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Selective social learning of plant edibility in 6- and 18-month-old infants

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Abstract

Recent research underscores the importance of social learning to the development of food preferences. Here we explore whether given the same social information—seeing an adult place something in his or her mouth—inferences about edibility can be selectively applied to certain entities. Given that humans have relied on gathered plant resources throughout our evolutionary history, coupled with the costs of trial and error learning, we predicted that human infants may possess selective social learning strategies that rapidly identify edible plants. Evidence from studies with 6- and 18-month-olds demonstrates that infants selectively identify plants, but not artifacts, as food sources after seeing the same food-relevant social information applied to both object types. These findings comprise the first evidence for content-specific social learning mechanisms that facilitate the identification of edible plant resources. Evolved learning mechanisms such as these have enabled humans to survive and thrive in varied and changing environments.

For many species, plants are central to survival as potential sources of food. As omnivores whose diets are composed of a wide variety of plant and animal matter, humans are no exception. Gathered plant resources have formed the basis of human diets across evolutionary time (Cordain, et al., 2000; Ungar & Sponheimer, 2011), therefore determining which plants are edible in a local environment has been an essential task throughout human evolution. Yet many plants are poisonous, and even deadly, when ingested. There are no morphological features common to all edible or to all poisonous plants (Brill & Dean, 1994; Peters, O'Brien, & Drummond, 1992), and identifying the specific edible and poisonous plants in a given environment through trial and error experimentation would be extremely costly. Such circumstances favor the evolution of social learning strategies (e.g., Barrett & Broesch, 2012; Boyd & Richerson, 1985; Galef, 2001; 2009) for acquiring information about edible plants.

Despite the ubiquity of plants and the essential role they have played throughout human evolution, there has been surprisingly little investigation of the ways in which humans acquire information about plants over the course of development. A large body of work has

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Author Contributions

A.E.W. developed the theoretical question. A.E.W. and K.W. designed the studies. Data collection and data analysis was performed by A.E.W. A.E.W. drafted the paper and K.W. provided critical revisions. A.E.W. and K.W. approved the final version of the paper for submission.

explored young children's knowledge of the properties that are common to both animals and plants as members of the overarching category "living things" (e.g., Carey, 1985; Inagaki & Hatano, 2002; Keil, 1989; Medin & Atran, 1999). From such research we know, for instance, that preschoolers understand that plants, like animals, can grow, heal themselves, and reproduce (Backscheider, Shatz, & Gelman, 1993; Inagaki & Hatano, 1996; Stavy & Wax, 1989). However, studies of children's acquisition of plant-specific knowledge have been few and far between (see Hickling & Gelman, 1995; Nguyen & Gelman, 2002 for exceptions). Recent research with adults has begun to elucidate the cognitive processes that enable humans to *locate* edible plant resources (New, Krasnow, Truxaw, & Gaulin, 2007; Krasnow, et al., 2011), but the strategies that enable humans to *identify* the edible plant resources in natural environments are not known.

In fact, developmental processes concerning human food learning in any context have received surprisingly little attention; yet the few existing studies underscore the importance of social learning. For example, young children prefer foods that an adult calls "yummy" (Lumeng, et al., 2008), and infants prefer foods offered by individuals who speak the same language as they do (Shutts, Kinzler, McKee, & Spelke, 2009). Infants also readily emulate the food preferences of both neutral and prosocial individuals, but not those of antisocial individuals (Hamlin & Wynn, 2012). In addition, social learning is a well-studied component of non-human animal food learning (e.g., Barker, Best, & Domjan, 1977; Galef, 2001; Santos, Hauser, & Spelke, 2001).

However, young children's decisions about what to eat are, famously, not determined by simply copying adult behavior. Under certain circumstances young children will attempt to consume things that they have never seen an adult eat (e.g., sponges and imitation dog feces; Rozin, et al., 1986), and infants do not make consistent inferences about the edibility of certain items they witness adults consume (e.g., sugar or liquids from bowls and glasses; Shutts, Condry, Santos, & Spelke, 2009). Social learning appears to operate in concert with other factors such as sensitive periods for food learning (Cashdan, 1994; 1998) and later-emerging aversions (e.g., disgust, contamination, and neophobia; Cashdan, 1998; Rozin, 1990).

In addition to these factors, we reasoned that there might be cases in which social information about edibility would be selectively tied to certain types of entities. Given that humans have relied on gathered plant resources throughout our evolutionary history, coupled with the costs of trial and error learning, we hypothesized that humans may possess selective social learning strategies that rapidly identify edible plants. Such strategies may operate in similar manner to established cases in which social information is preferentially tied to certain types of entities (e.g., learning about danger; Barrett & Broesch, 2012; Cook & Mineka, 1990; DeLoache & LoBue, 2009). To test this, we examined whether infants would preferentially identify a plant, relative to an artifact, as a food source after they see an adult place both entities in his mouth.

Experiment 1

Methods

Participants were 32 healthy, full term 18-month-old infants (16 female, 16 male; $M_{age} = 18$ months, 17 days; range = 18;4 – 18;30) who heard English spoken more than 50% of the time. Infants in all experiments were recruited from the greater New Haven area and tested in the Infant Cognition Center at Yale University. Eleven additional infants were tested but excluded for failure to choose (5 infants), failure to look at both options before choosing (2), fussiness (1), procedure error (1), video loss (1), and the Behind-Ear action being used for hearing aid training in the participant's home (1).

Our stimuli were a plant and an artifact, each with four removable objects (dried apricots or dried plums) attached. The plant was constructed from realistic-looking artificial leaves and branches arranged in a clay pot. The artifact was designed to control for many of the individual perceptual features of the plant: it was made from the same leaves and branches as the plant, which were spray-painted silver, stuck into a beige base, and encased in a glass cylinder. Thus, it had individual parts of the same shape, texture and number as the individual leaves on the plant, but did not itself look like a plant. The dried fruits were arranged to look like fruits growing on the plant, and placed in the same spatial configuration on the artifact (see Supplementary Methods and Figure S1, Panel A for details). Which dried fruit type (apricot/plum) was placed on the plant versus the artifact was counterbalanced across participants.

Infants sat on their parents' laps and parents were instructed not to direct their infant's attention. The show began with two introduction events: a curtain opened to reveal Experimenter 1 (E1) sitting between the plant and artifact while saying "*Hi, [infant name]!*" and waving. During the next two events, E1 performed the same action on the plant and artifact in a counterbalanced order. Half of the infants saw a food-relevant In-Mouth action: the curtain opened, E1 said "*Hi, [infant name],*" turned toward the plant/artifact, removed a dried fruit, paused, then placed the topmost part of the fruit in his mouth while saying "*Hmmm*" and looking down. E1 did not make eye contact with the infant after saying "*Hi*" and acted as if he was tasting the fruits for himself rather than explicitly demonstrating an action. The curtain lowered during the end of E1's vocalization. The other half of infants saw a food-irrelevant Behind-Ear action, which was the same as above except E1 placed the fruit behind his ear. Previous investigations used similar In-Mouth and Behind-Ear actions as examples of food-relevant and foodirrelevant actions, respectively (Santos, et al., 2001; Shutts, Condry, et al., 2009). In the final event sequence the curtain raised, E1 said "*Hi [infant name],*" removed the remaining dried fruits from the plant and artifact, and placed them on the white square closest to that object on the board (Video S1).

Finally, parents closed their eyes and a second experimenter (E2) who was blind to object identity offered infants a choice (see e.g., Feigenson & Carey, 2003; Hamlin, Wynn, & Bloom, 2007). E2 ensured that the infant saw both fruit types, asked "*Which one can you eat?*" in the In-Mouth condition, and "*Which one can you use?*" in the Behind-Ear condition and brought the board within the infant's reach. Each infant's choice was coded as the first fruit type they touched by two independent coders who were blind to object identity.

Coders (i) verified that infants looked at both options prior to making their choice, and (ii) recorded which fruit type infants chose. For Experiments 1–3, coder agreement was 98% on (i) and 100% on (ii).

The following were counterbalanced across participants in all experiments: (i) plant fruit type (i.e., dried apricots on the plant and dried plums on the artifact, or vice versa), (ii) plant position during the show and choice (right or left side), (iii) which object E1 acted on first (plant or artifact), and (iv) the object from which E1 removed the fruits first (plant or artifact).

Results and Discussion

If infants preferentially identify plants as food sources, participants who saw the In-Mouth action should choose the fruits from the plant over those from the artifact, even though they saw the same action demonstrated with both. Infants who observed the Behind-Ear action, in contrast, were predicted to choose both fruit types equally. As predicted, infants who saw the In-Mouth action chose the fruits from the plant (13 of 16 infants; binomial $P = .02$, two-tailed¹). Infants who saw the Behind-Ear action chose randomly (7 of 16 infants chose plant; binomial $P = .80$), a significantly different pattern of response than in the In-Mouth condition (Figure 1; Pearson Chi-Square = 4.80, $p = .03$).

Coders blind to the target of E1's action (plant vs. artifact) rated the affect displayed and recorded the duration of all of E1's In-Mouth and Behind-Ear actions and found no differences between actions directed at the plant and artifact (see Supplementary Analyses Section 1.1 for these same analyses for Experiments 1–3). Despite seeing the same social information (the In-Mouth action) applied to both object types, infants preferentially identified the plant as a food source.

Experiment 2

The Behind-Ear condition results rule out the possibility that infants generally prefer objects from plants over those from artifacts. However, our plant stimulus was likely more familiar to infants than our novel artifact. To rule out the possibility that specifically in *food* contexts infants prefer items from familiar over novel sources, we tested a new group of 18-month-olds using a more familiar artifact.

Methods, Results, and Discussion

Participants were 16 healthy, full term 18-month-old infants (8 female, 8 male; $M_{age} = 18$ months, 15 days; range = 18;2 – 19;2) who heard English spoken more than 50% of the time. An additional three infants were tested but excluded for failure to choose (2) and fussiness (1).

The procedure was identical to the Experiment 1 In-Mouth condition, except that a shelf was substituted for the novel artifact (Figure S1, Panel B; see Supplementary Methods for confirmation that the shelf would be more familiar to infants than the novel artifact used in

¹All reported p-values are two-tailed.

Experiment 1). This afforded a strong test of familiarity in food contexts because not only have our urban/suburban Western infants been exposed to shelves, but in their direct experience most food comes off of shelves (e.g., in a cupboard or refrigerator) that contain objects of various shapes and colors. The other items on our shelf were different shades of green, like the plant leaves. Infants saw E1 perform the In-Mouth action with dried fruits taken from the plant and from the shelf, and were asked by E2 “*Which one can you eat?*”

Again, as predicted, infants chose the fruits from the plant, replicating our finding from Experiment 1 (Figure 1). The number of infants choosing the plant over the shelf (12 of 16 infants, binomial $P = .078$, two-tailed) was virtually identical to the number of infants choosing the plant over the novel artifact in Experiment 1 (13 of 16 infants), notwithstanding infants’ familiarity with shelves and lack of familiarity with the novel artifact used in Experiment 1. Despite a lifetime of experience with food coming from shelves, after viewing the In-Mouth action infants identified the items from the plant over those from the shelf as edible.

Experiment 3

One explanation for our findings in Experiments 1 and 2 is that infants view *all* plants as food sources, or conversely, apply a rule that items from artifacts are generally inedible. If so, then when asked “*Which one can you eat?*”, infants would have selected fruits from the plant even without seeing a food-relevant In-Mouth action. But because many plants can be poisonous, unpalatable, and difficult to digest, viewing every plant as edible without some positive evidence that it is safe—such as seeing an adult put it in his or her mouth—would be costly. We therefore hypothesized that in the absence of a social cue of edibility, infants would no longer preferentially identify a plant as a food source.

Methods, Results, and Discussion

Participants were 16 healthy, full term 18-month-old infants (7 female, 9 male; $M_{age} = 18$ months, 20 days; range = 18;0 – 19;1) who heard English spoken more than 50% of the time. An additional three infants were tested but excluded for failure to choose.

The stimuli and procedure were the same as Experiment 1, except that infants saw E1 simply *look* pointedly at the plant and the novel artifact in turn while keeping his arms at his sides and saying “*Hmmm*,” the curtain lowered during the end of E1’s vocalization. In the next phase, the curtain raised, and E1 removed the dried fruits from both the plant and artifact and placed them on the same board used in the previous experiments. E2 then presented the board to infants, asking “*Which one can you eat?*” In this case, infants chose randomly between the plant and artifact (Figure 1; 9 of 16 infants chose objects from the plant; binomial $P = .80$). Without viewing the In-Mouth action, infants no longer identified the items from the plant as a more likely food source.

Experiments 1–3 demonstrate that by 18 months, infants preferentially identify a plant as a source of food on the basis of a single brief exposure to an adult putting an object from the plant into his mouth. Unlike some non-human primates who view any object placed in the mouth by an experimenter as food (Santos, et al., 2001), human infants use additional

criteria for determining edibility. The combination of the action and the ontological status of the object—in this case, that it is a plant—appears to be critical.

For Experiments 2 and 3, parents completed a questionnaire assessing their infant's experience with plants, including whether s/he had ever eaten fruit directly off of a plant before, and if s/he had previously eaten dried apricots or plums. None of the variables measured were related to infants' choices (see Supplementary Analyses Section 1.2). Nevertheless, 18-month-olds have had several months of experience with solid foods. Experiment 4 used a looking time paradigm to test whether much younger infants—6-month-olds, who typically are only just starting to eat mashed-up baby foods and have very limited (if any) experience with solid food items—preferentially identify plants as sources of food.

Experiment 4

We used a violation of expectation paradigm in which infants tend to look longer at unexpected or surprising events (e.g., Baillargeon, Spelke, & Wasserman, 1985; Thomsen, Frankenhuys, Ingold-Smith, & Carey, 2011). Therefore, if 6-month-olds selectively identify plants as potential food sources, they should look longer when the In-Mouth action is performed with the dried fruits from the artifact than with those from the plant, but should look equally long when the Behind-Ear action is performed with dried fruits from the plant and artifact.

Method

Participants were 32 healthy full term 6-month-old infants (16 male, 16 female; $M_{age} = 5$ months, 28 days, range = 5;15 – 6;15) divided evenly across two conditions. Sixteen additional infants were tested but excluded for failure to watch more than one pair of E2 events (6), failure to watch E1 events (1), procedure error (6), fussiness (2), and looking time differences greater than 2.5 standard deviations from the mean (1).

Infants sat on their parents' laps throughout a two-part presentation; parents were instructed not to direct their infant's attention. *Phase 1* was identical to Experiment 1 except that E1 remained motionless after acting while infants' looking times were recorded: E1 performed either the In-Mouth (Condition 1) or Behind-Ear (Condition 2) action with one dried fruit taken from the plant and one taken from the novel artifact (in a counterbalanced order), then removed the remaining fruits from their sources and placed them on two white squares on a board (Video S2).

The plant and artifact were removed from the stage for *Phase 2*, and E2, who was blind to object type, appeared behind the board. After a single event showing E2 seated behind the board while saying “Hi [infant name]!” and waving, there were six alternating test trials during which E2 performed either the In-Mouth (Condition 1) or Behind-Ear action (Condition 2) with the two dried fruit types on the board, alternating between the two squares (3 times each, for 6 trials in total; Video S2). After each action, E2 remained motionless as infants' looking times were recorded. Parents' eyes were closed during the test events.

Each trial ended when (i) the infant looked away for 2 consecutive seconds, or (ii) 30 seconds elapsed. Looking times were determined by an online coder, who was blind to event type, using the JHAB computer program. A second blind coder evaluated 25% of the participants; coder agreement was 99%. Counterbalancing was the same as Experiments 1–3, with the addition of (v) which fruit type E2 acted on first.

Results and Discussion

A repeated measures ANOVA examined the effects of object type (plant vs. artifact) and presentation order (act on plant first vs. artifact first) on infant looking times (see Supplementary Analyses Section 2.1 for details). As predicted, infants looked longer at In-Mouth actions performed with dried fruits from the artifact than with those from the plant (Figure 2) suggesting that preverbal infants expect plants, but not artifacts, to be sources of food. This was true for both E1's In-Mouth actions ($F(1,14) = 7.21, p = .018, \text{partial } \eta^2 = .34$) and E2's In-Mouth actions ($F(1,14) = 12.63, p = .003, \text{partial } \eta^2 = .47$). In contrast, infants who viewed the Behind-Ear action looked equally at the plant and artifact events performed by E1 ($F(1,13) = .84, p = .38, \text{partial } \eta^2 = .06$) and E2 ($F(1,14) = .002, p = .97, \text{partial } \eta^2 = .00$), demonstrating that there was no general tendency for infants to look longer at any action performed with the novel artifact.

As in Experiments 1–3, blind coders rated the events and found no differences between actions directed at the plant and artifact (Supplementary Analyses Section 2.2). Overall, infants' looking patterns were significantly different across the In-Mouth and Behind-Ear conditions for both the E1 and E2 events (object type $\times$ condition interactions for E1 events: $F(1,27) = 7.39, p = .01, \text{partial } \eta^2 = .22$; and for E2 events: $F(1,28) = 4.54, p = .04, \text{partial } \eta^2 = .14$) confirming that preverbal infants' differential expectations about plants were constrained to the food-relevant In-Mouth condition. Prior to extensive experience with solid foods, 6-month-old infants appear to expect plants to be food sources.

General Discussion

The findings reported here indicate that after viewing the same food-relevant social information—an adult placing something in his or her mouth—applied to a plant and artifact, 6- and 18-month-old infants preferentially identify the *plant* as the food source. A series of control conditions and questionnaire information ruled out alternate explanations—including prior experience eating fruit directly from plants—and indicated that viewing the food-relevant social information was necessary for identifying plants as food sources.

These findings add to the growing literature highlighting the role of social learning in the development of food preferences (e.g., Hamlin & Wynn, 2012; Lumeng, et al., 2008; Santos, et al., 2001; Shutts, Kinzler, et al., 2009). However, our results show that infants do not use social information alone, but also take into account other relevant contextual information—in this case, the *kind* of object acted upon. This type of selective social learning has been demonstrated before (e.g., Barrett & Broesch, 2012; Cook & Mineka, 1990; DeLoache & LoBue, 2009), and is similar to classic cases of prepared learning (Garcia & Koelling, 1966; Seligman, 1970), but to our knowledge, this is the first demonstration that human infants apply selective inferences to social information about edibility.

To be clear, we are not claiming that plants will be the *only* entity treated this way. For example, given the long history of humans processing food prior to consumption (Wrangham, 2009), it is likely that cues of preparation such as chopping or cooking may also be privileged. Similarly, extensive ontogenetic experience of certain objects being associated with food (e.g., plates, spoons, etc.) may privilege items associated with those objects in certain contexts. This is an area that is ripe for future exploration. Another important avenue for future research will be investigating the ways in which the content of the social information and the ontological status of the object interact. The actors in the current experiments deliberately conveyed neutral information (i.e., they said “*Hmmm*” instead of “*Mmmm*”). Understanding how infants react to negative information applied to a privileged category and/or positive information applied to other entities will be essential to mapping the development of food preferences.

Of course, selective social learning processes like those identified here will not underlie all aspects of human food learning. Human food learning processes are likely to be complex combinations of many underlying processes, including other types of social learning (e.g., Hamlin & Wynn, 2012; Lumeng, et al., 2008; Santos, et al., 2001; Shutts, Kinzler, et al., 2009), avoidance processes (e.g., Cashdan, 1998; Rozin, 1990), sensitive periods (e.g., Cashdan, 1994), and pedagogical demonstrations of food consumption and/or preparation (e.g., Csibra & Gergely, 2011).

Limitations and Alternative Explanations

Because this is the first investigation of selective social learning of plant edibility, there are several outstanding issues that remain to be addressed with future work. For example, the plant we used in the current experiments was a prototypical leafy green plant with fruits growing on it. It remains to be seen (i) to what degree this selective social learning will generalize to other types of plants, and (ii) what combination of features infants use to identify an object as a plant in the first place. Some of our other work provides insight into point (ii) by suggesting that that infants do not use simple features such as green color, leaf-shaped objects, or parts moving relative to the whole to identify plants (Wertz & Wynn, in press). Instead, it seems that infants rely on a probabilistic combination of features that has yet to be fully uncovered.

Similarly, although we have ruled out alternative explanations for the current findings including a general attraction to plants or bias toward familiarity in food contexts, and certain ontogenetic experiences (e.g., general experience with solid foods and specific experiences with plants such as fruit picking), other plausible alternatives remain. For example, we have characterized this selective social learning system as resulting from the ancestrally recurrent problem of identifying edible plants, but it is possible that it stems instead from other processes operating over either phylogenetic or ontogenetic time, or that it is instead part of a broader learning system that includes many different types of entities.

In any case, the current results leave open the question of how this kind of system develops over the first few months of life. Although we have ruled out certain experiences, there must be relevant environmental inputs; even “maturational” processes require the appropriate environmental conditions for development to occur (e.g., Maurer & Lewis, 2001). Some of

these inputs might be counterintuitive, and in principle, a learning system like this could be built (either entirely or in part) via earlier learning processes. The task going forward will be to identify and characterize the relevant inputs and describe how they contribute to the ontogenetic development of this selective social learning system.

Conclusions

Our current results demonstrate that, holding social information constant, infants identify plants over artifacts as food sources. This tendency is present early in ontogeny prior to any formalized instruction, and mirrors the ancestrally recurrent problem humans faced with respect to identifying edible plant resources. Our other work shows that, absent any social information from adults, infants selectively refrain from touching plant leaves (Wertz & Wynn, in press) suggesting that specialized responses to plants extend beyond inferences about candidate food items. Although more work is needed to characterize the nature of the cognitive mechanisms underlying these results, they are consistent with the existence of evolved learning mechanisms.

Generally speaking, these types of learning mechanisms enable the accumulation of cultural knowledge across many generations (Boyd & Richerson, 2006) and explain how a universal cognitive architecture can give rise to systematic cultural and individual differences (Tooby & Cosmides, 1992). For example, every individual may be equipped with the same rule for identifying edible plants, but the specific knowledge bank each individual develops depends on the types of plants and the existing cultural context that she encounters across her lifetime. Cognitive adaptations such as these have enabled humans to survive and thrive in varied and changing environments.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

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Figure 1.

Choices of 18-month-olds in Experiments 1 through 3. Asterisks indicate significant differences ($^{\dagger}p < .08$, two-tailed; $*p < .05$, two-tailed).

Figure 2. 6-month-olds' looking behavior in Experiment 4. Error bars represent ± 1 standard error of the mean (S.E.M.). * indicates $p < .05$, two-tailed. ** indicates $p < .01$, two-tailed.