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Abstract

A growing body of research investigating plant-related cognition and behaviors demonstrates that plants have shaped human minds and societies and that pursuing empirical research in this area can yield new insights into many aspects of human cognition and development, including food learning, danger avoidance, and cultural transmission. This research would greatly benefit from a validated measure that assesses experience with plants early in life. Here we present the validation of a new measure to assess such experience: The Plant Experience Questionnaire (PEQ), filling a major gap in the literature on plant-related cognition in infancy and early childhood. The PEQ was tested on a sample of 576 caregivers who completed the questionnaire about their child (age = 5-81 months). Factorial analysis revealed a four-dimensional structure of the questionnaire: (1) experience with indoor plants, (2) experience with outdoor plants, (3) eating from plants, and (4) parental prohibition from touching plants. The PEQ displayed good psychometric properties as shown with satisfactory internal consistency and convergent and discriminant validity and is suitable for a broad age range from infancy to early childhood. Therefore, the PEQ is an efficient and valuable tool for assessing plant experience in early life via parental report.

Keywords: Questionnaire validation; Plants; Infancy; Plant Experience Questionnaire

Introduction

Plants have played a fundamental role in human life and human evolution (see e.g., Hardy & Kobiak-Martens, 2016; Henry, Brooks & Piperno, 2014; Ungar & Sponheimer, 2011; Wertz, 2019). Studies of cultures that rely on subsistence practices such as hunting, foraging, and small scale horticulture show that plants are an essential component of human diets across the lifespan (Cordain et al., 2000; Crittenden, 2016; Crittenden & Schnorr, 2017; Kaplan, Hill, Lancaster, & Hurtado, 2000) and are used for a variety of purposes including manufacturing tools, as sources of toxic chemicals that facilitate fishing and hunting, and as part of rituals and medicines (e.g., Begossi, Hanazaki, & Tamashiro, 2002; Hardy, 2008). Human interactions with plants are also not limited to adulthood, as young children often participate in plant food foraging and preparation (Hewlett, 2017). Investigating plant-related cognition and behaviors can therefore yield new insights into many aspects of human cognition and development, including threat mitigation, food learning, social learning, cultural transmission and folk biological reasoning, among others.

In fact, a growing body of research reveals that plants have left their mark on human minds and societies. Interactions with plants and plant products are not cost-free as plants manufacture toxic chemicals that can be harmful to humans (Mithöfer & Boland, 2012; Palo & Robbins, 1991) yet humans must determine which plants in their local environment are edible or otherwise useful. These circumstances select for the evolution of social learning mechanisms (Oña, Oña, & Wertz, 2019). Accordingly, Wertz and colleagues have argued that infants rely on a combination of behavioral avoidance and social learning rules that allow them to safely negotiate encounters with plants. These cognitive systems are called Plant Learning and Avoiding Natural Toxins, or PLANT (Wertz, 2019). Recent studies have shown that infants avoid touching plants and plant food products (e.g., fruits and vegetables) compared to other natural or human-made objects (e.g., rocks and spoons; Elsner & Wertz,

2019; Wertz & Wynn, 2014a; Włodarczyk, Elsner, Schmitterer, & Wertz, 2018). Further, infants seek out social information from adults prior to touching plants (Elsner & Wertz, 2019) and learn from social cues. Directly witnessing an adult touch a plant reduces infants' plant avoidance (Włodarczyk, Rioux, & Wertz, 2020), and infants selectively learn that plants are edible after watching an adult eat from them (Wertz & Wynn, 2014b).

Food neophobia, the reluctance to eat new foods present in early childhood (Dovey, Staples, Gibson & Halford, 2008; Lafraire, Rioux, Giboreau & Picard, 2016; Reilly, 2019) is particularly strong for plant food products such as fruits and vegetables (Cole et al., 2017) and has been proposed as a mechanism for preventing accidental ingestion of plant toxins (Cashdan, 1994; 1998; Rioux, 2019). Similar to plant avoidance, food neophobia decreases with plant-related social learning (Rioux, 2019). For instance, learning botanical knowledge through gardening programs (e.g., Davis, Martinez, Spruijt-Metz & Gatto, 2016) is a promising approach to overcome food neophobia and enhance children' willingness to consume fruits and vegetables (see Appleton et al., 2016 and Dazeley, Houston-Price & Hill, 2012 for reviews).

Valuable ethnobotanical knowledge (e.g., the spatial location of plant resources, aspects of plant management, processing, or use) is also encoded in traditional narratives and practices (e.g., food taboos) transmitted culturally from one generation to the next (Placek, Madhivanan & Hagen, 2017; Scalise Sugiyama, Mendoza & Quiroz, 2020). This knowledge continues to accumulate with age and is selectively remembered, especially by women who have specialized in plant food gathering across evolutionary time (Cámara-Lereta,Fortuna & Bascompte, 2019; Henriques Da Silva, Ferreira Junior, Muniz de Medeiros & Albuquerque, 2019; Krasnow, Truxaw, Gaulin, New, Ozono, Uono, Ueno & Minemoto, 2011; New, Krasnow, Truxaw & Gaulin, 2007; Schniter, Macfarlan, Garcia, Ruiz-Campos, Beltran, Bowen & Lerbak, 2020; Silverman & Eals, 1992).

Plants also hold a special place in humans' folk biological reasoning, presenting unique characteristics that make them halfway between inanimate objects and living entities (Brule, Labrell, Megalakaki, Fouquet & Caillie, 2014). From an early age children recognize both animals and plants as distinct from non-living entities in term of growth (Inagaki & Hatano, 1996; Hickling & Gelman, 1995), death (Nguyen & Gelman, 2002), communication abilities (Ojalehto, Medin, & García, 2017) or origin of object properties (Gelman & Kremer, 1991), while they understand that plants do not intentionally move as humans and animals do (Brule et al., 2014). Reasoning about plants is also highly dependent to one's own experience with them (Betz & Coley, 2020; Medin, Lynch, Coley & Atran, 1997; Ojalehto et al., 2017). Environmental richness and experiences contribute to the salience and availability of ecological knowledge when reasoning about plants and enhance conceptual flexibility in biological thinking (e.g., Betz & Coley, 2020).

Studies investigating infants' and young children's responses to, and reasoning about plants, would benefit greatly from validated psychometric tools that provide a clear assessment of experience with plants early in life. While infants' and children's behavior in the context of a study is an important and informative indicator, it does not provide a picture of their everyday experience with plants that could plausibly influence their responses (e.g., Betz & Coley, 2020). There is a validated questionnaire for older children (10- to 15-year-olds), that assesses attitudes towards plants (Fancovicova & Prokop, 2010). This questionnaire asks general questions about the perceived importance of plants in daily life (e.g., "Life is impossible without plants" or "I am interested in reading books about plants"). Yet, to the best of our knowledge, there is no validated questionnaire measure that assesses plant experience in infancy and early childhood.

To bridge this gap, Wertz and Wynn developed a hetero-assessment questionnaire that asked parents about their infant's prior experience with plants (Wertz & Wynn, 2014a;

2014b). This questionnaire was originally used with infants from 8 to 18 months of age and asked (i) how often infants were exposed to plants, (ii) how often their parents actively showed them different plants, (iii) how often infants observed their parents caring for plants, (iv) whether infants had ever eaten fruits or vegetables from plants, (v) how often infants tried to touch indoor and outdoor plants, (vi) how often parents stopped their infant from touching plants, and (vii)-(viii) two open ended question asking which plants parents allowed their infant to touch and whether there was any other information about their infants' experiences with plants that they would like to note. This initial, but not-yet-validated, questionnaire was subsequently translated into German by a bilingual native German speaker and adapted for use in a broader range of studies that included infants and young children. This updated version of the questionnaire (a) assessed infants' and young children's experiences with indoor and outdoor plants separately for questions (i)-(vi) and (b) asked about their experience "in the last month" and "in the last summer months" separately for each question to account for infants and children participating in studies during seasons in which outdoor vegetation is quite different than during the summer (e.g., during the winter time in some climates when plants lose their leaves). This updated version of the questionnaire has now been in use for several years but has not yet been validated (e.g., Elsner & Wertz, 2019; Włodarczyk et al., 2018; see Supplementary Material section 1).

In the present study we validated this new measure of infants' and young children's experience with plants--the Plant Experience Questionnaire (PEQ)--for the first time. We took special care to measure the properties that would be expected of any sound psychometric instrument, namely internal consistency, factor structure, construct validity and convergent and discriminant validity (see, for example, DeLauzon-Guillain et al., 2012; Hinkin, 1995; Ritchey, Frank, Hursti, &Tuorila, 2003; Vallerand, 1989). Note that the open-ended questions were not included in this validation.

Materials and Methods

Participants

Data were collected between Spring 2015 and Fall 2019 as part of ten larger independent studies conducted in our lab with infants and young children (e.g., Elsner & Wertz, 2019; Włodarczyk et al., 2018). Infants that were born before the 36th week of pregnancy were excluded from these studies; some studies also excluded infants who did not hear German spoken at least 50% of the time. All studies were approved by a local Ethics Committee and parents gave consent for their infant or child's participation. Parents were typically compensated with 10 Euros per hour of participation and infants and children were given a participation certificate. In total, 576 parents filled out the German Plant Experience Questionnaire (PEQ) for their infant or child (263 females, mean age = 27 months, age range = 5-81 months).

Questionnaire

The questionnaire items are listed in Table 1 (translated from German, see also SM section 1 for the original German version). Parents rated each question on a five-point Likert scale (1 = never, to 5 = nearly every day), separately for indoor and outdoor plants as well as two time points (last summer months vs. last month), resulting in 24 question items in total. Note that the time point distinction was not created in order to distinguish infants and young children along that dimension. Instead, this was done to make sure that at least one of these two time points correspond to a season in which the plants in the local area are in a phenological state that includes leaves. Our studies were conducted in a climate zone with demarcated seasonal events (e.g., cold winter seaon) in which many plants lose their leaves in the scenescence stage and opportunities for interaction with outdoor vegetation are limited. At the same time, because some infants from our samples could be as young as 6 months old, we could not only ask about experience during last summer months, as some infants may not

have experienced a period of summer months when plants are not in scenescence when tested. None of the questions were reverse-scored items, as this has been shown to diminish scale reliability and possibly introduce systematic errors (Gehlbach & Brinkworth, 2011). A preliminary analysis of the responses revealed that all 24 questions were understood by the participants' caregivers as the proportion of missing answers were extremely low for each question (all < 3%).

Table 1: List of the 24 items of the Plant Experience Questionnaire (translated from the original German items):

Questions about indoor plants	
1_indoor_last	How often did your infant/child interact with indoor plants in the last month?
1_indoor_summer	How often did your infant/child interact with indoor plants in the last summer months?
2_indoor_last	How often did you point out or name different indoor plants for your infant/child in the last month?
2_indoor_summer	How often did you point out or name different indoor plants for your infant/child in the last summer months?
3_indoor_last	How often did your infant/child see you caring for indoor plants in the last month?
3_indoor_summer	How often did your infant/child see you caring for indoor plants in the last summer months?
4_indoor_last	How often did your infant/child eat from indoor plants in the last month?
4_indoor_summer	How often did your infant/child eat from indoor plants in the last summer months?
5_indoor_last	How often did your infant/child try to touch indoor plants in the last month?
5_indoor_summer	How often did your infant/child try to touch indoor plants in the last summer months?
6_indoor_last	How often did you stop your infant/child from touching indoor plants in the last month?
6_indoor_summer	How often did you stop your infant/child from touching indoor plants in the last summer months?
Questions about outdoor plants	
1_outdoor_last	How often did your infant/child interact with outdoor plants in the last month?
1_outdoor_summer	How often did your infant/child interact with outdoor plants in the last summer months?
2_outdoor_last	How often did you point out or name different outdoor plants for your infant/child in the last month?
2_outdoor_summer	How often did you point out or name different outdoor plants for your infant/child in the last summer months?
3_outdoor_last	How often did your infant/child see you caring for outdoor plants in the last month?
3_outdoor_summer	How often did your infant/child see you caring for outdoor plants in the last summer months?
4_outdoor_last	How often did your infant/child eat from outdoor plants in the last month?
4_outdoor_summer	How often did your infant/child eat from outdoor plants in the last summer months?
5_outdoor_last	How often did your infant/child try to touch outdoor plants in the last month?
5_outdoor_summer	How often did your infant/child try to touch outdoor plants in the last summer months?
6_outdoor_last	How often did you stop your infant/child from touching outdoor plants in the last month?
6_outdoor_summer	How often did you stop your infant/child from touching outdoor plants in the last summer months?

Note. See Supplementary Material section 2 for the English version of the questionnaire.

Statistical analysis

To test the validity of the PEQ, we assessed its (i) construct validity, (ii) reliability and (iii) convergent and discriminant validity. To assess its construct validity, we used a two- step procedure (Hair, Black, Babin, Anderson, 2010). First, on a first sub-sample (N_1 = 240, randomly chosen from the total sample N = 576 by shuffling the data and then taking the first 240 subjects, 111 females, mean age = 26 months, age range = 5-81 months) we performed an iterative Exploratory Factor Analysis (EFA) using maximum-likelihood factor analysis with an oblique rotation, to allow factors to correlate. We chose this first sub-sample size to have a ratio of 10 subjects per item question (5 subjects per question is a minimum for EFA, Pituch & Steven, 2009). The goal of this first step was to evaluate the factor structure underlying the set of items and inform the selection of items for inclusion in the final questionnaire. The optimum number of factors was determined using a combination of the Kaiser criterion (factors with eigenvalues greater than one should be retained for interpretation; Kaiser, 1960) and Cattell's scree plot criterion (a scree plot for eigenvalues is used to determine the point at which the last significant drop takes place; Cattell, 1966). Factor loading superior of 0.50 was used as the cut-off for determining which items belonged to a particular factor. Then in a second step, on a second sub-sample (N_2 = 336, 152 females, mean age = 28 months, age range = 5-81 months) we performed a Confirmatory Factor Analysis (CFA), using weighted least squares with mean and variance adjustment (WLSMV), to verify that the model found in the first step fitted a new set of data. This second sub-sample size allowed us to have a ratio of more than 10 subjects per estimated parameters, necessary for CFA (Kline, 2011). To determine how well the model fitted the new set of data, we focused on six fit indices: the $\frac{Chi^2}{df}$, the Goodness-of-Fit Index (GFI), the Comparative Fit Index (CFI), the Tucker-Levis index (TLI), the Standardized Root Mean Square Residual (SRMR) and the Root Mean Square Error of Approximation (RMSEA) (Kline, 2011; Jackson, Gillaspy, & Purc-

Stephenson, 2009; Pituch & Steven, 2009; Wheaton, Muthén, Alwin, and Summers, 1977). The objective was to obtain a RMSEA below .05, an SRMR below 0.8, an $\frac{Chi^2}{df}$ inferior to 3 and fit indexes higher than .90 (Pituch & Steven, 2009, Table 16:3 for commonly used model fit indices and recommended cut-off).

To assess the scale's reliability, we calculated its overall internal consistency (Cronbach's alpha coefficient). In addition, the internal consistency of each subscale was also measured. The objective was to obtain values above 0.7 (DeLauzon-Guillain et al., 2012; Hair et al., 2010). The convergent validity was assessed using the composite reliability (CR) and average variance extracted (AVE) for each factor as well as with factors loadings of the final CFA model. The objective was to obtain factors loadings and AVE above 0.5 for each factor and an AVE above 0.7 (Hair et al., 2010). Finally, the discriminant validity of the questionnaire was assessed with standardized correlation values between the different questionnaire factors or subscales. The objective was to obtain values below 0.85 (Kline, 2011).

After the scale validation procedure, we also examined differences in children's PEQ scores, according to age and sex. To that end, the mean PEQ scores for each subscale and for each sex were compared (Mann Whitney's test), and correlations between PEQ scores and children's age were assessed (Spearman correlation coefficient). A non-parametric approach was chosen because of the non-normal distribution of the variables.

We set the alpha level at 0.05 for all statistical analyses. R 3.1.2 software (Rstudio, 2016) was used to conduct the statistical analyses. The packages *Psych (*functions *Factanal* and *Eigen)* were used to perform the EFA. The package *Lavaan* (functions *Cfa*) was used to perform the CFA.

Results

Preliminary analysis

Prior to entering items into the factor analysis, we screened them for appropriate item endorsement rates and variability in the total sample (N = 576). The majority of items had moderate means (between 2 and 4 on the 5-point Likert-like scale), suggesting that ceiling and floor effects were not an issue (Clark & Watson, 1995). Similarly, standard deviations suggested sufficient variability (i.e., SD > 1 according to Whitley & Kite, 2013). Only one item failed to meet this criterion, but given this small proportion and the small departures from the ideal, we decided to retain this item for the subsequent analysis.

Iterative Exploratory Factor Analysis (EFA) and Item Refining.

Prior to entering items into the Exploratory Factor Analysis (EFA), we assured whether our data were appropriate for this analysis, using the Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy (Kaiser, 1974). The KMO measure of sampling adequacy was 0.7, indicating it was adequate to run a factor analysis. We ran an EFA on the PEQ scores for all 240 respondents ($\boldsymbol{N_1}$) on the 24-score questionnaire (see Table 1), using maximum-likelihood factor analysis with an oblique rotation. Primary analysis indicated that the optimum number of factors was four. The first factor had an eigenvalue of 7.89 and explained 20.3% of the variance. The second factor had an eigenvalue of 3.61 and explained 16.8 % of the variance. The third factor had an eigenvalue of 2.56 and explained 11.2 % of the variance. The fourth factor had an eigenvalue of 1.67 and explained 10.6 % of the variance. The other factors had eigenvalues close to or below 1. The four-factor model thus explained 58.9 % of the variance.

Inspection of factor loadings indicated that items 1_indoor_last, 1_ indoor _summer, 2_ indoor _last, 2_ indoor _summer, 3_ indoor _last, 3_ indoor _summer, 5_ indoor _last and 5_ indoor _summer (see Table 1) loaded on the first dimension (therefore named *experience*

with indoor plants dimension). Items 1_outdoor_last, 1_ outdoor _summer, 2_ outdoor _last, 2_ outdoor _summer, 5_ outdoor _last and 5_ outdoor _summer (see Table 1) loaded on the second dimension (therefore named *experience with outdoor plants* dimension). Items 4_indoor_last, 4_indoor_summer, 4_ outdoor _last, 4_ outdoor _summer (see Table 1) loaded on the third dimension (therefore named *eat from plants* dimension). Finally, Items 6_ indoor _last, 6_ indoor _summer, 6_ outdoor _last, 6_outdoor_summer (see Table 1) loaded on the fourth dimension (therefore named *prohibit from touching plants* dimension). Only 2 items (3_ outdoor _last and 3_ outdoor _summer) seemed to be problematic as their factor loadings were lower than 0.40 on any dimension. We therefore decided to remove these 2 problematic items from the questionnaire. Moreover, inspection of the correlation matrix revealed that some items were strongly correlated. For a given question, responses for the two time points (i.e., last summer months and last month) were always strongly correlated (e.g., 4_indoor_last, 4_indoor_summer, $r = 0.80$, all *rs* $0.64 < r < 0.82$). Additionally, across participants, the average difference between the two time points for a given question (e.g., 4_indoor_last and 4_ indoor _summer) was always less than 0.4 (possible range = [-5; 5]; see also SM section 4 for the distribution of differences between the two time points for each question). Instead of removing one time point, we summed the scores from these two time points for each question prior entering them to a second exploratory factor analysis. We did this because if we kept only the *summer months* time point, young infants may not have experienced a summer months period where plants are not in scenescence when tested. Indeed, if we single out our youngest infants (6-month-olds), responses for the two time points were less strongly correlated (all *rs* $0.26 < r < 0.79$) than it was for the entire sample. If we kept only the *last month* time point, we may not capture infants' experience during a season when plants' phenological state includes leaves when tested (i.e., participants could be tested in European winter). Indeed, if we single out infants and young children tested in

winter and fall, responses for the two time points were also less strongly correlated (all *rs* 0.31 < *r* < 0.79) than for the entire sample . It is important to note that despite these fluctuations, it was possible to sum these scores because the last month/last summer months distinction was not created to distinguish infants and young children along that dimension, and responses for the two time points always loaded on the same dimension. We then re-analyzed the data using the new and shortened version of the scale: a scale without items 3_ outdoor _last and 3_ outdoor _summer and consisting of 11 scores, instead of 24 (see Table 2).

Inspection of the second scree plot indicated that it was again appropriate to extract four factors. The first factor had an eigenvalue of 3.83 and explained 20.8 % of the variance. The second factor had an eigenvalue of 2.06 and explained 20.5 % of the variance. The third factor had an eigenvalue of 1.31 and explained 12 % of the variance. The fourth factor had an eigenvalue of 1.21 and explained 11.5 % of the variance. The other factors had eigenvalues below 1. The four-factor model thus explained 64.8 % of the variance. Inspection of factor loadings indicated that all the items loaded rather strongly on the expected latent dimensions found in the previous step (see Table 2).

Table 2: Descriptive statistics and factor loadings from the Exploratory Factor Analysis

Item	Mean	SD	Factor 1	Factor 2	Factor 3	Factor 4
1_indoor	5.71	2.40	0.96			
2_indoor	4.64	2.25	0.72			
3_indoor	5.48	2.35	0.60			
4_indoor	3.75	2.31			0.89	
5_indoor	5.77	2.30	0.65			
6_indoor	4.06	2.37				0.96
1_outdoor	6.74	2.41		0.87		
2_outdoor	5.83	2.31		0.68		
4_outdoor	4.14	2.25			0.68	
5_outdoor	6.79	2.36		0.93		
6_outdoor	3.73	1.84				0.55

Note. The criterion for loading was > 0.50. Each item is the sum of the two time points (e.g., 1_indoor = 1_indoor_last + 1_indoor_summer, see Supplementary Material section 3, for a guide to the scoring procedure).

As shown in Table 3, internal consistencies for each of the four dimensions were within acceptable levels. The overall internal consistency of the scale was 0.80, showing good overall scale reliability. These findings encouraged us to run a Confirmatory Factor Analysis (CFA) with the updated questionnaire and to assess its validity.

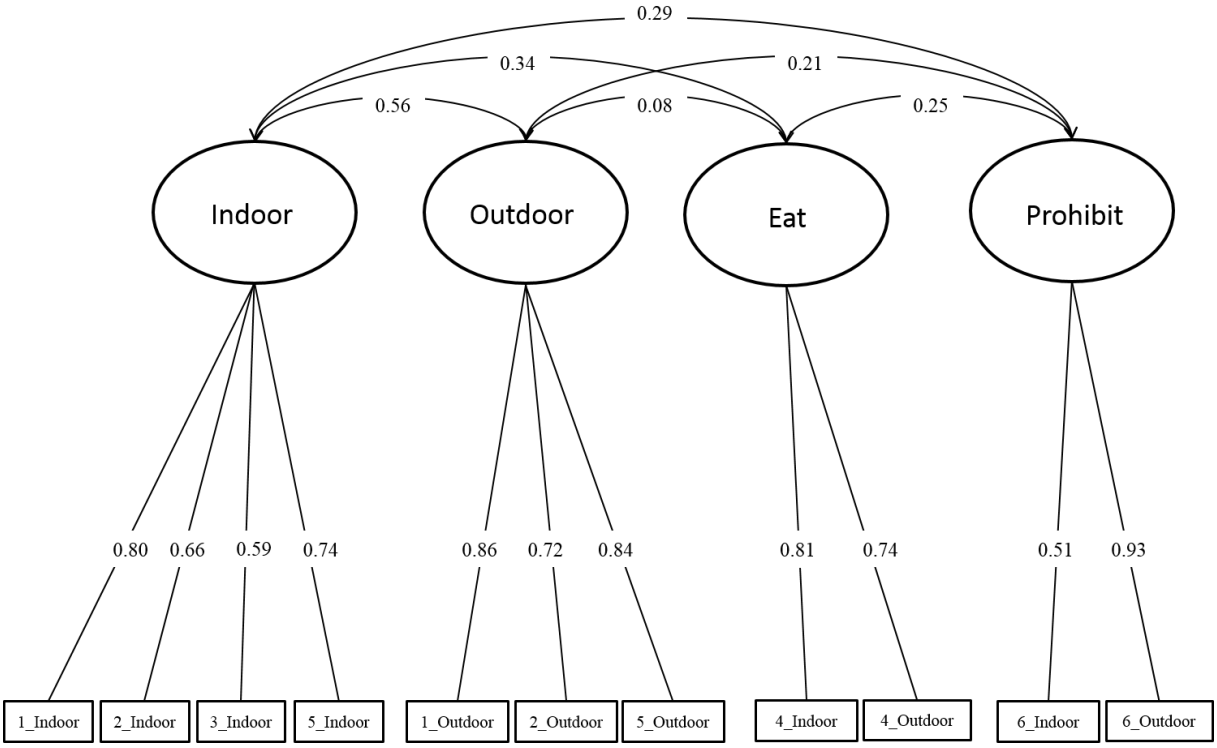
Table 3. Descriptive statistics and internal consistency estimates for the 4-dimension model.

Dimension	Mean	SD	Range	Internal consistency
Experience with indoor plants	21.80	7.40	8-40	0.83
Experience with outdoor plants	19.42	6.21	6-30	0.87
Eat from plants	7.87	4.03	4-20	0.69
Prohibit from touching plants	7.80	3.65	4-20	0.65

Confirmatory Factor Analysis (CFA)

Prior to entering items into the Confirmatory Factor Analysis (CFA), we assessed whether our data were appropriate for this analysis, using Mardia's test of multivariate skewness and kurtosis (Pituch & Steven, 2009). This test yielded a significant p-value ($p < 0.001$) indicating the non-normality of the data. However, individual Kurtosis and Skew values (for each of the 11 variables) were all between -1 and 1 suggesting no serious departures of the normality assumption (Pituch & Steven, 2009). We then ran a CFA to test the four-factor model's fit to a new data sample ($N_2 = 336$), using weighted least squares with mean and variance adjustment (WLSMV).This estimator was chosen to account for the slightly non-normal data (Rosseel, 2012). Model 1 specifications included uncorrelated errors and the variance of one item on each factor fixed to 1. Additionally, all constructs were allowed to correlate with each other. Based of fit indices, model 1 showed acceptable fit: *RMSEA* = 0.074 [0.056-0.091], *SRMR* = 0.078, Chi^2 = 101.18, *Df* = 38 ($\frac{Chi^2}{df}$ = 2.66), *CFI* = 0.96, *TLI* = 0.94. Only the RMSEA value was greater than the expected value (0.5), but nevertheless within an acceptable range (0.5 < RMSEA < 0.8; Pituch & Steven, 2009). Figure 1 shows the final model (model 1) and reveals strong factors loadings on the expected dimensions (see Figure 1).

Figure 1: Path diagram yielded by the Confirmatory Factor Analysis for the final model (model 1)



Convergent and discriminant validity

As shown in Figure 1 the factor loadings were all relatively high. Composite Reliability (CR) and Average Variance Extracted (AVE) for each factor was within acceptable level ([0.79, 0.49], [0.85, 0.65], [0.75, 0.60] and [0.63, 0.48] for the dimensions *Experience with indoor plants*, *Experience with outdoor plants*, *Eat from plants* and *Prohibit from touching plants* respectively. Correlation between factors were all below 0.85 (see Figure 1). This suggests acceptable scale convergent and discriminant validity.

PEQ scores according to child's age and sex

Results from mean comparisons using Mann-Whitney tests showed that boys and girls did not differ significantly on the *Experience with indoor plants, Experience with outdoor plants* and *Eat from plants* dimensions (all p values > 0.1). Nevertheless, parents reported prohibiting girls from touching plants significantly more than boys ($W = 26268$, $p = 0.0034$).

Finally, Spearman's correlation coefficients revealed that all four dimensions were moderately to strongly correlated with age ($0.13 < r < 0.49$, all p values < 0.0025). Unsurprisingly, as children age, their experiences with plants increase.

Discussion

The aim of the present study was to validate a questionnaire assessing experience with plants in infants and young children: The Plant Experience Questionnaire (PEQ). The development and study of valid measure of experience with plants in early life is an important contribution for advances in the study of plant-related cognitive mechanisms (e.g., Brule et al., 2014; Crittenden, 2016; Henriques Da Silva et al., 2019; Nguyen & Gelman, 2002; Wertz, 2019) including food learning, danger avoidance, specialized categorization and reasoning processes, social learning, and cultural transmission. Our findings showed that the PEQ displayed good psychometric properties. Reliability, as measured through internal consistency was satisfactory, with coefficients comparable to those of widely recognized reliable scales used in child or infant studies such as the Child Food Neophobia Scale (Pliner 1994) and the Infant Behavior Questionnaire (IBQ-R; Gartstein & Rothbart, 2003), and comparable to the reliability of the Plant Attitude Questionnaire (Fancovicova & Prokop, 2010). The convergent and discriminant validity of the PEQ was also adequate, as demonstrated by relatively high factor loadings and medium correlations between the four dimensions of the questionnaire.

It is worth noting that, as children age, we would expect that their experience with plants would increase, and the PEQ scores indeed capture such an increase. Such a finding indicates predictive validity for this measure. This is consistent with findings from Fancovicova & Prokop (2010) showing that older children increase their utilization of plants between 10 and 15 years of age. Our finding that gender did not impact three out of the four dimensions of the PEQ is also consistent, as they did not find systematic gender effects on

older children' interaction with plants (Fancovicova & Prokop, 2010). The factor analysis supported a four-dimensional structure of the questionnaire, with four dimensions moderately to strongly correlating with each other: (1) experience with indoor plants, (2) experience with outdoor plants, (3) eat from plants, and (4) prohibit from touching plants. Scores on each of these four dimensions (or subscales) can be obtained by simply summing the scores of all items loading on the same dimension (see Table 2 and SM section 3). These types of scores would be particularly helpful to explore the possible influence of prior experience with plants on participants' responses during behavioral studies investigating aspects of plant-relevant cognition in infancy and early childhood. For example, studies investigating behavioral avoidance of plants in infancy (e.g., Elsner & Wertz, 2019; Wertz & Wynn, 2014a; Wertz & Wynn, 2014b; Włodarczyk et al., 2018), studies of young children's behaviors toward plant foods (e.g., fruits and vegetables; Rioux, 2019), and studies investigating folk biological reasoning (e.g., Betz & Coley, 2020).

One important caveat for researchers who may want to use this scale in the future is the issue of assessing plant experience at two time points. Due to our geographic location in northern Europe, we asked caregivers about their infant's or child's experience with plants both during the *last month* and during the *last summer months* in order to capture outdoor plant experience that included plants not in scenecense. This was necessary for us because northern Europe is a place with strongly demarcated seasonal variation in vegetation. Further, many of our studies include infants who are less than a year old. Under these conditions, having two separate time points for each question is meaningful. However, if researchers conduct their studies in a geographic location without strongly demarcated seasonal variation in vegetation, they could consider using only the *last month* time point, regardless of their participants' age. In addition, if researchers conduct their studies with children older than 1 year of age (and have therefore experienced a full seasonal cycle), they could consider using

only one time point. Specifically, researchers testing in locations with strong seasonal variations in vegetation could use only the *last summer months* time point, while researchers testing in locations without strong seasonal variations in vegetation could use only the *last month* time point. Researchers can make these decisions depending on the best fit for climatic conditions in their study location and their participant populations, but such deviations from the PEQ formulation we present here should be noted in their published work.

We acknowledge that there are limitations to this study. First, we lack an assessment of temporal reliability, which is often measured with test-retest procedures (Vallerand, 1989) as the data analyzed for this validation study were part of larger studies whose aims were not directly to validate a questionnaire regarding plant experience. Future studies should therefore assess the temporal reliability of the PEQ. Second, the participant sample of the present study consists mainly of children from a single region of Germany that may have idiosyncratic features as a population. This limits the generalization of this study to other populations and future studies could investigate the psychometric properties of the PEQ in other cultural contexts.

Nevertheless, despite these limitations, we believe that the present study provides support for the psychometric properties of the Plant Experience Questionnaire (PEQ) in terms of good internal consistency, construct validity, and convergent and discriminant validity. The PEQ represents an efficient and valuable tool for assessing plant experience in early life through parental report and adds to the literature assessing children's attitude toward plants via questionnaire measures (Fancovicova & Prokop, 2010). Importantly, one strength of the PEQ is that it is suitable for a broad range of children. This hetero-assessment questionnaire can be used with infants and young children not capable of completing questionnaire measures on their own. Developing and validating questionnaires to measure experiences with plants in early life has important implications for the study of newly-discovered aspects of

human plant-related cognition (e.g., Wertz, 2019), the investigation of folk biological reasoning (e.g., Brule et al., 2014), and cultural transmission of plant knowledge (e.g., Sclaisze et al., 2020) and broader areas that are closely entwined with plant-related cognition, such food learning, social learning, and danger avoidance in infancy and early childhood.

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Supplementary Material

1. German version of the Plant Experience Questionnaire
2. English version of the Plant Experience Questionnaire
3. Scoring procedure
4. Distribution of differences between the two time points (i.e. *last month* and *last summer months*) for each question

1. German version of the Plant Experience Questionnaire

Fragebogen zur Erfahrung mit Pflanzen

Wir möchten gern mehr über die Erfahrungen Ihres Kindes mit Pflanzen erfahren. Die folgenden Fragen beziehen sich auf die jüngsten Erfahrungen Ihres Kindes mit Pflanzen sowohl während des letzten Monats als auch während des letzten Sommers, d.h. auf den Zeitraum der letzten Sommermonate von Juni bis August.

Die erste Hälfte des Fragebogens beschäftigt sich mit den Erfahrungen Ihres Kindes mit Außenpflanzen, zum Beispiel mit Pflanzen im Garten oder draußen in einem Park oder Wald (aber keine Topfpflanzen).

Erfahrung mit Außenpflanzen

1a) Wie oft während des **letzten Monats** hat Ihr Kind in irgendeiner Weise mit Außenpflanzen **interagiert**?

1	2	3	4	5
Nie		Manchmal		Fast jeden Tag

1b) Wie oft während der **letzten Sommermonate** hat Ihr Kind in irgendeiner Weise mit Außenpflanzen **interagiert**?

1	2	3	4	5
Nie		Manchmal		Fast jeden Tag

2a) Wie oft während des **letzten Monats** haben Sie Ihrem Kind Außenpflanzen **gezeigt** oder diese für Ihr Kind **benannt**?

1	2	3	4	5
Nie		Manchmal		Fast jeden Tag

2b) Wie oft während der **letzten Sommermonate** haben Sie Ihrem Kind Außenpflanzen **gezeigt** oder diese für Ihr Kind **benannt**?

1	2	3	4	5
Nie		Manchmal		Fast jeden Tag

3a) Wie oft während des **letzten Monats** hat Ihr Kind Sie **beim Pflegen** von Außenpflanzen, zum Beispiel in einem Hof oder Garten, **beobachtet**?

1	2	3	4	5
Nie		Manchmal		Fast jeden Tag

3b) Wie oft während der **letzten Sommermonate** hat Ihr Kind Sie **beim Pflegen** von Außenpflanzen, zum Beispiel in einem Hof oder Garten, **beobachtet**?

1	2	3	4	5
Nie		Manchmal		Fast jeden Tag

4a) Wie oft während des **letzten Monats** hat Ihr Kind Früchte oder Gemüse direkt von einer Außenpflanze **gegessen** (z.B. in einem Erntegarten mit Früchten zum Selbstpflücken oder während es Ihnen im Garten geholfen hat)?

1	2	3	4	5
Nie		Manchmal		Fast jeden Tag

4b) Wie oft während der **letzten Sommermonate** hat Ihr Kind Früchte oder Gemüse direkt von einer Außenpflanze **gegessen** (z.B. in einem Erntegarten mit Früchten zum Selbstpflücken oder während es Ihnen im Garten geholfen hat)?

1	2	3	4	5
Nie		Manchmal		Fast jeden Tag

5a) Wie oft während des **letzten Monats** hat Ihr Kind **versucht**, Außenpflanzen **zu berühren**?

1	2	3	4	5
Nie		Manchmal		Fast jeden Tag

5b) Wie oft während der **letzten Sommermonate** hat Ihr Kind **versucht**, Außenpflanzen **zu berühren**?

1	2	3	4	5
Nie		Manchmal		Fast jeden Tag

6a) Wie oft während des **letzten Monats** haben Sie Ihr Kind davon **abgehalten**, Außenpflanzen **zu berühren**?

1	2	3	4	5
Nie		Manchmal		Fast jeden Tag

6b) Wie oft während der **letzten Sommermonate** haben Sie Ihr Kind davon **abgehalten**, Außenpflanzen **zu berühren**?

1	2	3	4	5
Nie		Manchmal		Fast jeden Tag

Erfahrung mit Zimmer- und Balkonpflanzen

Die zweite Hälfte des Fragebogens erfasst die Erfahrungen Ihres Kindes mit Zimmer- und Balkonpflanzen, zum Beispiel mit Pflanzen in Ihrer Wohnung oder in der Küche sowie mit Topfpflanzen auf dem Balkon oder der Terrasse.

1a) Wie oft während des **letzten Monats** hat Ihr Kind in irgendeiner Weise mit Zimmer- und Balkonpflanzen **interagiert**?

1	2	3	4	5
Nie		Manchmal		Fast jeden Tag

1b) Wie oft während der **letzten Sommermonate** hat Ihr Kind in irgendeiner Weise mit Zimmer- und Balkonpflanzen **interagiert**?

1	2	3	4	5
Nie		Manchmal		Fast jeden Tag

2a) Wie oft während des **letzten Monats** haben Sie Ihrem Kind verschiedene Zimmer- und Balkonpflanzen **gezeigt** oder diese für Ihr Kind **benannt**?

1	2	3	4	5
Nie		Manchmal		Fast jeden Tag

2b) Wie oft während der **letzten Sommermonate** haben Sie Ihrem Kind verschiedene Zimmer- und Balkonpflanzen **gezeigt** oder diese für Ihr Kind **benannt**?

1	2	3	4	5
Nie		Manchmal		Fast jeden Tag

3a) Wie oft während des **letzten Monats** hat Ihr Kind Sie **beim Pflegen** von Zimmer- und Balkonpflanzen zu Hause **beobachtet**?

1	2	3	4	5
Nie		Manchmal		Fast jeden Tag

3b) Wie oft während der **letzten Sommermonate** hat Ihr Kind Sie **beim Pflegen** von Zimmer- und Balkonpflanzen zu Hause **beobachtet**?

1	2	3	4	5
Nie		Manchmal		Fast jeden Tag

4a) Wie oft während des **letzten Monats** hat Ihr Kind Früchte oder Gemüse direkt von einer Zimmer- oder Balkonpflanze **gegessen** (z.B. von eingetopften Kräutern in der Küche oder von Topfpflanzen auf dem Balkon oder Fensterbrett)?

1	2	3	4	5
Nie		Manchmal		Fast jeden Tag

4b) Wie oft während der **letzten Sommermonate** hat Ihr Kind Früchte oder Gemüse direkt von einer Zimmer- oder Balkonpflanze **gegessen** (z.B. von eingetopften Kräutern in der Küche oder von Topfpflanzen auf dem Balkon oder Fensterbrett)?

1	2	3	4	5
Nie		Manchmal		Fast jeden Tag

5a) Wie oft während des **letzten Monats** hat Ihr Kind versucht, Zimmer- und Balkonpflanzen **zu berühren**?

1	2	3	4	5
Nie		Manchmal		Fast jeden Tag

5b) Wie oft während der **letzten Sommermonate** hat Ihr Kind versucht, Zimmer- und Balkonpflanzen **zu berühren**?

1	2	3	4	5
Nie		Manchmal		Fast jeden Tag

6a) Wie oft während des letzten Monats haben Sie Ihr Kind davon abgehalten, Zimmer- und Balkonpflanzen zu berühren?

1	2	3	4	5
Nie		Manchmal		Fast jeden Tag

6b) Wie oft während der **letzten Sommermonate** haben Sie Ihr Kind davon **abgehalten**, Zimmer- und Balkonpflanzen **zu berühren**?

1	2	3	4	5
Nie		Manchmal		Fast jeden Tag

7) Im Allgemeinen, **welche Pflanzen** (Zimmer- und Außenpflanzen) **darf** Ihr Kind grundsätzlich **anfassen**?

8) Gibt es noch irgendwelche **anderen relevanten Informationen** in Bezug auf die Pflanzenerfahrungen Ihres Kindes, die Sie gern hinzufügen würden?

Vielen Dank!

2. **English version of the Plant Experience Questionnaire**

Plant Experience Questionnaire

We would like to learn more about your child's experience with plants. The following questions pertain to your child's most recent experience with plants, both their experience during the last month and their experience during the last summer, i.e. from June to August.

The first part of the questionnaire deals with your child's experience with outdoor plants, for example with plants in a garden or in a park or forest (but not potted plants).

Experience with outdoor plants

1a) How often has your child interacted with outdoor plants, in any way, during the **last month**?

1	2	3	4	5
Never		Sometimes		Nearly every day

1b) How often has your child interacted with outdoor plants, in any way, during the **last summer months**?

1	2	3	4	5
Never		Sometimes		Nearly every day

2a) How often have you shown your child outdoor plants, or named them for your child, during the **last month**?

1	2	3	4	5
Never		Sometimes		Nearly every day

2b) How often have you shown your child outdoor plants, or named them for your child, during the **last summer months**?

1	2	3	4	5
Never		Sometimes		Nearly every day

3a) How often has your child watched you taking care of outdoor plants during the **last month**, for example in a yard or garden?

1	2	3	4	5
Never		Sometimes		Nearly every day

3b) How often has your child watched you taking care of outdoor plants during the **last summer months**, for example in a yard or garden?

1	2	3	4	5
Never		Sometimes		Nearly every day

4a) How often has your child eaten fruit or vegetables directly from an outdoor plant during the **last month** (e.g., in a harvest garden with fruit for self-picking or while helping you in the garden)?

1	2	3	4	5
Never		Sometimes		Nearly every day

4b) How often has your child eaten fruit or vegetables directly from an outdoor plant during the **last summer months** (e.g., in a harvest garden with fruit for self-picking or while helping you in the garden)?

1	2	3	4	5
Never		Sometimes		Nearly every day

5a) How often has your child tried to touch outdoor plants during the **last month**?

1	2	3	4	5
Never		Sometimes		Nearly every day

5b) How often has your child tried to touch outdoor plants during the **last summer months**?

1	2	3	4	5
Never		Sometimes		Nearly every day

6a) How often have you stopped your child from touching outdoor plants during the **last month**?

1	2	3	4	5
Never		Sometimes		Nearly every day

6b) How often have you stopped your child from touching outdoor plants during the **last summer months**?

1	2	3	4	5
Never		Sometimes		Nearly every day

Experience with indoor and balcony plants

The second part of the questionnaire covers your child's experience with indoor and balcony plants, for example with plants in your home or kitchen and with potted plants on the balcony or terrace.

1a) How often has your child interacted with indoor and balcony plants, in any way, during the **last month**?

1	2	3	4	5
Never		Sometimes		Nearly every day

1b) How often has your child interacted with indoor and balcony plants, in any way, during the **last summer months**?

1	2	3	4	5
Never		Sometimes		Nearly every day

2a) How often have you shown your child different indoor and balcony plants, or named them for your child, during the **last month**?

1	2	3	4	5
Never		Sometimes		Nearly every day

2b) How often have you shown your child different indoor and balcony plants, or named them for your child, during the **last summer months**?

1	2	3	4	5
Never		Sometimes		Nearly every day

3a) How often has your child watched you taking care of indoor and balcony plants at home during the **last month**?

1	2	3	4	5
Never		Sometimes		Nearly every day

3b) How often has your child watched you taking care of indoor and balcony plants at home during the **last summer months**?

1	2	3	4	5
Never		Sometimes		Nearly every day

4a) How often has your child eaten fruit or vegetables directly from an indoor or balcony plant during the **last month** (e.g., from potted herbs in the kitchen or potted plants on the balcony or windowsill)?

1	2	3	4	5
Never		Sometimes		Nearly every day

4b) How often has your child eaten fruit or vegetables directly from an indoor or balcony plant during the **last summer months** (e.g., from potted herbs in the kitchen or potted plants on the balcony or windowsill)?

1	2	3	4	5
Never		Sometimes		Nearly every day

5a) How often has your child tried to touch indoor and balcony plants during the **last month**?

1	2	3	4	5
Never		Sometimes		Nearly every day

5b) How often has your child tried to touch indoor and balcony plants during the **last summer months**?

1	2	3	4	5
Never		Sometimes		Nearly every day

6a) How often have you stopped your child from touching indoor and balcony plants during the **last month**?

1	2	3	4	5
Never		Sometimes		Nearly every day

6b) How often have you stopped your child from touching indoor and balcony plants during the **last summer months**?

1	2	3	4	5
Never		Sometimes		Nearly every day

7) **In general, which plants** (indoor and outdoor plants) is your child allowed to touch?

8) Is there **any other relevant information** regarding your child's experience with plants that you would like to add?

Thank you very much!

3. Scoring procedure

The Plant Experience Questionnaire is composed of 22 questions and is divided into four subscales:

1. Experience with indoor plants
2. Experience with outdoor plants
3. Eat from plants
4. Prohibit from touching plants

Items of the *Experience with indoor plants* subscale:

1_indoor_last	=	How often did your infant/child interact with indoor plants in the last months?
1_indoor_summer	=	How often did your infant/child interact with indoor plants in the last summer months?
2_indoor_last	=	How often did you point out or name different indoor plants for your infant/child in the last months?
2_indoor_summer	=	How often did you point out or name different indoor plants for your infant/child in the last summer months?
3_indoor_last	=	How often did your infant/child see you caring for indoor plants in the last months?
3_indoor_summer	=	How often did your infant/child see you caring for indoor plants in the last summer months?
5_indoor_last	=	How often did your infant/child try to touch indoor plants in the last months?
5_indoor_summer	=	How often did your infant/child try to touch indoor plants in the last summer months?

Items of the *Experience with outdoor plants* subscale:

1_outdoor_last	=	How often did your infant/child interact with outdoor plants in the last months?
1_ outdoor _summer	=	How often did your infant/child interact with outdoor plants in the last summer months?
2_ outdoor _last	=	How often did you point out or name different outdoor plants for your infant/child in the last months?
2_ outdoor _summer	=	How often did you point out or name different outdoor plants for your infant/child in the last summer months?
5_ outdoor _last	=	How often did your infant/child try to touch outdoor plants in the last months?
5_ outdoor _summer	=	How often did your infant/child try to touch outdoor plants in the last summer months?

Items of the *Eats from plants* subscale:

4_indoor_last	=	How often did your infant/child eat from indoor plants in the last months?
4_indoor_summer	=	How often did your infant/child eat from indoor plants in the last summer months?
4_outdoor_last	=	How often did your infant/child eat from outdoor plants in the last months?
4_outdoor_summer	=	How often did your infant/child eat from outdoor plants in the last summer months?

Items of the *Prohibit from touching plants* subscale:

6_indoor_last =	How often did you stop your infant/child from touching indoor plants in the last months?
6_indoor_summer =	How often did you stop your infant/child from touching indoor plants in the last summer months?
6_outdoor_last =	How often did you stop your infant/child from touching outdoor plants in the last months?
6_outdoor_summer =	How often did you stop your infant/child from touching outdoor plants in the last summer months?

Caregivers answer to each item on a five-point Likert scale (1 = never, to 5 = nearly every day).

Subscales' scores are to be computed by the following method: **Sum all numerical item responses for a given subscale.**

Note that, if caregiver omitted an item, that item receives no numerical score.

For example, score on the *Eat from plants* subscale is obtained as follow:

Eat_from_plant = 4_indoor_last + 4_indoor_summer + 4_outdoor_last + 4_outdoor_summer

4. Distribution of differences between the two time points (i.e. last month and last summer months) for each question

Figure S1: Distribution of differences between the two time points (i.e. *last month* and *last summer months*) for each question.