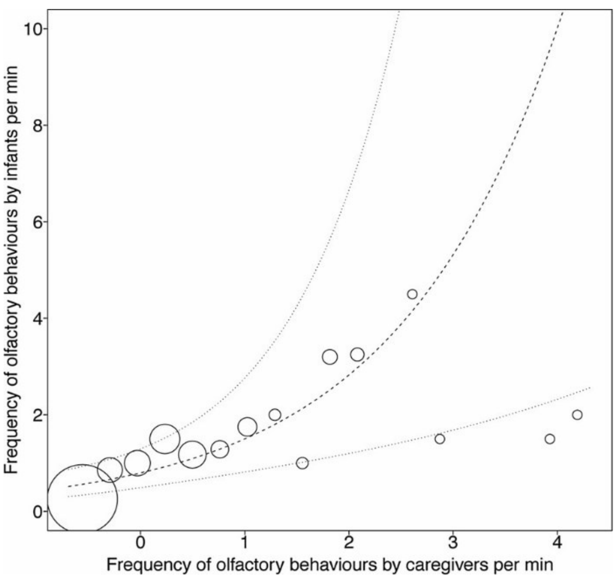

Fig. 3. Infants' olfactory behaviour frequencies as a function of caregivers' frequency. The area of the bubbles corresponds to the respective number of phases. The dashed line shows the fitted model and the dotted lines the 95 % confidence interval.

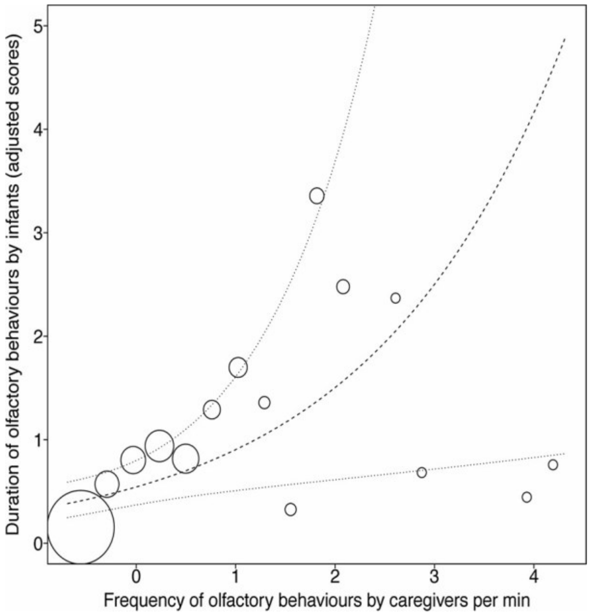

Fig. 4. Infants' olfactory behaviours durations as a function of caregivers' frequency. The area of the bubbles corresponds to the respective number of phases. The dashed line shows the fitted model and the dotted lines the 95 % confidence interval.

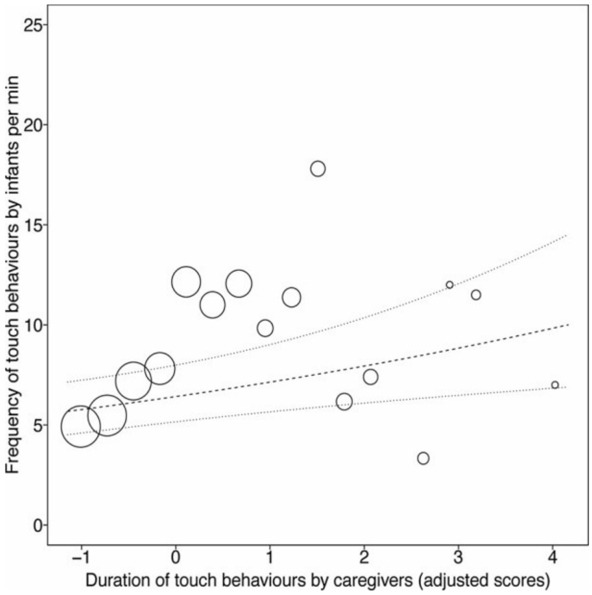

Fig. 5. Infants' touching frequencies as a function of caregivers' touching durations. The area of the bubbles corresponds to the respective number of phases. The dashed line shows the fitted model and the dotted lines the 95 % confidence interval.

plants, but it was limited to certain aspects of olfactory and touching behaviours. Infants whose caregivers smelled the plants more often exhibited higher frequencies and durations of smelling the plants themselves. Further, the duration of caregivers' touches was related to the frequency of infants' touches. However, infants' duration of smelling and the frequency and duration of their touches were not significantly related to those same behaviours in their caregivers. In addition, infants tended to touch and smell the lavender more than the other plants. Although not initially predicted, we found that female infants touched and smelled the plants longer than male infants did, and infants accompanied by male caregivers touched the plants longer than infants accompanied by female caregivers.

4.5. Hypothesis C: the effect of caregivers' knowledge about the plants on infants' plant-related behaviours

To investigate whether differences in the occurrence of infants' touch and olfactory behaviours emerged between study conditions (HIC and LIC), we ran Mann–Whitney *U* tests on the types of touch behaviours (as frequencies) across conditions. The results showed a significant difference in infant touch behaviour frequencies between the HIC and LIC (see Table 2). Infants exhibited more frequent touch behaviours, specifically simple touch and pinching, when their caregiver had less information about the plants (the LIC condition), suggesting that their behaviours are somehow influenced by information provided to caregivers. In contrast, no significant differences emerged in the frequency of olfactory behaviours displayed by infants across conditions (HIC vs. LIC, Table 3). Our model analyses showed no significant effects of age or a condition x age interaction on infants' behaviours towards the plants. Furthermore, there was no difference in infants' ages across the HIC and LIC (see model details in the Supplementary Material). In sum, there seems to be a specific influence of the caregiver's prior knowledge about the plants on some touching behaviours, but no influence on olfactory behaviours.

Additionally, we looked at the caregivers' touch and olfactory behaviours across the LIC and HIC and did not find any significant differences. Therefore, those results are not reported here. However, we might expect differences in the caregivers' use of verbal information shared with the infant between the two conditions, as caregivers in the HIC were provided rich textual information about the plants encountered. We aim to test this hypothesis in a forthcoming follow-up study.

5. Discussion

Plants provide rich multimodal opportunities for learning about the natural world early in life. As this study is, to our knowledge, the first to investigate the spontaneous interactions between infants and caregivers engaged in social learning practices about plants in an outdoor garden setting, our hypotheses were mostly informed by previous work on infants' touch behaviours towards plants conducted in a laboratory setting (see Wertz, 2019 for a review), and by observations from our pilot study. Our aim was (1) to systematically investigate how and when sensory behaviours, and particularly those related to touch and olfaction, were employed and (2) to assess whether infants' initial approach to our selected plants was influenced by their own previous experience, their caregivers' behaviours, and/or the caregivers' knowledge of the plants.

We tested three hypotheses and found some support for two of the three. Our first hypothesis, that prior experience with plants may reduce children's initial reluctance to touch them, was not supported by our results. Our analyses for this hypothesis provided evidence that infants show some caution towards the plants they encountered: infants were more likely to approach the plants after their caregivers did, an effect that was especially pronounced for olfactory behaviours. This evidence is in line with previous laboratory findings of infants' reluctance to touch plants (Elsner & Wertz, 2019; Wertz & Wynn, 2014b; Włodarczyk et al., 2018). However, infants were not more likely to touch a particular plant before their caregiver if they had seen that type of plant in the past, suggesting that the prior experience of seeing a plant in a different context did not influence infants' behaviour in this study.

We found support for our second hypothesis that there should be a relationship between caregivers' and infants' olfactory and touch behaviours towards the plants. When caregivers smelled the plants more frequently, their children also smelled the plants more frequently and for longer bouts. Similarly, when caregivers touched the plants for longer bouts, infants touched the plants more frequently. Finally, we found some support for our third hypothesis that caregivers' knowledge about plant influences their child's behaviours. Somewhat counterintuitively, infants whose caregivers had more information about the plants touched them less frequently, while children's olfactory behaviours were apparently not influenced by their caregivers' prior knowledge about the plants.

5.1. Exploring plants with olfactory behaviours

Our findings on the systematic and spontaneous deployment of olfactory behaviours while exploring plants contribute to the current literature indicating that olfaction–and the many ways this sense can be exploited, is an important part of how humans acquire

Table 2
Descriptive data for infant touch frequency per minute and results of Mann-Whitney *U* test on frequencies of touch behaviours by condition and touch type.

Touch type	*M*	*SD*	Comparison between HIC-LIC
Simple touch			
HIC	5.26	5.68	W = 6042
LIC	6.96	7.62	$p = 0.05$*
Pinching			
HIC	0.54	1.82	W = 6042
LIC	1.50	2.78	$p < 0.001$**
Picking off			
HIC	0.80	1.72	W = 6042
LIC	1.03	1.93	$p = 0.23$

* $p = .05$, two-tailed.

** $p < .001$, two-tailed.

Table 3
Descriptive data for infant olfactory behaviours frequency per minute and results of Mann-Whitney *U* test on frequencies of olfactory behaviours by condition and type.

Olfactory behaviour type	*M*	*SD*	Comparison between HIC-LIC
Self			
HIC	0.30	0.94	W = 732
LIC	0.33	0.95	$p = 0.97$
Other			
HIC	0.4	0.99	W = 7025
LIC	0.46	0.98	$p = 0.4717$
Direct			
HIC	0.04	0.23	W = 7420.5
LIC	0.02	0.20	$p = 0.4633$

knowledge (Bushdid et al., 2014; McGann, 2017) in naturalistic settings. At the same time, our findings shed light on infants' multimodal and embodied learning experience of how plants can be approached and explored. Our observations reveal that caregivers spontaneously produce olfactory behaviours when introducing infants to plants. Mainly, caregivers smell a piece of the plant held in their hand, or the residue left on their hand after having rubbed it on the plant. In turn, infants engage with plants using very similar behaviours and integrate olfactory information with hands-on exploration by smelling a piece of the plant or its residue on their own hand. Both caregivers and infants only very rarely smell the plant directly (i.e., without touching it). One interesting difference emerged between infants and caregivers: infants frequently smelled plant parts or residue offered on their caregiver's hand, while caregivers rarely smelled plants in their infants' hands. We believe these kinds of exchanges reflect the spontaneous, reciprocal social learning interactions that infants might typically experience in outdoor settings, or with domestic plants at home. Such interactions are likely of paramount importance for infants to learn about the specific plants they will encounter in their local environment and gain a broader understanding of the natural world.

Additionally, olfactory cues may be particularly important for discriminating between similar looking plants, as one of the biggest challenges in learning about plants is correctly distinguishing between toxic and edible plants (Wertz, 2019; Wertz & Wynn, 2014a) a task that is made particularly difficult by the fact that many edible plants can look very similar to toxic plants (see e.g., Oña et al., 2019). The spontaneous production of olfactory behaviours when infants and caregivers interact with plants, along with the tight link between olfaction and memory (e.g., Herz, 2012; Sullivan et al., 2014), may facilitate the retention of plant information that is acquired via the exploration of scents.

5.2. Exploring plants with touch behaviours

Infants and their caregivers exhibited several touch behaviours when exploring our selected plants together. They touched the plants most frequently by contacting them with unspecific gestures (i.e., with a *simple touch*), and less frequently by *pinching* or *picking off* a part of a plant. In contrast to olfactory behaviours (where infants and caregivers showed some difference in how they explored the plants' scents), the types of touch behaviours displayed by participants was similar.

The current results also provide some evidence that infants exhibit caution when approaching plants in a naturalistic setting: they were significantly less likely to take the initiative to approach plants before their caregiver, and caregivers most often were the first member of the dyad to smell and touch the plants. This finding is consistent with a growing set of laboratory studies that have found that 8- to 18-month-old infants take longer to touch plants and touch them less frequently than other types of objects (Elsner & Wertz, 2019; Wertz & Wynn, 2014b; Włodarczyk et al., 2018). Yet, from a methodological perspective, there is reason for caution in interpreting this finding in the current study. The studies in the lab directly compared infants' responses to plants to their responses to different kinds of artefacts and naturally-occurring entities (e.g., shells, stones). The current study looked only at interactions with plants and thus claims of plant specificity cannot be made on the basis of these observations alone.

Interestingly, infants seemed more reluctant to smell plants than to touch them before their caregiver did. One possible explanation for the differences between overall frequencies of infants' touch and olfactory behaviour might lie in the peculiarly social nature of touch as an intersubjective experience since social interactions early in life are formed through embodied intercorporeal ways of being and acting in the world (Goodwin, 2017), wherein touch is a key component. Therefore, infants might be more familiar with caregivers' touch behaviours in social learning interactions, and more prone to use those behaviours on their own. Another possible explanation may be that putting one's face close to a plant causes more exposure to plant dangers like toxins or stinging hairs (see e.g., Włodarczyk et al., 2018). This interpretation is also consistent with our observation that infants (and their caregivers) showed a marked preference for indirect ways of smelling the plants (e.g., sniffing plant parts or residue in their hand).

It is also possible that the methodological structure of this study may have prompted infants to wait for their caregiver to interact with the plants. Because caregivers were asked to focus on introducing the selected plants to their child at the beginning of each phase, they might have produced "interactional formats" (Bruner, 1985), that is, habitual formats of interactions involving actions and verbal communication by caregivers often in coordination with the infant's behaviour (Fantasia et al., 2014; Garvey, 1974), which over time or repetitions become familiar for the infant. Therefore, a similar format might have been repeated each time our participants encountered a new plant (for instance, caregivers beginning with a verbal introduction of the plant followed by a touch), in turn prompting infants to imitate or reproduce those behaviours in a similar way and expect the caregivers to always act first in the interaction. However, a look at whether infants or their caregivers touched the plants first across the five phases indicated that, in most cases, there was a switch from the caregiver touching first to the child touching first (74 % of cases) or from the child touching first to the caregiver touching first (85 % of cases) as the phases progressed (see First Touch Behaviours in the Supplementary Material for details). Therefore, although the interactional structure of the session may be responsible for some of the behaviour we observed, we do not believe it can account for it entirely.

There were a sizeable minority of cases in which infants touched our study plants before their caregivers did, and this behaviour was not related to having previously encountered that specific type of plant in a different context. The procedure we adopted in this study was designed specifically to encourage spontaneous, and thus more relaxed, interactions between not only adults and children, but also with the plants and the general surrounding environment. The simple fact that caregivers were encouraged to present plants (albeit minimally), and that children had the opportunity to ask questions or make observations with the support of a trusted adult, may favour the perception of plants as generally less threatening than in the laboratory context. Young children also usually have greater familiarity with gardens and public parks compared to a research laboratory; in this case, environmental familiarity might mitigate the effect of avoidance or social reference strategies (Walden & Baxter, 1989; Young & Lewis, 1979), making it less necessary for infants to seek information from their caregivers or rely on their presence.

Our results also showed a multifaceted connection between infants' previous experience with the selected plants (as reported by the caregivers) and their touch and olfactory behaviours in the garden. On the one hand, infants' first touch to the plants appeared to be independent of whether they had seen it before. It is possible that the question we used for this analysis, "*Has your child seen this plant before?*", may not have captured the relevant information about infants' prior experiences. However, we also found no relationship between infants' behavioural engagement with plants in this study and their previous general experiences with plants in different contexts as measured by the Plant Experience Questionnaire. On the other hand, our analyses showed that other aspects of experience do seem to influence infants' behaviour. Specifically, we found a significant effect of the type of plant on infants' duration of touch indicating that lavender–the plant most-frequently experienced prior to the study–was touched more often compared to all other plants. In contrast, oak was approached less frequently by infants in the study but was also already known by the majority of infants in our sample.

Combined, these findings suggest that previous experience with some specific plants, (e.g. those with strong olfactory properties, such as lavender) might influence infants' initial approach of, and possibly memory for, those plants; while previous experience with plants lacking these strong olfactory cues (such as oak), may require more exposure to influence infants' behaviour. However, we could not exclude that routine behaviours that caregivers adopt towards certain plants, might broadly influence how infants engage with them. For instance, caregivers may produce more olfactory behaviours for plants that are traditionally used for their scent, such as lavender. Similarly, infants might have also had more exposure to plants commonly found in home balconies or gardens (such as oregano or lavender). Further research is needed to explore these possibilities and gain a better understanding of this phenomena.

In sum, we observed some evidence in the garden of the reluctance to approach plants previously observed in a laboratory setting. At the same time, our findings suggest complex influences of previous experience on infants' behaviour towards plants while the interactional nature of our semi-structured observations that remain to be explored.

5.3. Relationships between caregiver and infant behaviours towards plants

The current findings shed light on an interesting relationship between a caregiver's knowledge and behaviours towards plants and the plant-directed behaviours of the infants. Specifically, when caregivers smelled the plants more frequently, their infants engaged in olfactory behaviours more frequently and for longer durations. Similarly, infants touched the plants more frequently when their caregivers also engaged in touch behaviours for longer. These findings indicate a link between caregiver and child behaviours towards plants. These coordinated behaviours may provide a multimodal foundation for knowledge transfer, and although we cannot make causal inferences about the direction of the relationship we observed, our findings are consistent with the large literature on gestural and imitative learning (Bates & Dick, 2002; Tomasello & Camaioni, 1997). Our findings are also in line with well-established literature on the essential role that caregivers play in infants' learning and exploratory behaviours (Bruner, 1959; Lombrozo, 2016; Murphy & Messer, 2000; Vygotsky, 1978), and with recent laboratory-based studies showing evidence that infants use social information seeking and social learning strategies to glean cues from their caregivers about plants (Elsner & Wertz, 2019; Wertz & Wynn, 2014a, 2019; Włodarczyk et al., 2020).

Whilst we found that caregivers' behaviours towards plants was positively related to their infants', we found a negative effect of caregivers' knowledge about plants on infants' production of some (but not all) touch behaviours. Recall that half of the caregivers in this study were provided with more detailed information about the plants they would encounter prior to the study, such as the plant's name, growing environment, whether it was edible, and its common uses (High Information Condition; HIC) while the other half of caregivers were only provided with the plants' names (Low Information Condition; LIC). We found that infants in the HIC showed lower frequencies of simple touch and pinching compared to infants in the LIC. A possible, yet counterintuitive, explanation for these results may lie in another important communicative tool that caregivers use to provide information about the selected plants in this study. Specifically, caregivers in the HIC might have provided more information about the plants through verbal communication, while caregivers in the LIC might have employed mostly direct olfactory and touch behaviours in the absence of specific information to convey. We are currently working on verbal analyses of caregiver-infant interactions towards plants in outdoor settings to examine this possibility.

We did not have a priori hypotheses about how the sex of the infant or caregiver might influence their plant-related interactions. We nevertheless included participants' sex as control variable in our models because it is an important dimension that has significant effects in other contexts such as the attachment relationship (van Polanen, Colonnesi, Fukkink, & Tavecchio, 2017), social anxiety (Bögels, Stevens, & Majdandzic, 2011), and the overall quality of play interactions (Lamb, 1977). In the whole, we did not find much evidence that infants' olfactory or touch behaviours were influenced by their own sex or the sex of the caregiver accompanying them. The few significant gender effects we observed were that female infants touched and smelled the plants longer than male infants (but not more frequently), and infants accompanied by male caregivers touched the plants for longer than infants accompanied by female caregivers. These results are difficult to interpret, but seem consistent with previous findings showing that the sex of the child (and of caregiver) can impact infant-caregiver learning interactions (e.g. with mothers displaying more socially-oriented behaviours and fathers adopting more teaching-oriented behaviours; Landerholm & Scriven, 1981).

5.4. Implications

The results of this study have both methodological and theoretical implications. Although previous studies had explored olfactory behaviours in infancy in the past (Durand et al., 2013; Schaal, 2017) the present study is, to our knowledge, the first to investigate the combination of olfactory and touch behaviours as information sharing interactions between adults and infants in an outdoor garden setting. The demonstration of sensory capacity in a laboratory setting is far from the demonstration of its function in the normal course of behaviour in real-life circumstances. Our study underscores the potential that observations of more naturalistic interactions have to elucidate facets of behaviour that are of critical importance but may be overlooked in the confines of a laboratory. Indeed, there is a growing consensus within research in developmental psychology about the importance of studying human behaviour and experience as they spontaneously emerge in ecological contexts (e.g., Costall, Bremner, & Slater, 2004; Wicker, 1979). Integrating different research methods, such as laboratory studies and observation of semi-structured interactions as we have done, broadens the scope of the findings and enhances the possibilities for making connections to practical applications.

Previous studies indicated that caregivers provide a rich array of opportunities for young children to acquire information regarding naturalistic entities (Crowley et al., 2001; Rigney & Callanan, 2011), for example, in book-reading activities with their young children (Gelman, Coley, Rosengren, Hartman, & Pappas, 1998). The research method we adopted allowed us to study the multimodal and dynamic nature of interactions between caregiver and infant in a context highly suitable for eliciting spontaneous information sharing between caregivers and infants (Blake, Vitale, Osborne, & Olshansky, 2005; Rogoff, 1990, 2003). Thus, our work adds to growing body of evidence supporting more ecological methods as systematic and scientifically sound methods addressing unique yet complementary questions with experimental studies (see e.g., Dahl, 2017; Dahl & Turiel, 2019).

6. Conclusions

The current study highlights the important role that sensory behaviours, specifically touch and olfactory behaviours, play in interactions between caregivers and young children as they explore the natural world together. Overall, our findings complement recent laboratory studies showing that interactions with more knowledgeable and trusted others enable infants to (1) safely learn about plants by initially avoiding them and observing others (Elsner & Wertz, 2019; Wertz & Wynn, 2014a, 2019; Włodarczyk et al., 2020) and (2) practice their own emerging cultural skills in a supervised environment (Rogoff, 2003). By taking our study into the garden and observing semi-structured interactions, we were able to capture the kinds of rich, multimodal behaviours that can provide an important basis for social learning early in life, but may never occur in more restricted laboratory settings. In this way, caregiver-child explorations of plants provide a novel and ideal context for broadening the scope of current studies of social learning (e.g., Koenig & Sabbagh, 2013; Legare & Harris, 2016). This approach can address fundamentally important issues about multisensory social learning contexts in more naturalistic real-world environments.

CRediT authorship contribution statement

Valentina Fantasia: Conceptualization, methodology, data curation, writing - original draft, review and editing. **Linda Oña**: Formal analysis, writing - original draft, reviewing & editing. **Chelsea Wright**: Data curation, resources. **Annie E. Wertz**: conceptualization, writing - reviewing & editing, supervision, funding acquisition.

Declaration of Competing Interest

None.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at https://hdl.handle.net/21.11116/0000-0008-C4E6-7.

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