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The Development of Picture Comprehension Across Early Environments: Evidence From Urban and Rural Toddlers in Western Kenya

Rebecca Zhu[1] | Helen O. Pitchik[2] | Tabitha Nduku Kilonzo[3] | Jan Engelmann[1] | Lia C. Fernald[4] | Alison Gopnik[1]

[1]Department of Psychology, University of California – Berkeley, Berkeley, California, USA | [2]Division of Epidemiology, School of Public Health, University of California – Berkeley, Berkeley, California, USA | [3]International Education, RTI International, Nairobi, Kenya | [4]Division of Community Health Sciences, School of Public Health, University of California – Berkeley, Berkeley, California, USA

Correspondence: Rebecca Zhu (rebeccazhu@berkeley.edu)

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ABSTRACT

Early childhood researchers frequently use learning materials and assessments involving pictures, across different cultures and contexts. However, there is variation in when and how children across cultures and contexts begin to understand and learn from pictures. While children growing up in high-income contexts often have more experience with picture books and other kinds of two-dimensional visual symbols, children growing up in low-income, rural contexts in low- and middle-income countries often have less experience with pictures and other kinds of visual symbols. The current research leverages variation in picture experience within a geographical region to investigate whether previous picture experience is related to toddlers' (1) performance on a picture-based word learning task, and (2) referential understanding, controlling for maternal education, number of toys, caregiver talk, and caregiver play. One hundred and twenty-eight toddlers in urban and rural western Kenya ($n = 64$ per area), who had varying amounts of picture experience, participated in a picture-based word learning task. Preregistered analyses with the entire sample showed no relation between picture experience and performance on a picture-based word learning task, or between picture experience and referential understanding. However, exploratory analyses found a positive association between picture experience and performance on the picture-based word learning task in the urban sample, but not the rural sample. We found no association between toddlers' referential understanding and picture experience, in either sample. We discuss how these results may inform the efficacy of learning materials and the validity of assessments used with children from diverse global backgrounds.

1 | Introduction

In high-income Western contexts, the most widely used learning materials (e.g., books, posters) and assessment tools of early cognitive abilities (e.g., Bayley Scales of Infant and Toddler Development, Denver Developmental Screening Test, Wechsler Preschool, and Primary Scale of Intelligence) all involve picture stimuli as part of a battery of tests (Fernald et al. 2017). As

Summary

- Researchers frequently use learning materials and assessment tools involving picture stimuli, across many different cultures and contexts.
- However, children in different contexts have varying experiences with pictures, and it is unclear when and how children across contexts understand and learn from pictures.
- Preregistered analysis, involving urban and rural toddlers in two small western Kenya communities, showed no association between early experience with pictures and picture-based word learning.
- Exploratory analyses showed a positive association between early experience with pictures and picture-based word learning for toddlers in urban, but not rural, western Kenya community.

educators and researchers adopt these education materials and assessment tools in different parts of the world (e.g., Cromwell et al. 2014; Ranjitkar et al. 2018; Shin et al. 2002), they make an implicit assumption: that children across cultures and contexts understand pictures in the same way. However, differences in picture comprehension could change the efficacy of learning materials and the validity of assessment scores. Thus, in order to determine how to appropriately translate learning materials and assessment tools globally, exploring *when* and *how* children understand pictures across cultures and contexts is of paramount importance (Callaghan et al. 2011; Callaghan and Corbit 2015; DeLoache et al. 1998; Walker, Walker, and Ganea 2013).

Children growing up in WEIRD (i.e., Western, educated, industrialized, rich, Democratic) or high-income contexts in other parts of the world are inundated with pictures and other visual symbols (e.g., televisions, tablets, picture books). Urban and suburban North American children understand pictures very early in development: for example, by at least 24 months, U.S. and Canadian toddlers demonstrate during testing that they know that two-dimensional pictures refer to three-dimensional objects in the world (Ganea et al. 2009; Preissler and Carey 2004). Similarly, by 30 months, older toddlers can use a picture showing the location of a hidden toy to retrieve the toy (DeLoache and Burns 1994). Moreover, these toddlers demonstrate that they are capable of understanding the dual nature of pictures, namely, that pictures are simultaneously objects in their own right–for example, a small, thin *photo*–as well as representations of other objects–for example, a depiction of a *car* (DeLoache et al. 1998; Preissler and Bloom 2007). Additionally, US children are sensitive to the role of intention when interpreting pictures from 2 or 3 years of age, specifically taking into account what the drawer intended to depict when interpreting the content of the depiction (Gelman and Ebeling 1998; Preissler and Bloom 2008). North American preschoolers can learn novel concepts from picture books, and also apply these concepts to actual objects in the world (Ganea, Ma, and DeLoache 2011; Strouse and Ganea 2021).

However, there are few cross-cultural studies on the development of picture comprehension. Some previous research has investigated whether children living in environments without many picture books or other visual symbols begin to understand pictures at the same age as their counterparts living in environments with an abundance of visual symbols. Three-month-old infants from a high-income country, with relatively limited experience with pictures due to their young age, can perceive faces on screens, suggesting that even very young infants can understand the content of pictures (Barrera and Maurer 1981). Additionally, psychologists Hochberg and Brooks (1962) did not expose their child to visual representations until 19 months of age, but their child was still able to recognize and name objects in pictures upon his very first encounters (though we strongly caution against generalizing findings from a single child). These results suggest that picture perception is intuitive for infants and toddlers. In contrast, other research suggests that picture comprehension is not always intuitive for young children, but rather may be acquired through experience. Twenty-four-month-old US toddlers who saw pictures revealing the locations of hidden toys struggled to find the actual toys, suggesting that young children may have some difficulty interpreting the relation between pictures and their referents (DeLoache and Burns 1994). Callaghan and Rankin (2002) demonstrate that longitudinal training over the course of a few months improved young children's comprehension and production of graphic symbols, suggesting that social experiences might facilitate children's understanding of two-dimensional visual symbols. Moreover, children living in low-to-middle-income environments without pictures succeed on cognitive tasks involving objects, but not on cognitive tasks involving pictures (Callaghan et al. 2011; Callaghan, Rochat, and Corbit 2012; Walker, Walker, and Ganea 2013). Preschoolers living in picture-sparse rural environments in India (i.e., a village 70 km from Vijayawada, Andhra Pradesh) and Peru (i.e., a village in the rural Montaro Valley area of the Central Highlands) performed similarly to their rural middle-class Canadian counterparts on a false belief task involving objects. However, these same rural Indian and rural Peruvian preschoolers only performed worse than their rural Canadian counterparts on a false belief task involving black-and-white line drawings (Callaghan, Rochat, and Corbit 2012). Moreover, young toddlers living in Kwala, a rural village in the Kibaha-Pwani District of Tanzania's Coast Region–another early environment with very few pictures–were not able to learn a word for an object that was depicted in a color photograph, but succeeded in learning the word when the actual object was presented in real life (Walker, Walker, and Ganea 2013). Thus, these studies suggest that children who predominantly encounter pictures in school materials and assessment tools might not learn as effectively from existing school materials and might perform more poorly on standard assessments that involve picture stimuli, compared to their peers with abundant pictures, and other two-dimensional visual stimuli in their environments.

While previous research focuses on variation in picture comprehension *across* countries (i.e., between U.S. and Tanzanian children, Walker, Walker, and Ganea 2013; or between Canadian, Indian, and Peruvian children, Callaghan, Rochat, and Corbit 2012), our research is the first to focus on variation across communities *within* a single country and geographic region. By investigating variation in picture comprehension within two communities in a similar geographic region, we built upon previous research examining differences across countries (Callaghan,

Rochat, and Corbit 2012; Walker, Walker, and Ganea 2013), to provide additional evidence on the association between children's performance on a picture-based word learning task and their experience with pictures. The current paper used a culturally appropriate version of a classic picture comprehension task (Preissler and Carey 2004) with samples of both urban and rural toddlers residing in two communities in western Kenya near Kisumu–whose parents have reported more and less experience with pictures, respectively (UNICEF 2011; though more work is necessary to critically compare and contrast these two contexts). In particular, we adapted the content of the task, such that items intended to be familiar or novel will indeed be familiar or novel to toddlers in these two western Kenyan communities.

Specifically, we tested two research questions. Our first research question investigated whether early experience with pictures was related to toddlers' ability to *learn* from pictures. We hypothesized that toddlers with more early experience with pictures would be more likely to learn from pictures. Our second research question investigated whether early experience with pictures was related to toddlers' understanding that pictures *refer* to actual objects in the world. We hypothesized that toddlers with greater early experience with pictures would be more likely to understand the referential nature of pictures. Overall, the present research added to the literature on the development of picture comprehension across cultures and contexts (Callaghan, Rochat, and Corbit 2012; Walker, Walker, and Ganea 2013), by contributing data from additional contexts (i.e., urban and rural western Kenya). Moreover, this registered report contributed useful open-source material and data for cross-cultural developmental psychology.

2 | Methods

2.1 | Overview

We conducted a pilot study and a full preregistered study. The purposes of the pilot study were to (1) ensure that a sample of children living in a small community in western Kenya near Kisumu were willing to participate in this experimental task, (2) verify the proposed length of the experimental task, (3) ensure that there are no technical or logistical issues, and (4) provide preliminary evidence that early experience with pictures relates to picture comprehension abilities. For full stimuli from the pilot data and the current study, please see Appendix A (Figures A1–A8). For full pilot data results, please see the Supporting Materials on Open Science Framework (https://osf.io/3ydu6/).

2.2 | Pilot

In the pilot study, we tested a sample of 32 toddlers (Mean [*M*] = 2.29 years, Standard Deviation [*SD*] = 0.21 years, range = 2.01–2.87 years) residing in rural western Kenya on a conceptual replication of the Preissler and Carey (2004) paradigm. Since learning materials (e.g., picture books) frequently involve cartoons–as opposed to more realistic photographs or more abstract black-and-white line drawings–we also chose to use cartoons in the present experiment (though more work is necessary to quantify the prevalence of cartoons, photographs, and line drawings in learning materials across cultures and contexts). Five additional toddlers participated, but their data were excluded due to experimenter error (one child) and refusal to complete the experiment (four children). Of the children who refused to complete the experiment, three children refused to continue the experiment during part 1 of the word learning trials, and one child refused to continue the experiment after the first warm-up trial. We visited children at their homes, and children participated in a quiet space either indoors (i.e., the living room) or outdoors (i.e., the front yard). For each child, a local experimenter conducted the study in the regional language, Luo. Unlike Preissler and Carey's (2004) U.S. sample, which consisted of toddlers from New York and Boston, the toddlers in this rural western Kenya sample came from rural low-SES backgrounds and had infrequent exposure to picture books and visual symbols (mean number of picture books in the home = 0.91, *SD* = 1.4, range = 0–7; 50% reported no books). We also found variation in their home experiences: 53% of primary caregivers looked at picture books with their child in the past week, and 47% of primary caregivers did not look at picture books with their child in the past week. 44% of primary caregivers reported that toys were present in the home. 41% of primary caregivers reported talking to their child even when busy. We did not measure the frequency or variety of caregiver play in the pilot data. However, we also wish to note that in some cultures and contexts–including, possibly, the two communities in Western Kenya near Kisumu involved in the present research–children may interact more frequently with siblings and peers, rather than parents (Lew-Levy et al. 2020, 2023; Maynard 2002). Consequently, caregiver questionnaires may not be fully representative of children's everyday experiences.

2.3 | Sample Characteristics

In collaboration with a local non-profit organization, SWAP (Safe Water and AIDS Project), we collected data from 128 typically-developing 2-year-olds in and around the Kisumu area, in Nyanza Province, Kenya. Sixty-four toddlers were recruited from urban Kisumu and 64 toddlers were recruited from Rachuonyo East, a rural sub-county approximately 1–2 h outside of Kisumu. Sixteen additional toddlers participated but did not provide usable data due to refusals to complete the study (i.e., "fussed out"). In Kisumu, three toddlers fussed out on part one of the word-learning trials. In Rachuonyo, six toddlers fussed out on the picture-choice warm-up trials, and seven toddlers fussed out on part one of the word learning trials. Consequently, we recruited 144 toddlers in total, and 128 toddlers were included in the final dataset. In Kisumu, participants were recruited over the phone from SWAP's existing participant database. In Rachuonyo, participants were recruited through community health volunteers (i.e., local village representatives who acted as a liaison between researchers and families).

The proposed experiment was powered to detect differences between children with frequent experience with picture books (i.e., who had looked at picture books in the past week) and children with infrequent experience with picture books (i.e., who had not looked at picture books in the past week) within two communities in western Kenya near Kisumu, where experience with picture books was measured through caregiver responses

to a question about the frequency of looking at picture books with their children in the past week. Based on our pilot data with rural western Kenyan toddlers from Rachuonyo South near Kisumu, we predicted that approximately 60%–70% of children with frequent experience with picture books would succeed at picture comprehension tasks. To sufficiently inform the current power analysis, we also examined previous literature comparing group-level performance on picture comprehension tasks. Previous studies on picture comprehension across cultures (i.e., Callaghan et al. 2011; Callaghan, Rochat, and Corbit 2012; Walker et al. 2013) typically had sample sizes of approximately 13–14 child participants per age group. Additionally, most previous research did not present effect sizes or proportions in each group, only *p*-values for differences. One study in rural Tanzania found differences between learning words for a picture versus an object, among 15–23-month-old children, 92% learned a word for an actual object, while 31% learned a word for a photographed object (Walker, Walker, and Ganea 2013). Consequently, we powered this study to detect a difference of 20 percentage points in success on picture-based word learning tasks between children with frequent experience with picture books and children with infrequent experience with picture books, assuming 40% success in the group with infrequent experience with picture books, 90% power and alpha of 0.05.

Inclusion criteria included (1) typical development (i.e., no developmental delays, as reported by the mother/primary caregiver) and (2) fluency in the local language (i.e., Luo) in which the experiment will be conducted. Fluency in the local language was assessed through parental reports (i.e., before participating in the study, the primary caregiver confirmed that their child understands Luo). Exclusion criteria included (1) external interference (i.e., parents or siblings providing answers or otherwise influencing the participants' responses), (2) experimenter error (e.g., providing incorrect instructions, implementing incorrect procedure, or missing stimuli), and (3) fussing out (i.e., failure to complete the entire study).

2.4 | Ethics Statement

This study is approved by the university's Committee for the Protection of Human Subjects. All parents of child participants provided informed consent. All families received a token gift for participating. To ensure that the participants involved understand the research goals and participation procedure, all information was explained verbally in the local language by a fluent translator and in a culturally appropriate and understandable manner. Parents were given a copy of the consent forms, translated into their local language, to keep for their records. If parents provided informed consent via a signed paper consent form, their children were able to participate in the study.

2.5 | Experimental Procedure

For the present study, we ran a culturally-adapted version of the Preissler and Carey (2004) experiment on learning a word for a picture and understanding the referential nature of pictures. We previously piloted the design with 32 toddlers in rural Rachuonyo. We coded only ostensive, communicative responses involving pointing, eye contact, or other efforts to engage the experimenter. Non-communicative responses, such as picking up an object without making eye contact with the experimenter, were not coded. To account for possible side-biasing behavior, the placement of the pictures and objects was counterbalanced across trials and randomized across participants.

Toddlers were tested in quiet areas (i.e., either their homes or a private room in a community center). Local experimenters fluent in the local language conducted the experiments, under the supervision of the first author. Similar to our pilot study and the original Preissler and Carey (2004) study, experimenters provided positive feedback when participants answered correctly, and no feedback when participants answered incorrectly.

2.5.1 | Warm-Up Trials–Real-Item Bias (Outcome-Neutral Quality Check)

As a warm-up, the experimenter presented two trials involving a familiar real object and a picture of a familiar object. On one trial, the experimenter presented an actual ball and a picture of a chicken, and said, "Show me a chicken". Next, the experimenter presented a picture of a flower and an actual cup, and said, "Show me a flower." The experimenter coded whether the toddler chose the correct response. As in Preissler and Carey's (2004) original experimental paradigm, if the child did not respond despite five prompts from the experimenter, the experimenter moved on to the next part of the procedure. The left-right placement was counterbalanced across trials, such that the correct picture was placed on the right side on one trial and on the left side on the other trial. Trial order was counterbalanced across participants, such that half of the children received the chicken trial first, and the other half of the children received the flower trial first. In the original Preissler and Carey (2004) study on referential understanding, these familiar object trials served as a control by demonstrating that children do not always choose actual objects over pictures (e.g., because objects are more salient or interesting than pictures). Moreover, success in these warm-up trials demonstrated that children understood the instructions and were generally motivated to complete the task. Thus, data from the Real Item Bias warm-up trials served as a quality check for the proposed study, orthogonal to the research hypotheses. Specifically, if toddlers performed above chance levels in the Real Item Bias warm-up trials, this result would indicate that the experimental paradigm was appropriate for the study population. However, if toddlers performed only at chance levels in the Real Item Bias warm-up trials, this result would indicate that the experimental paradigm was inappropriate and that further analyses may be invalid.

2.5.2 | Warm-Up Trials–Picture Choice

As another warm-up, the experimenter presented two trials involving a real object and a picture of the same item. On one trial, the experimenter presented an actual spoon and a picture of a spoon, and said, "Show me a spoon." Next, the experimenter presented a picture of a shoe and an actual shoe, and said, "Show me a shoe." The experimenter coded whether the toddler chose

the picture, object, or both. Once again, left-right placement was counterbalanced across trials, such that the object was placed on the right side on one trial and on the left side on the other trial. Trial order was also counterbalanced across participants, such that half of the children received the spoon trial first, and the other half of the children received the shoe trial first. These warm-up trials captured children's baseline propensity to choose objects or pictures, when presented with known objects.

2.5.3 | Word Learning Trials

To assess whether children learn a novel word for a novel picture, we showed children a novel object, named a dax and then presented children with two kinds of word learning trials. Firstly, we presented children with dichotomous-choice trials, in which children must correctly select a picture of a dax over a picture of a banana three trials in a row. Next, we presented children with a single five-picture trial, in which children must select the picture of a dax out of an array with four other pictures of novel objects. Children who succeeded at both parts of the word learning trials (i.e., both the dichotomous-choice and five-picture trials) were categorized as participants who successfully learned the novel word for the novel picture. Children who succeeded at only one part of the word learning trials, or neither parts of the word learning trials, were categorized as participants who did not learn the novel word for the novel picture.

2.5.4 | Word Learning Trials Part 1–Dichotomous Choice

The experimenter presented the child with a picture of a novel object and said, "This is a dax. Can you touch the dax?" Then, the experimenter presented the picture of the dax and a picture of a banana and said, "Show me a dax." The dax/banana trial was repeated three times, with the experimenter prompting, "Show me a dax" on each trial. Left-right placement of the pictures was randomized across trials. If the toddler accurately selected the picture of the dax on all three trials, the experimenter moved on to the next phase of the study. If the child did not accurately select the picture of the dax three times, the experimenter repeated the procedure, by returning to the initial word learning phase (i.e., presenting the picture of the dax alone and repeating, "This is a dax") and then to the three dax/banana trials (i.e., presenting the picture of the dax and the picture of the banana and saying, "Show me a dax"). The experimenter repeated the procedure up to four times, thus providing each child with up to five opportunities to accurately select the picture of the dax on three consecutive trials. After five sets, the experimenter moved on to the next phase regardless of whether the child succeeded at providing the correct answer on three consecutive trials.

2.5.5 | Word Learning Trials Part 2–Five Pictures

We then presented children with one final word learning trial. The experimenter presented the picture of the dax alongside four other pictures of novel objects, and said, "Show me a dax." The experimenter will code whether the toddler chose the correct picture. Placement of the correct picture was randomized across participants, such that the picture was placed in the center, far left, or far right of the five-picture array across participants.

2.5.6 | Test Trial

Each child received a single test trial. On the trial, the experimenter presented the picture of a dax and the actual dax and said, "Show me a dax." The experimenter coded whether the toddler chose the picture, object, or both. Left-right placement was counterbalanced across participants, such that the object was placed on the right side for half of the participants, and on the left side for the other half of the participants.

2.5.7 | Experience With Pictures

We asked primary caregivers questions relating to the child's early experience with pictures. Specifically, we collected data for a similar picture variable to the variable used in our pilot study, namely, *looking at picture books* (i.e., how many days in the past week parents had looked at picture books with their child). The planned analysis used a continuous picture variable (i.e., *how many days* parents had looked at picture books with their child in the past week) rather than the initial dichotomous picture variable (i.e., *whether* parents had looked at picture books with their child in the past week) used in our pilot study. See Appendix B for the full questionnaire.

2.5.8 | Additional Variables

We also collected other demographic information from the primary caregiver, such as information related to socioeconomic status (i.e., the number of years of formal education completed by the child's mother). For primary caregiver education, we used the same categorical measure (i.e., no formal school education, under 7 years of formal education, or over 7 years of formal education) as a previous picture comprehension study (Walker, Walker, and Ganea 2013). Categorical measures of parental education are frequently used in child development research (e.g., Walker, Walker, and Ganea 2013; Pitchik et al. 2021).

We also collected three additional continuous variables regarding the child's environment, relating to the presence of toys (i.e., how many toys are in the home), frequency of caregiver play (i.e., how many days in the past week the caregiver played with the child), and frequency of caregiver talk (i.e., how many days in the past week the primary caregiver talked to the child, even when the caregiver is busy).

2.6 | Analysis Plan

We used logistic regressions to examine the association between experience with pictures and (1) learning a novel word for a picture (i.e., by succeeding on both the dichotomous-choice and five-picture trials), and (2) demonstrating an understanding of the referential nature of pictures (i.e., by selecting the object over the picture, or the object along with the picture, on the final test trial), compared to their counterparts with less experience with

pictures. The analyses also controlled for four additional home environment variables (i.e., level of maternal education, presence of toys in the home, frequency of caregiver talk, and frequency of caregiver play), which may be confounders of the association between children's experience with pictures and children's performance on the experimental task. We conducted two analyses, one for each outcome (i.e., learning a novel word for a picture, and understanding the referential nature of pictures). We made a preregistered decision to not correct for multiple comparisons (i.e., within and across the two analyses), given our preplanned analyses and unidirectional hypotheses. However, we noted that this preregistered decision may inflate the significance of the results. Moreover, we noted that the current paradigm's measures of picture-based word learning and referential understanding only generated one data point per participant, and thus provided a limited amount of data.

2.6.1 | Exploratory Analyses

We tested for heterogeneity in results based on residence location (urban vs. rural) by including residence location as a control variable and then also an interaction term between residence location and picture experience. We also conducted exploratory subgroup analyses within only the urban Kisumu sample, and only the rural Rachuonyo sample. Firstly, we ran exploratory analyses similar to the preregistered analyses (i.e., logistic regressions to examine the association between experience with pictures and learning a novel word for a picture, controlling the level of maternal education, presence of toys in the home, frequency of caregiver talk, and frequency of caregiver play). Due to the small sample size, we also ran bivariate analyses without control variables (i.e., logistic regressions to examine the association between experience with pictures and learning a novel word for a picture, without controlling for potential confounding variables).

3 | Results

3.1 | Data and Code Availability Statement

The study materials, anonymized data, R code for the main study and the pilot study, and Stage 1 Registered Report protocol are public through the Open Science Framework (https://osf.io/3ydu6/).

3.2 | Demographics

Data from the caregiver questionnaire showed variation in all variables involved in the preregistered analyses, both across the entire sample of toddlers, and within urban and rural samples (see Figure 1, Table 1 in Appendix C). For example, both urban and rural caregivers reported looking at picture books with their child from as infrequently as 0 days in the past week to as frequently as 7 days in the past week (urban $M = 2.50$ days, $SD = 1.89$ days; rural $M = 3.33$ days, $SD = 2.05$ days). Similarly, urban caregivers reported playing with their child from as infrequently as 0 days in the past week to as frequently as 7 days in the past week ($M = 5.31$ days, $SD = 2.16$ days), and rural caregivers reported playing with their child as infrequently as 1 day in the past week to as frequently as 7 days in the past week ($M = 4.94$ days, $SD = 2.11$ days). There was also variation in toddlers' early picture environments both within and across samples (see Figure 2, Table 1 in Appendix C). For example, urban caregivers reported having anywhere from 0 to 20 picture books in their home, while rural caregivers reported having anywhere from 0 to 12 picture books in their home. Only four out of 128 toddlers (three in Kisumu, one in Rachuonyo) attended daycare.

Toddlers in the sample from rural Rachuonyo looked at picture books with their caregivers ($M = 3.33$ days, $SD = 2.05$ days) significantly more frequently than toddlers from the urban Kisumu sample ($M = 2.50$ days, $SD = 1.89$ days), $t(126) = 2.38$, $p = 0.02$. In the urban sample 53.13% ($n = 34$) of toddlers learned the word for the picture, compared to 45.31% ($n = 29$) of toddlers in the rural sample. An exploratory logistic regression without control variables found no difference in word learning, operationalized as successful performance on both Part 1 and Part 2 of the word learning trials, between toddlers in the urban and rural samples (difference: $\beta = 0.31$, $SE = 0.35$, $p = 0.38$, OR: 0.73, 95% CI: 0.36, 1.46). On the final test trial, 29.69% ($n = 19$) of toddlers in both the urban and rural samples demonstrated referential understanding by selecting the object, or both the object and the picture, over only the picture.

3.2.1 | Real-Item Bias Warm-Up Trials (Outcome-Neutral Quality Check)

One potential risk was that our experimental paradigm was not culturally appropriate (e.g., recruited toddlers were not motivated to complete the task, or did not understand the instructions). We believed that this risk was unlikely, because our pilot data showed that toddlers performed at near-ceiling levels on the Real Item Bias warm-up trials (i.e., in which toddlers had to point at a "flower" and a "chicken", two words they are already familiar with). This near-ceiling performance suggested that toddlers were generally motivated to complete the experimental paradigm and understand the instructions. Thus, data from the Real Item Bias warm-up trials served as a quality check for the proposed study, orthogonal to the research hypotheses. Specifically, if toddlers performed above chance levels in the Real Item Bias warm-up trials, this result indicated that the experimental paradigm was appropriate and high-quality. However, if toddlers performed only at chance levels in the Real Item Bias warm-up trials, this result indicated that the experimental paradigm was inappropriate and that further analyses may be invalid.

In the present study, we found that children passed the outcome-neutral quality checks at significantly above-chance levels, indicating that the experimental paradigm was appropriate and high-quality. Specifically, toddlers selected the correct answer on both Real-Item Bias warm-up trials: toddlers selected the picture of the chicken over the actual ball, 88% ($n = 111$) selecting chicken, 12% ($n = 15$) selecting ball (binomial test, $p < 0.001$, RR = 1.76), and the picture of the flower over the actual cup, with 98% ($n = 124$) selecting flower, and 2% ($n = 3$) selecting cup (binomial test, $p < 0.001$, RR = 1.95). Two toddlers included in the dataset did not respond to warm-up trials: one toddler did not respond on the chicken/ball trial, and another toddler did not respond on either Real-Item Bias warm-up trial.

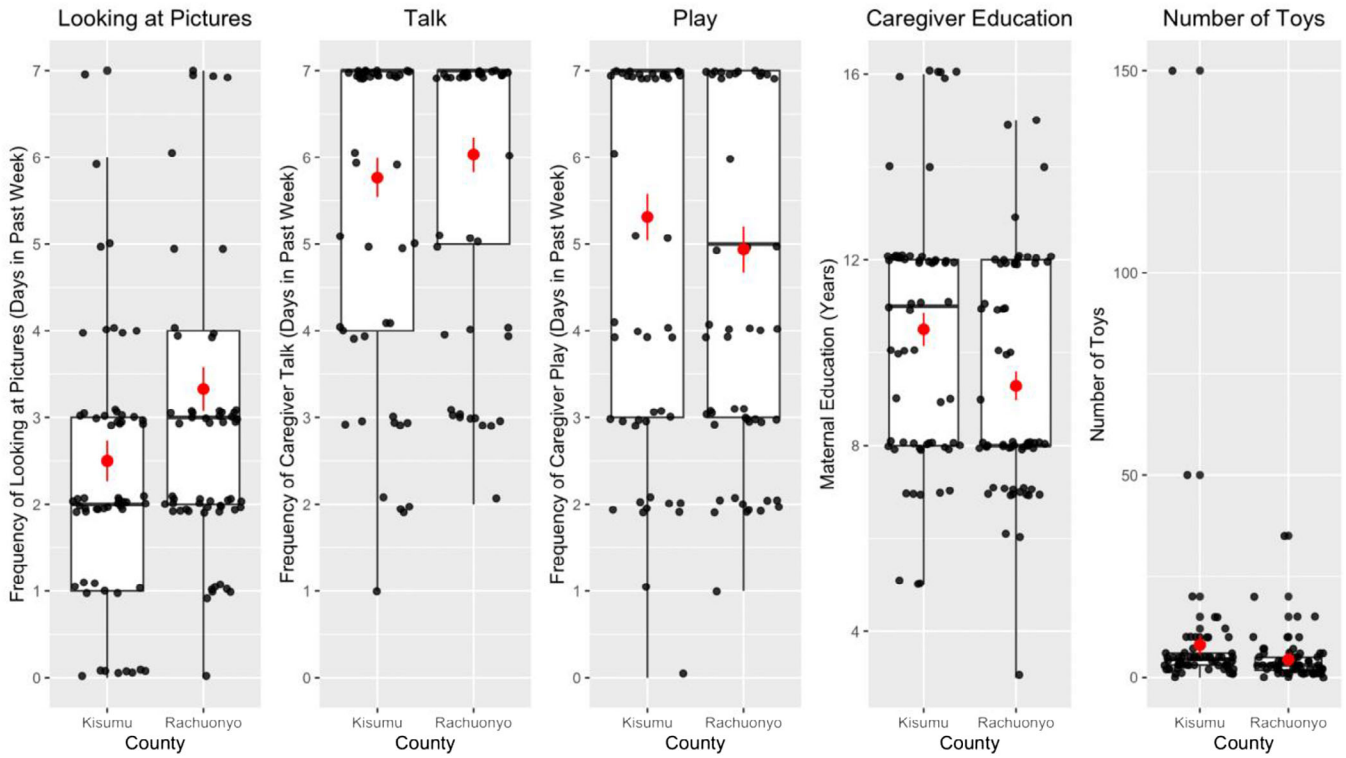

FIGURE 1 | Data visualization of children's early environments and experiences.

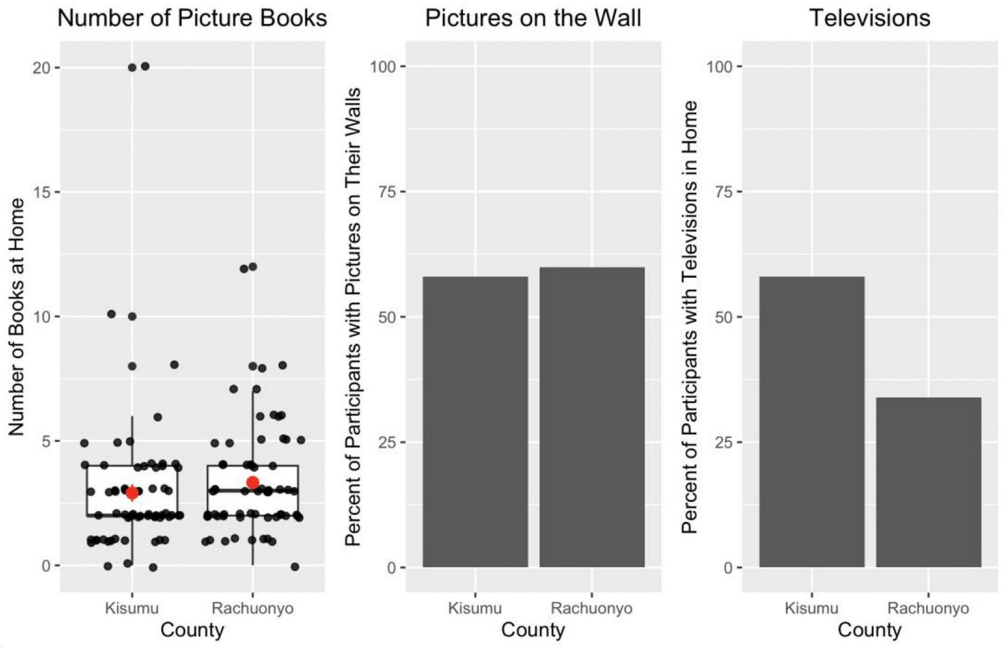

FIGURE 2 | Data visualization of children's early picture experiences.

3.2.2 | Picture Choice Warm-Up Trials

On the Picture Choice warm-up trials, the vast majority of toddlers selected either the actual object or only the picture of the object on the spoon trial (91% of toddlers) and the shoe trial (93% of toddlers). 9% and 7% of toddlers selected both the picture and object on the spoon and shoe trial, respectively, and these responses were categorized alongside the object responses, since researchers have previously interpreted "both" responses as demonstrating an understanding of the referential nature of pictures (Preissler and Carey 2004). Toddlers chose between the object and the picture at chance levels on both the spoon trial, 42% ($n = 54$) selecting actual spoon or both actual spoon and picture of spoon, 58% ($n = 74$) selecting picture of spoon, binomial test,

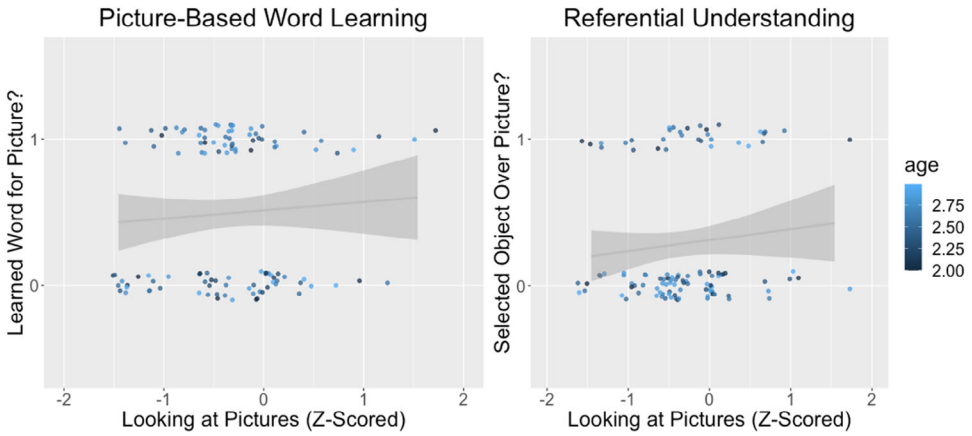

FIGURE 3 | The linear association and associated confidence interval between looking at pictures (i.e., how many days in the past week caregivers had looked at picture books with their child) and picture-based word learning (i.e., selecting the dax in both the three dichotomous choice trials and the five novel pictures trial), and referential understanding (i.e., selecting only the object, or both the object and the picture in the final picture-object choice trial).

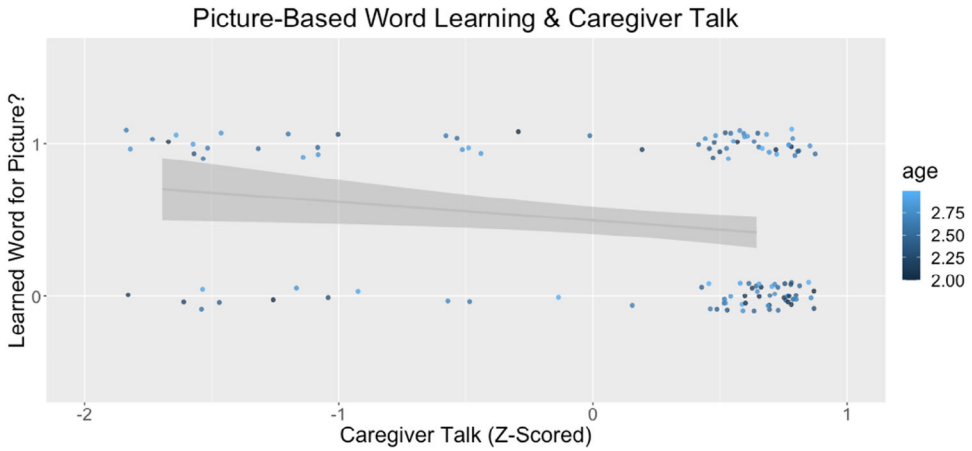

FIGURE 4 | The linear association and associated confidence interval between frequency of caregiver talk (i.e., how many days in the past week caregivers talked to their children even when busy) and picture-based word learning (i.e., selecting the dax in both the three dichotomous choice trials and the five novel pictures trial). There was little variation in the caregiver talk variable, with the majority of caregivers reporting they talked to their children daily, suggesting possible mismeasurement in the caregiver talk variable.

$p = 0.09$, RR = 0.84). However, toddlers significantly preferred the picture over the object on the shoe trial, 38% ($n = 48$) selected the actual shoe or both actual shoe and picture of shoe, 62% ($n = 80$) selected the picture of shoe, binomial test, $p = 0.006$, RR = 0.75).

3.2.3 | Preregistered Analyses for Hypothesis 1–Learning From Pictures

All continuous variables were standardized (i.e., z-scored). In the total sample of both urban and rural children, after controlling for frequency of caregiver play and talk, number of toys in the home, and caregiver education levels, we did not find a significant association between children's ability to learn a word for a picture and frequency of looking at pictures ($\beta = 0.11$, $SE = 0.18$, $p = 0.56$, OR: 1.11, 95% CI: 0.78, 1.60) (see Figure 3 for a visualization of the linear correlation between children's ability to learn a word for a picture and the frequency of looking at pictures, without accounting for control variables, in the total sample). We found a significant negative association between children's ability to learn a word for a picture and one of the control variables, specifically frequency of caregiver talk ($\beta = -0.42$, $SE = 0.19$, $p = 0.03$, OR: 0.66, 95% CI: 0.44, 0.96) (see Figure 4 for a visualization of the linear correlation between children's ability to learn a word for a picture and the frequency of caregiver talk, without accounting for control variables, in the total sample). We found no association between children's ability to learn a word for a picture and any of the other control variables (all p's > 0.30). For regression results, see Table 1.

3.2.4 | Preregistered Analyses for Hypothesis 2–Understanding the Referential Nature of Pictures

In the total sample including both urban and rural children, we found no association between children's understanding of the referential nature of pictures and frequency of looking at

TABLE 1 | Regression outputs for a preregistered analysis on toddlers' picture-based word learning in the entire sample.

	Coefficient	SE	OR	95% CI LL	95% CI UL	*p*
Intercept	0.55	0.91	1.74	0.29	10.75	0.54
Frequency of looking at picture books in the past week	0.11	0.18	1.11	0.78	1.60	0.56
Frequency of caregiver play in the past week	−0.10	0.19	0.90	0.62	1.31	0.58
Frequency of caregiver talk in the past week	−0.42	0.19	0.66	0.44	0.96	0.03*
Number of toys in the home	0.38	0.37	1.46	0.90	3.72	0.31
Maternal education level	−0.31	0.49	0.73	0.28	1.90	0.52

Note: Analyses were conducted with logistic regression; picture-based word learning defined as selecting the dax in both three dichotomous choice trials in a row and the five novel pictures trial.
*Indicates $p < 0.05$; $n = 128$.

TABLE 2 | Regression outputs for a preregistered analysis on toddlers' referential understanding in the entire sample.

	Coefficient	SE	OR	95% CI LL	95% CI UL	*p*
Intercept	−0.98	0.98	0.37	0.05	2.40	0.32
Frequency of looking at picture books in the past week	0.23	0.20	1.26	0.85	1.87	0.25
Frequency of caregiver play in the past week	0.00	0.21	1.00	0.67	1.51	0.99
Frequency of caregiver talk in the past week	0.22	0.22	1.25	0.83	1.97	0.31
Number of toys in the home	−0.92	0.74	0.40	0.07	1.07	0.22
Maternal education level	0.01	0.52	1.01	0.37	2.93	0.99

Note: Analyses were conducted with logistic regression; referential understanding defined as the child selecting only the object, or both the object and the picture in the final picture-object choice trial; $n = 128$.

pictures, and no association between children's understanding of the referential nature of pictures and any of the control variables (all *p*'s > 0.21). For all estimates, see Table 2.

3.2.5 | Exploratory Analyses for Hypothesis 1–Learning From Pictures

We conducted exploratory analyses to examine possible differences by residence location (i.e., urban, rural). A logistic regression examining the association between learning a novel word for a picture and experience with pictures, the association between learning a novel word for a picture and residence location (i.e., urban, rural), and the association between learning a novel word for a picture and the interaction between experience with pictures and residency, controlling level of maternal education, presence of toys in the home, frequency of caregiver talk, and frequency of caregiver play), found a significant association between children's ability to learn a word for a picture and the interaction between experience with pictures and residence location (for interaction, $\beta = -0.95$, $SE = 0.41$, $p = 0.02$, OR: 0.39, 95% CI: 0.17, 0.84). There was also a significant positive association between children's ability to learn a word for a picture and frequency of looking at pictures ($\beta = 0.67$, $SE = 0.31$, $p = 0.03$, OR: 1.95, 95% CI: 1.10, 3.80), as well as a significant negative association between children's ability to learn a word for a picture and frequency of caregiver talk ($\beta = -0.40$, $SE = 0.20$, $p = 0.046$, OR: 0.67, 95% CI: 0.45, 0.98). We found no association between children's ability to learn a word for a picture and any of the other variables (all *p*'s > 0.26). For regression results, see Table 3.

Given the significant community-level interaction, we also conducted exploratory analyses within only the urban Kisumu sample, and only the rural Rachuonyo sample, for the dependent variable of learning a novel word for a picture. In the urban Kisumu sample, we found a significant positive association between children's ability to learn a word for a picture and frequency of looking at pictures with their caregivers, in a logistic regression that included control variables ($\beta = 0.67$, $SE = 0.33$, $p = 0.04$, OR: 1.96, 95% CI: 1.06, 3.99). We found no association between children's ability to learn a word for a picture and any of the control variables (all *p*'s > 0.11). We found a marginal positive association between children's ability to learn a word for a picture and frequency of looking at pictures with their caregivers, in a logistic regression without control variables ($\beta = 0.59$, $SE = 0.31$, $p = 0.054$, OR: 1.81, 95% CI: 1.03, 3.49). For regression results, see Table 4.

In contrast, in the rural Rachuonyo sample, we found no association between children's ability to learn a word for a picture and frequency of looking at pictures with their caregivers, or between children's ability to learn a word for a picture and any of the control variables (all *p*'s > 0.22). Similarly, we found no association between children's ability to learn a word for a picture and frequency of looking at pictures with their caregivers, in a logistic regression without control variables ($\beta = -0.30$, $SE = 0.26$, $p = 0.24$, OR: 0.74, 95% CI: 0.43, 1.21). See Figure 5 for a visualization of the linear correlation between children's ability to learn a word for a picture and the frequency of looking at pictures, without accounting for control variables, separated by urban and rural samples. For regression results, see Table 5.

TABLE 3 | Regression outputs for an exploratory analysis on toddlers' picture-based word learning in the entire sample, including an interaction between frequency of looking at pictures and community.

	Coefficient	SE	OR	95% CI LL	95% CI UL	*p*
Intercept	1.31	1.01	3.70	0.52	28.02	0.19
Frequency of looking at picture books in the past week	0.67	0.31	1.95	1.10	3.80	0.03*
Frequency of caregiver play in the past week	−0.11	0.19	0.90	0.61	1.31	0.57
Frequency of caregiver talk in the past week	−0.40	0.20	0.67	0.45	0.98	0.046*
Number of toys in the home	0.36	0.37	1.44	0.89	3.71	0.32
Maternal education level	−0.57	0.51	0.57	0.20	1.53	0.26
Rural residence location	−0.37	0.40	0.69	0.31	1.49	0.35
Frequency of looking at picture books in the past week × Rural residence	−0.95	0.41	0.39	0.17	0.84	0.02*

Note: Analyses were conducted with logistic regression; picture-based word learning defined as selecting the dax in both three dichotomous choice trials in a row and the five novel pictures trial; $n = 128$; Urban residence location compared to rural residence location.
*indicates $p < 0.05$

TABLE 4 | Regression outputs for an exploratory analysis on toddlers' picture-based word learning in the urban Kisumu sample.

	Coefficient	SE	OR	95% CI LL	95% CI UL	*p*
Intercept	1.97	1.77	7.16	0.24	306.46	0.27
Frequency of looking at picture books in the past week	0.67	0.33	1.96	1.06	3.99	0.04*
Frequency of caregiver play in the past week	−0.24	0.29	0.79	0.44	1.38	0.41
Frequency of caregiver talk in the past week	−0.44	0.28	0.64	0.36	1.10	0.11
Number of toys in the home	1.16	0.95	3.19	1.01	34.45	0.22
Maternal education level	−0.89	0.91	0.41	0.06	2.41	0.33

Note: Analyses were conducted with logistic regression; picture-based word learning defined as selecting the dax in both three dichotomous choice trials in a row and the five novel pictures trial; $n = 64$.
*indicates $p < 0.05$

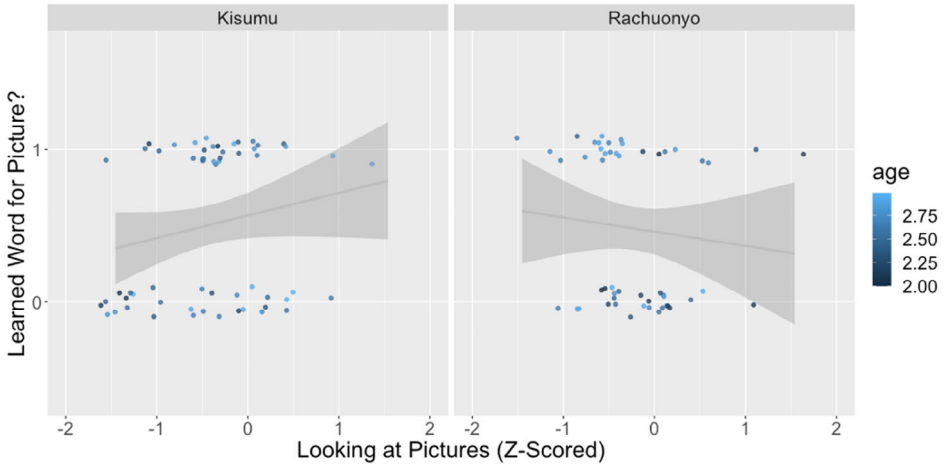

FIGURE 5 | The linear association and associated confidence interval between looking at pictures (i.e., how many days in the past week caregivers had looked at picture books with their child) and picture-based word learning (i.e., selecting the dax in both the three dichotomous choice trials and the five novel pictures trial) in urban Kisumu and rural Rachuonyo samples.

3.2.6 | Exploratory Analyses for Hypothesis 2–Understanding the Referential Nature of Pictures

We conducted exploratory analyses to examine possibly differences by residence location (i.e., urban, rural). A logistic regression examining the association between referential understanding and experience with pictures, the association between referential understanding and residence location (i.e., urban, rural), and the association between referential understanding and the interaction between experience with

TABLE 5 | Regression outputs for an exploratory analysis on toddlers' picture-based word learning in the rural Rachuonyo sample.

	Coefficient	SE	OR	95% CI LL	95% CI UL	*p*
Intercept	0.32	1.14	1.37	0.13	13.58	0.78
Frequency of looking at picture books in the past week	−0.24	0.28	0.79	0.44	1.36	0.40
Frequency of caregiver play in the past week	−0.05	0.27	0.95	0.56	1.63	0.86
Frequency of caregiver talk in the past week	−0.33	0.27	0.72	0.41	1.22	0.23
Number of toys in the home	−0.22	0.31	0.80	0.37	1.39	0.47
Maternal education level	−0.29	0.63	0.75	0.21	2.58	0.64

Note: Analyses were conducted with logistic regression; picture-based word learning defined as selecting the dax in both three dichotomous choice trials in a row and the five novel pictures trial; $n = 64$.

TABLE 6 | Regression outputs for an exploratory analysis on toddlers' referential understanding in the entire sample, including an interaction between frequency of looking at pictures and community.

	Coefficient	SE	OR	95% CI LL	95% CI UL	*p*
Intercept	−0.88	1.06	0.41	0.05	3.08	0.40
Frequency of looking at picture books in the past week	0.15	0.29	1.16	0.64	2.08	0.61
Frequency of caregiver play in the past week	−0.02	0.21	0.98	0.67	1.48	0.94
Frequency of caregiver talk in the past week	0.23	0.22	1.26	0.83	1.99	0.30
Number of toys in the home	−1.02	0.79	0.36	0.06	1.05	0.20
Maternal education level	0.003	0.53	1.00	0.36	3.00	0.99
Rural residence location	−0.26	0.42	0.77	0.33	1.75	0.53
Frequency of looking at picture books in the past week × Rural residence	0.21	0.40	1.23	0.57	2.71	0.60

Note: Analyses were conducted with logistic regression; referential understanding defined as child selecting only the object, or both the object and the picture in the final picture-object choice trial; $n = 128$.

pictures and residence location, controlling level of maternal education, presence of toys in the home, frequency of caregiver talk, and frequency of caregiver play), yielded no significant associations (all p's > 0.19). For regression results, see Table 6. Given no evidence of a significant residence location-level interaction, we did not conduct exploratory analyses with urban Kisumu and rural Rachuonyo subgroups, for the dependent variable of referential understanding.

4 | General Discussion

Our current research contributes to the literature on children's picture comprehension in global contexts. In terms of basic cognitive science, the present research explores possible cultural and contextual variation in children's "pictorial competence"–namely, their capacity to perceive, interpret, understand, and use pictures (DeLoache et al. 2003). In terms of applied educational research and policy, the present research may contribute to a better understanding of what kinds of learning materials and assessments are effective and valid for children around the world. The present research also contributes a valuable open dataset and useful experimental materials on variation in toddlers' picture comprehension, early picture experiences, and other demographic and environmental variables from global contexts which contributes to improving the external validity, generalizability, and replicability of developmental science (Singh and Rajendra 2024), specifically two small communities in western Kenya near Kisumu.

4.1 | Planned Analyses–Learning From Pictures

In our first preregistered analysis on toddlers' word learning, we found no association between toddlers' performance on a picture-based word learning task and how frequently they looked at picture books with their caregiver. In both preregistered analyses we controlled for multiple covariates that we hypothesized would confound the relationship between frequency of looking at picture books with caregivers and success on the picture-based word learning task. However, one of the control variables, caregiver talk, did not perform as expected within the logistic regression, resulting in a negative association between caregiver talk and learning a word for a picture when controlling for all other variables in the model. Interpretation of the coefficient on this control variable should not be considered a primary result, as we did not consider this to be the primary exposure of interest for which we chose relevant confounders (Westreich and Greenland 2013). However, this may be an indication that the caregiver talk variable is not capturing what was intended as this negative association runs counter to a large literature demonstrating a positive association between frequency of caregiver talk and linguistic development in U.S. children (Hart and Risley 1995; Hoff 2003; Weisleder and Fernald 2013). There was little variation in this

variable, with the majority of caregivers reporting they talked to their children daily. As such it may not be providing rich enough information about the early language environment to control for this appropriately. Moreover, the quality, rather than the quantity, of child-directed speech might be more strongly related to children's language outcomes (Anderson et al. 2021). Our question (i.e., "In the past week, how many days did you talk to your child, even when you were busy?") captured the quantity, but not quality, of maternal talk. However, emerging research also shows that there is substantial variation in children's early linguistic experiences (e.g., frequency of child-directed speech) across cultures and contexts (Cristia et al. 2019; Cristia, Gautheron, and Colleran 2023), which might contribute to different word learning strategies across early environments (Sperry, Sperry, and Miller 2019). Indeed, there is some evidence that coordinated joint attention has a positive relationship with vocabulary size in a community of urban Mozambican infants, but a contrasting negative correlation with vocabulary size in a community of rural Mozambican infants (Mastin and Vogt 2016), suggesting that future cross-cultural and cross-contextual research may yield further surprising language acquisition findings. Overall, to determine whether there is a real and robust negative association between language learning and child-directed speech in some contexts, more research on linguistic and cognitive development in diverse contexts is required.

4.2 | Planned Analyses–Understanding the Referential Nature of Pictures

In our second preregistered analysis on toddlers' referential understanding, we found no association between toddlers' performance on a referential understanding task and how frequently they looked at picture books with their caregiver, or any other environmental variables. We found that over 70% of toddlers selected the picture over the object in the final test trial, which might tentatively suggest that toddlers in the sample did not understand that the new word that was learned referred to a picture but not to an actual object. However, it is important to note that Preissler and Carey's (2004) original study was conducted with black-and-white line drawings, whereas the present study used clipart pictures. Different kinds of pictures varying in their degree of realism can elicit different responses, for example, U.S. infants demonstrate more manual behaviors (i.e., grasping at the picture) with realistic color photographs of objects than with abstract black-and-white line drawings of objects (Pierroutsakos and DeLoache 2003). Children may have more difficulty understanding the representational nature of color photographs than of black-and-white line drawings–that is, they may struggle to understand that a color photograph of a toy is a *representation* of a toy, and not an *actual* toy (Ganea et al. 2009). Thus, the more realistic and detailed clipart pictures used in the present study may be harder for children to interpret as referents than the black-and-white line drawings used in Preissler and Carey's (2004) original study. Future research should clearly delineate the various processes underlying children's picture comprehension (e.g., perceiving pictures, understanding the representational nature of pictures), as well as investigate whether and how the development of picture comprehension varies depending on the kind of picture (i.e., photographs, clipart, line drawings).

4.3 | Exploratory Analyses–Learning From Pictures

In exploratory analyses that examined the association between picture book exposure and word learning by residency status (urban vs. rural), we found that the associations differed across these settings. When controlling for residency location we found that there was a positive association between looking at picture books and word learning. When looking at children in urban and rural locations separately, we found that urban toddlers' success at learning a word for a picture was positively related to how frequently they looked at picture books with their caregivers, after controlling for other measures of caregiver-child interaction and caregiving environment variables (i.e., caregiver talk, caregiver play, number of toys, maternal education). In contrast, in the rural Rachuonyo sample, rural toddlers' success at learning a word for a picture was not related to how frequently they looked at picture books with their caregiver, or any other environmental variables. We caution against making strong inferences from these exploratory results, which have relatively small sample sizes, and emphasize the need for further research replicating and extending the current work.

Nonetheless, this exploratory result with urban Kisumu toddlers may provide some within-culture evidence for an association between experience with pictures and toddlers' ability to learn from pictures in certain environments. Early environmental variation, specifically in terms of children's experience with pictures, may lead to differing developmental trajectories in children's picture comprehension. In turn, variation in children's picture comprehension may be associated with further variation in the efficacy of learning materials and validity of assessment tools used in global contexts. In our entire sample, the large majority of caregivers (91%) reported looking at picture books with their children at least once in the past week, whereas in the pilot data, only half of primary caregivers (53%) reported looking at picture books with their child in the past week. This may skew the distribution of the picture experience variable. Similar to the data that demonstrated that most caregivers in our sample reported daily talk with their child, this data may be driven by desirability bias, or the current sample may simply not have much variation in our chosen measure of picture experience. More work on early picture comprehension across cultures and contexts is required to investigate the robustness and generalizability of our initial results.

Additionally, we found a tentative association between toddlers' ability to learn a word for a picture and the frequency with which they looked at picture books in urban, but not rural, toddlers. One possible explanation is that urban and rural caregivers may have differing ways of looking at picture books with their toddlers (e.g., having back-and-forth conversations about the pictures, reading stories that accompany the pictures, simply looking at the pictures without any conversation). Just as the quality, rather than the quantity, of child-directed speech can be more strongly related to children's language outcomes (Anderson et al. 2021), it is possible that the quality, rather than the quantity, of caregivers' picture book interactions with children might be associated with children's capacity to understand and learn from pictures. The current research only measured the quantity of caregiver-child picture experiences, but future research might consider investigating the quality of caregiver-child picture experiences as

well. Another possible explanation, put forth by local research assistants from these communities, is that rural toddlers may be receiving more input from people other than their primary caregivers. In some cultures and contexts, children may rely primarily on siblings and peers, rather than parents, for teaching (Lew-Levy et al. 2020, 2023; Maynard 2002). Consequently, the primary caregiver questionnaire used in the present study might better capture the experiences of toddlers growing up in urban environments. Just as pictures may be inappropriate research tools in some contexts, primary caregiver questionnaires may also be inappropriate research tools in rural contexts with larger caregiving networks. However, these ideas remain speculative, and more theoretical and empirical work is necessary to develop a comprehensive framework of caregiving across cultures and contexts (Gopnik 2023). Indeed, recent work has begun to investigate the role of other caregivers (e.g., grandparents) in global child development (Cuartas et al. 2020). Consequently, more detailed information about these global contexts might help strengthen researchers' understanding of child development within these contexts.

Moreover, rural Rachuonyo toddlers fussed out of the study more frequently than their urban Kisumu counterparts (13 Rachuonyo fuss-outs vs. three Kisumu fuss-outs). Consequently, it is possible that if the children that were excluded from the sample had performed more poorly on the tasks than those that were included, the current sample would overestimate rural toddlers' performance. We did not collect parent questionnaires from the toddlers who fussed out, since fuss-outs were not included in our preregistered sample or analysis. However, it is possible that the toddlers who fussed out may have had different early experiences (e.g., differing experiences with pictures or general caregiver interactions) from toddlers who participated. Thus, future research might consider including data from toddlers who fussed out in the analyses. Overall, more work is required to investigate the differences in our initial findings between the urban Kisumu and rural Rachuonyo toddlers.

4.4 | Summary

Overall, our results contribute a valuable open dataset with young children from global contexts, and provide some preliminary evidence for the hypothesis that early picture experience relates to effective learning from pictures. While Preissler and Carey (2004) found that upper-middle-class U.S. toddlers performed at near-ceiling levels on a picture-based word learning task, we found substantial variation in performance on a similar task amongst toddlers growing up in two small communities in western Kenya near Kisumu. Our results confirm these previous findings suggesting differences in picture understanding across cultures (Callaghan et al. 2011; Callaghan, Rochat, and Corbit 2012; Walker, Walker, and Ganea 2013), using two measures (i.e., measures of picture-based word learning and referential understanding of pictures). Therefore, these results reinforce the message that picture-based experimental paradigms may produce inaccurate measurements in global early childhood research. Moreover, the results also suggest that variation in performance on picture-based paradigms may be due to picture experience, given the exploratory results with urban children demonstrate a positive association between children's picture experience and performance on a picture-based word learning task. Still, more research is required to determine to what extent these cross-cultural differences are due to picture experience, as compared to differences in other factors (e.g., task pragmatics, linguistic translations), as well as how helpful interventions involving increased picture experience might be in changing children's performance in tasks involving pictures in global early childhood contexts. Indeed, the current research is not without limitations. Participants in the urban and rural samples were recruited in different ways (i.e., through the phone from an existing participant database and through community health volunteers networking, respectively), which might potentially introduce bias in the participant samples. Moreover, the current study used only one paradigm, and the paradigm's measure of referential understanding only generated one data point per child, leading to relatively less power than paradigms using multiple trials per child (e.g., Callaghan et al. 2011). Moreover, we made a preregistered decision not to correct for multiple comparisons, which may inflate the significance of the results. Consequently, more converging evidence from different experimental paradigms would strengthen the claims that the development of picture comprehension varies across cultures and contexts. Thus, future research should investigate the extent to which our current findings are replicable and generalizable (e.g., to other age ranges and early environmental contexts). Moreover, to establish a stronger causal link, one possible future direction is to conduct experimental training studies with children, either within a single session or across many sessions longitudinally (Callaghan and Rankin 2002). For example, caregiver-child intervention sessions geared around dialogic reading may change how toddlers learn from pictures.

Accurate assessment of child development is crucial in order to understand the determinants and distribution of development outcomes in populations, and to evaluate and refine policies and interventions designed to improve global developmental outcomes. The results of this research might help determine that we should have reasonable confidence in the current picture-based learning materials and assessment tools. However, the results of these studies also might, on the contrary, suggest that important changes are required to adapt and validate these materials and tools. Thus, this work could shape research and policy through its impact on curriculum development and intervention design, by informing how learning content is delivered and how assessments are conducted. If we find that success on tasks involving pictures is related to early experience with picture books, there are several kinds of policy suggestions we might make. For example, at the school and national levels, if current curricula rely on pictures, we may suggest that teachers dedicate class time to helping young students begin to interpret pictures and other visual symbols before using learning materials involving pictures. We might also design interventions that promote engagement with picture books at scale. There is a promising example of a dialogic reading intervention in rural western Kenya that may be a starting point for promoting picture book exposure in young children (Knauer et al. 2020). Moreover, at the global level, we may recommend that researchers measuring children's cognitive abilities in communities with fewer pictures use assessment tools that involve actual objects rather than pictures, so that confusion with pictures does not mask children's cognitive competencies. The results of this research thus promise to improve early childhood development interventions and policies, and thus positively impact millions of children worldwide.

This study contributes towards a larger call for a more global developmental science (Singh, Rajendra, and Mazuka 2022; Singh et al. 2023). In particular, conducting more work on the development of picture comprehension across cultures and contexts is an interesting and consequential future direction for both basic cognitive science and applied educational research. For example, this research brings more data to bear on the question of how and when children worldwide begin to perceive, interpret, understand, and use pictures. In particular, the current research provides an open dataset demonstrating some early diversity in the developmental trajectories of picture comprehension across cultures and contexts. Moreover, given that classroom learning materials and early cognitive assessment tools often involve pictures, this research could help teachers, researchers, and policy-makers determine the most effective learning materials and valid assessment tools for children from diverse backgrounds.

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The study materials, anonymized data, and R code for the main study and the pilot study will be made public through the Open Science Framework.

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Appendix A

Study Stimuli

Note: Items with outlined boxes (e.g., chicken, flower) were presented as pictures, whereas items without outlines (e.g., ball, cup) were presented as objects.

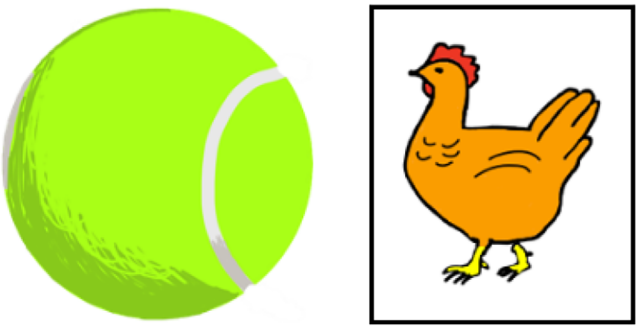

FIGURE A1 | Instruction: Show me a chicken. (Luo Translation: *Siemna gueno.)*

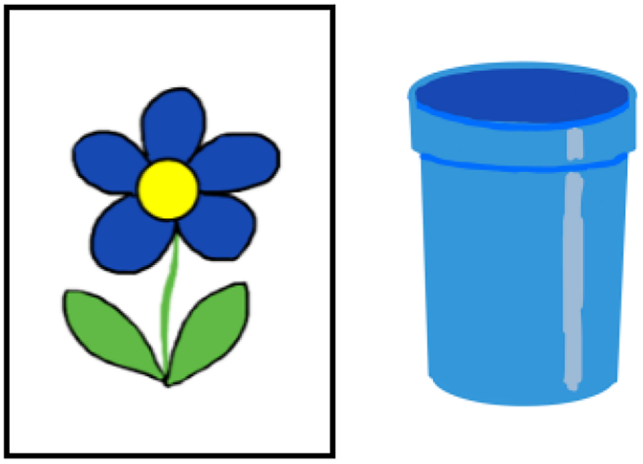

FIGURE A2 | Instruction: Show me a flower. (Luo Translation: *Siemna maua*.)

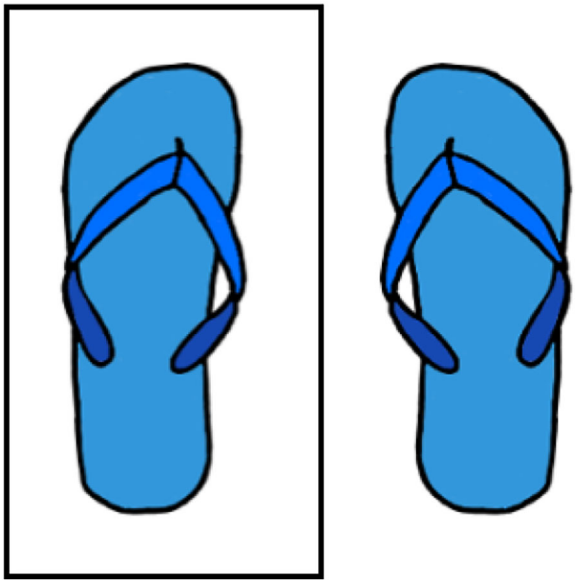

FIGURE A3 | Instruction: Show me a shoe. (Luo Translation: *Siemna apato*.)

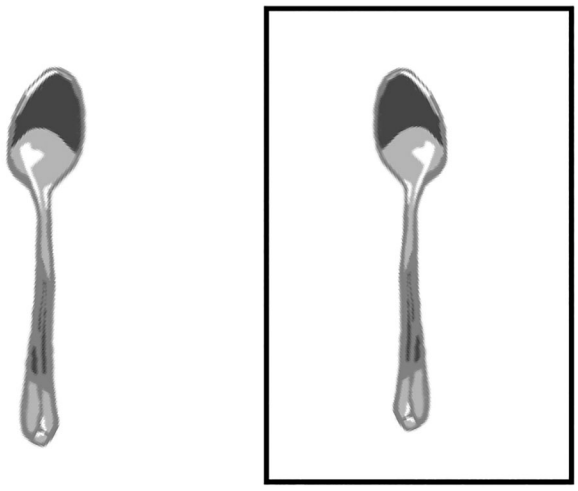

FIGURE A4 | Instruction: Show me a spoon. (Luo Translation: *Siemna ojika*.)

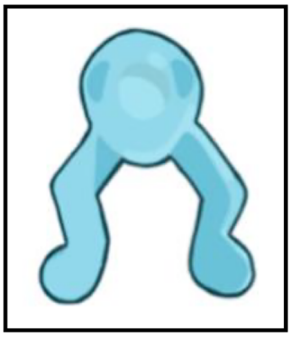

FIGURE A5 | Instruction: This is a dax. Can you touch the dax? (Luo Translation: *Mae iluongoni dax. Inyalo mulo dax?)*

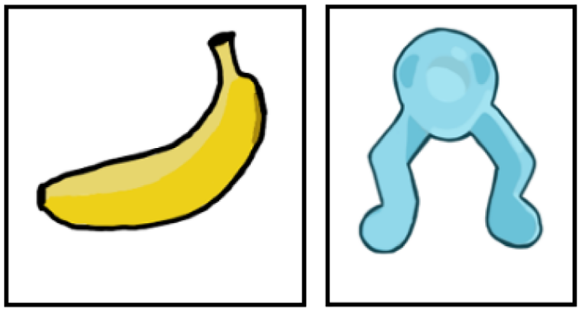

FIGURE A6 | Instruction: Show me a dax. (Luo Translation: *Siemna dax.*)

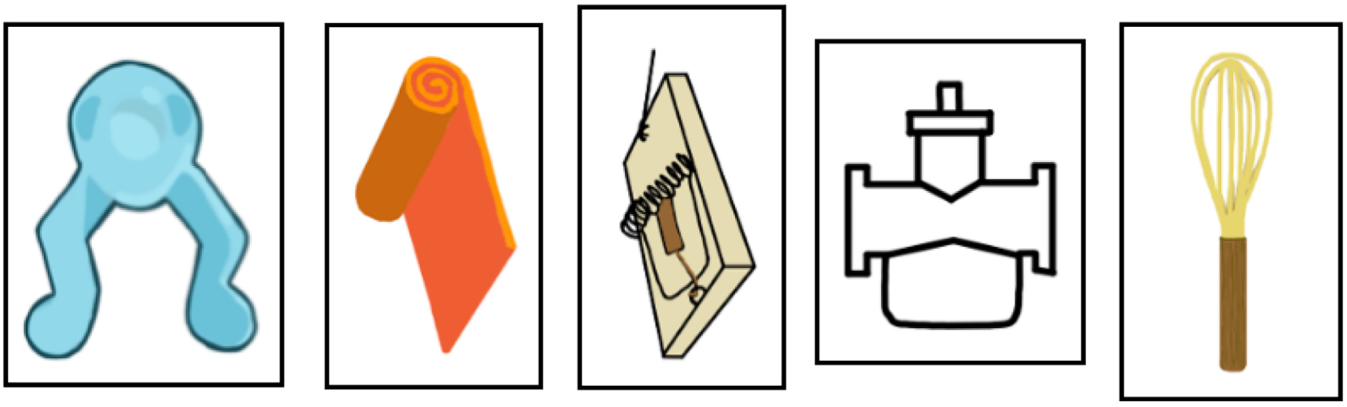

FIGURE A7 | Instruction: Show me a dax. (Luo Translation: *Siemna dax.*)

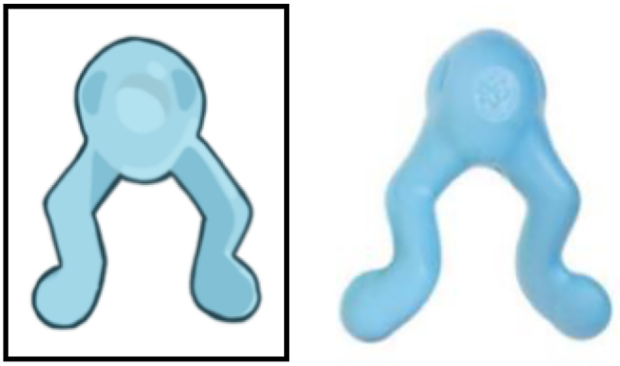

FIGURE A8 | Instruction: Show me a dax. (Luo Translation: *Siemna dax.*)

Appendix B

Caregiver Questionnaire

Picture Experience

1. In the past week, how many days did you look at picture books with your child? (0–7 days)
2. Do you have picture books in your home? If yes…
   - 2A. How many? (any number)
   - 2B. Do any of the picture books contain photographs? (yes/no)
   - 2C. Do any of the picture books contain cartoons/clipart? (yes/no)
   - 2D. Do any of the picture books contain line drawings? (yes/no)
   - 2E. Do any of the picture books contain pictures of animals? (yes/no)
   - 2F. Do any of the picture books contain pictures of vehicles? (yes/no)
   - 2G. Do any of the picture books contain pictures of objects? (yes/no)
   - 2H. Do any of the picture books contain pictures of plants? (yes/no)
   - 2I. Do any of the picture books contain pictures of food? (yes/no)
   - 2J. Do any of the picture books contain pictures of toys? (yes/no)
3. Does your house have pictures / posters / paintings / calendars on the wall? (yes/no)
4. Do you have a television in your home? (yes/no)
5. What do you think your child knows about pictures? (open-ended)

Additional Variables

6. In the past week, how many days did you play with your child? (0–7 days)
7. How many years of school have you [the mother] completed? (no formal school education, under 7 years of formal education–equivalent to primary school, or over 7 years of formal education–equivalent to some secondary school or university)
8. How many toys does the child have in the home? (any number)
9. In the past week, how many days did you talk to your child, even when you were busy? (0–7 days)

Additional Daycare Questions

10. Does your child go to daycare center that has picture books? If yes…
    - 10A. How many? (any number)
    - 10B. Do any of the picture books contain photographs? (yes/no)
    - 10C. Do any of the picture books contain cartoons/clipart? (yes/no)
    - 10D. Do any of the picture books contain line drawings? (yes/no)
    - 10E. Do any of the picture books contain pictures of animals? (yes/no)
    - 10F. Do any of the picture books contain pictures of vehicles? (yes/no)
    - 10G. Do any of the picture books contain pictures of objects? (yes/no)
    - 10H. Do any of the picture books contain pictures of plants? (yes/no)
    - 10I. Do any of the picture books contain pictures of food? (yes/no)
    - 10J. Do any of the picture books contain pictures of toys? (yes/no)
11. If you child goes to daycare, does the daycare have pictures / posters / paintings / calendars on the wall? (yes/no)
12. Does the daycare have a television? (yes/no)

Appendix C

Supporting table

Variable	Urban Kisumu ($n = 64$)	Rural Rachuonyo ($n = 64$)	Total ($n = 128$)
Learned word for picture[a]	53.1% ($n = 34$)	45.3% ($n = 29$)	49.2% ($n = 63$)
Referential understanding[b]	29.7% ($n = 19$)	29.7% ($n = 19$)	29.7% ($n = 38$)
Frequency of looking at picture books with primary caregiver (number of days in past week)	2.50 (1.89) range = 0–7	3.33 (2.05) range = 0–7	2.91 (2.00) range = 0–7
Frequency playing with of caregiver (number of days in past week)	5.31 (2.16) range = 0–7	4.94 (2.11) range = 1–7	5.13 (2.14) range = 0–7
Frequency of caregiver talking to child even when busy (number of days in past week)	5.77 (1.81) range = 1–7	6.03 (1.60) range = 2–7	5.90 (1.71) range = 1–7
Number of toys in the home	8.03 (19.25) range = 0–150	4.39 (5.39) range = 0–35	6.21 (14.20) range = 0–150
Maternal education (years)	10.50 (2.83) range = 5–16	9.28 (2.46) range = 3–15	9.89 (2.71) range = 3–16
Less than 8 years of education (primary or less)	34.4% ($n = 22$)	57.8% ($n = 37$)	46.1% ($n = 59$)
Nine or more years (started secondary or more)	65.6% ($n = 42$)	42.2% ($n = 27$)	53.9% ($n = 69$)

Note: Data presented with either % (n) or mean (SD).

[a]Children succeeded in selecting the dax in both three dichotomous choice trials in a row and the five novel pictures trial.

[b]Children either selected only the object, or both the object and the picture.