

Investigating children's performance on vocabulary assessments involving object and picture stimuli in global contexts: Evidence from Kisumu, Kenya

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Abstract

The most common assessments of early cognitive and linguistic abilities typically involve pictures stimuli. As these assessments spread worldwide, researchers make an implicit assumption: that children across contexts understand pictures in the same way, at the same developmental timepoint. What if this assumption does not hold for some or all kinds of pictures? In the present research, a preregistered sample of 128 3- to 7-year-olds from Kisumu, Kenya participated in a Swahili vocabulary assessment. Using a within-subjects design, each participant completed vocabulary trials in four formats (i.e., objects, photographs, cartoons, black-and-white line drawings). Preregistered analyses showed that children performed equally accurately across object, photograph, and cartoon formats, but less accurately in the black-and-white line drawing format. However, further exploratory analyses suggested that a subset of black-and-white drawings drove this difference. These findings suggest that caution is necessary in the use of picture stimuli and that assessments involving line drawings may sometimes underestimate children's capacities.

Keywords: cognitive development, picture comprehension, cross-cultural research, measurement

Humans possess remarkable, and potentially species-unique, capacities to understand and use various kinds of visual media (e.g., pictures, videos, scale models, maps). In particular, previous research shows that high-income children growing up in Western contexts understand pictures early in development. For example, high-income U.S. toddlers know that pictures refer to actual objects in the world (Preissler & Carey, 2004) and appreciate the role of intention when interpreting pictures (Gelman & Ebeling, 1998). Moreover, children in these settings can learn novel concepts from picture books and apply these concepts to actual entities (Ganea, Ma, & DeLoache, 2011). But how do these abilities develop?

While many cognitive scientists argue that some kind of experience with pictures is necessary for the picture comprehension (DeLoache, Pierroutsakos, & Uttal, 2003; Zhu et al., 2025), it is unclear exactly what quality and quantity of picture experience facilitates this development. One possibility is that only minimal picture experience is necessary for the development of full comprehension, and thus that children across diverse environments understand pictures in similar ways, at similar developmental timepoints. Another possibility is that more extensive picture experience (e.g., being surrounded by picture books, television screens, billboards, posters) is necessary for the development of full comprehension, and thus that children living in environments without many picture books

or other visual media understand pictures at a later timepoint than their counterparts living in environments with an abundance of pictures. Since children growing up in high-income, urban contexts typically all possess extensive picture experience, cognitive scientists must work with global populations to explore possible consistency or diversity in children's developing capacities to understand and learn from pictures.

Moreover, the most widely used learning materials (e.g. books, posters) and assessments of early cognitive and linguistic abilities use picture stimuli (Fernald, Prado, Kariger, & Raikes, 2017). As these materials and assessments spread across the world, researchers make the implicit assumption that children across contexts understand pictures in the same way, at the same developmental time point. What if this assumption does not hold? Differences in picture comprehension can change the efficacy of learning materials and the validity of assessments (Draper et al., 2022; Jukes et al., 2024). Thus, it is also important to investigate when and how children understand pictures across cultures and contexts to determine how to appropriately translate learning materials and assessments globally.

Indeed, there is already some evidence that picture-based assessments may underestimate children's capacities, in some global contexts (Callaghan et al., 2011; Walker, Walker, & Ganea, 2013; Zhu, Kilonzo, Engelmann, & Gopnik, 2024). For example, preschoolers living in rural environments in India (i.e., a village 70 kilometers from Vijayawada, Andhra Pradesh) and Peru (i.e., a village in the rural Montaro Valley area of the Central Highlands) performed more accurately on a false belief task when the task was presented using objects rather than black-and-white line drawings (Callaghan et al., 2011). Similarly, young toddlers living in a rural village in the Kibaha-Pwani District of Tanzania's Coast Region do not map a novel word to a novel photograph, but succeed in mapping a novel word onto a novel object (Walker et al., 2013). Moreover, low- to middle-income 2- to 7-year-olds in their first month of formal schooling living in Mombasa County, Kenya (i.e., a mix of urban and rural areas) performed significantly more accurately on an object-based vocabulary assessment than on a cartoon-based vocabulary assessment. In contrast, high-income urban and suburban 2- and 3-year-olds living in the San Francisco Bay Area, U.S. performed equally accurately on object-based and cartoon-based vocabulary assessments (Zhu et al., 2024). Furthermore, in a sample

of toddlers living in urban Kisumu, Kenya, variation in toddlers' early picture experience is related to variation in toddlers' ability to learn from pictures (Zhu et al., 2025). Thus, this data suggests that assessments involving pictures may underestimate children's capacities in some global contexts.

However, more work is necessary to investigate the generalizability of these initial findings. For example, it is unclear if these initial findings, which were either conducted with young toddlers and preschoolers (Callaghan et al., 2011; Walker et al., 2013; Zhu et al., 2025) or children in their very first month of formal schooling (Zhu et al., 2024), might generalize to older children with more formal schooling experience, and thus likely also more picture experience. Determining whether assessments involving pictures are appropriate for children who have already completed some formal schooling will provide insight into whether researchers and policy-makers need to adapt assessments for many children in global contexts, or perhaps only the youngest learners.

Moreover, previous cross-cultural work on children's picture comprehension contrasted object-based tasks with only one other kind of picture-based task (i.e., photographs, black-and-white line drawings) (Callaghan et al., 2011; Walker et al., 2013; Zhu et al., 2024). However, different kinds of picture stimuli may pose various advantages and disadvantages for young children's understanding of pictures (Pierroustakos & DeLoache, 2003; Simcock & DeLoache, 2006). For example, color photographs or cartoons may be easier for children to understand and learn from, because they are more perceptually similar to objects than black-and-white line drawings (Ganea et al., 2011). However, black-and-white line drawings may be more culturally neutral than color photographs or clipart, as the former typically depict fewer contextually salient features (e.g., skin color). Thus, the present experiment contrasted objects with three common picture formats (i.e., photographs, cartoons, black-and-white line drawings), to explore whether possible differences between object and picture stimuli hold for multiple kinds of picture formats.

Methods

Open Science Statement

Preregistration, materials, deidentified data, and analysis scripts are publicly available.

Participants

A preregistered sample of 128 Kisumu children ($M = 5.39$ years; range = 3.01-7.99 years; 58 girls, 70 boys; 92% attending daycare/school; $M = 2.48$ years in daycare/school, range = 0-7 years in daycare/school) participated in a Swahili vocabulary assessment. Researchers tested two additional children whose data were excluded due to fussiness (one child) or experimenter error (one child).

Kisumu is the third largest city in Kenya, and a relatively small metro region containing a population of approximately one million individuals. The majority of Kisumu households are classified as low or middle socioeconomic status, with

substantial variation in income levels and access to basic household assets (Were et al., 2022). Thus, Kisumu children are likely to have more variation in their picture experiences, compared to U.S. convenience samples.

Children were recruited from a local database maintained by a local non-profit organization, the Safe Water and AIDS Project (SWAP), and participated in the experiment in a quiet room at the SWAP office. The experiment was approved by a U.S. university's Committee for the Protection of Human Subjects, as well as by the Kenya Medical Research Institute (KEMRI), the National Commission for Science, Technology, and Innovation (NACOSTI), and the local Kisumu County government. All parents of child participants provided informed consent.

Stimuli & Procedure

We designed a Swahili vocabulary task involving four blocks, each presented in a different format (e.g., objects, photographs, cartoons, black-and-white line drawings). Each block consisted of four trials, leading to a total of sixteen trials. The order of the blocks, as well as the order of the trials within each block, was semi-randomized across participants.

Target words were selected from Swahili Communicative Development Inventory (CDI) production data from two communities in Coastal Kenya (Alcock et al., 2015). We used CDI production data, rather than comprehension data, because there the former had more items and less noise in the data. We found approximately 76 viable words (i.e., typically artifact nouns) in the Swahili CDI. We split these words into four quartiles by age of acquisition. Each block included one target word from each of the four quartiles, ensuring that the four blocks were relatively similar in difficulty.

In addition to the target word, each array consisted of one near distractor and two random distractors. Near and random distractors were all artifacts that Kisumu children were relatively familiar with. Many distractors were items on the Swahili CDI (Alcock et al., 2015) or used in previous research with Kenyan preschoolers (Zhu et al., 2024). Furthermore, local SWAP employees again confirmed that all artifacts were familiar to Kisumu children. Similarity scores were calculated through correlations from the THINGS database (Hebart et al., 2019). Near distractors were conceptually similar to, and had high correlations with, target items (average correlation = 0.82, range = 0.66-0.95). Random distractors were less conceptually similar to, and had lower correlations with, target items (average correlation = 0.36, range = 0.17-0.53).

Using a within-subjects design, each participant completed all sixteen vocabulary trials. Across participants, each target word was presented in all four formats an equal number of items. On each trial, a local experimenter presented children with either a laminated piece of paper depicting four objects, or a tray with four objects (see Fig. 1) and prompted the participant to select one of the four items (e.g., "Nionyeshe mswaki", meaning "Show me a toothbrush" in Swahili). Within each block, the placement of the target item was counterbalanced across trials. For a full list of target and

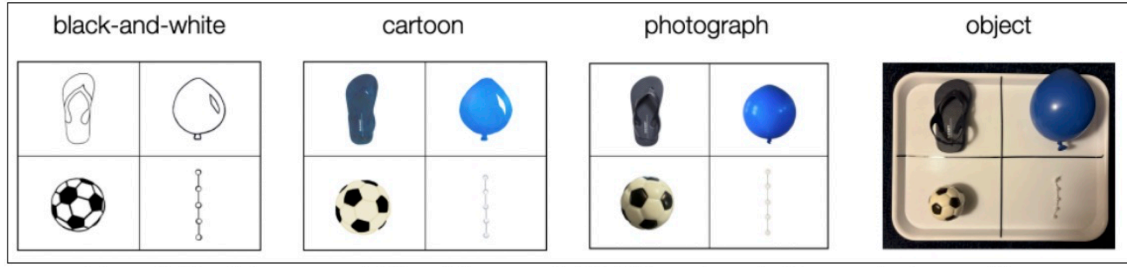


Figure 1: Stimuli for a noun trial (Show me the ball / Nyoneshi mpira) across the four conditions.

distractor items, see Table 1.

Results

Confirmatory Analyses

We fit generalized linear mixed-effects models to children's scores to assess the factors that influenced their response accuracy. A first preregistered mixed-effects model was fit to the response scores (accurate/inaccurate), including fixed effects for format (object/photograph/cartoon/black-and-white line drawing). We initially planned to include random slopes for the effect of condition on each child, and condition on each item. However, the model with this random effects structure failed to converge; per lab standard operating procedures, the reported model used the maximal random effects structure that did converge, which included random intercepts for each child and item. The model yielded a main effect of format, such that children were more accurate in the object format than the black-and-white line drawing format ($\hat{\beta} = -0.44$, 95% CI $[-0.78, -0.10]$, $z = -2.55$, $p = .011$). There was no difference between children's accuracy in the object format and the photograph format ($\hat{\beta} = 0.00$, 95% CI $[-0.34, 0.34]$, $z = -0.01$, $p = .994$), or in the object format and the cartoon format ($\hat{\beta} = -0.11$, 95% CI $[-0.45, 0.23]$, $z = -0.65$, $p = .517$).

We also ran a second preregistered mixed-effects model including child age as an additional variable. This second mixed-effects model was fit to the response scores (accurate/inaccurate), including fixed effects for format (object/photograph/cartoon/black-and-white line drawing) and age (in years), and the interactions between format and age. We initially planned to include random slopes for the effect of condition on each child, and the three-way interaction between condition, age, and item. However, the model with this random effects structure again failed to converge, and the reported model used the maximal random effects structure that did converge, which included random intercepts for each child and item. The model yielded a main effect of age, such that older children were more accurate ($\hat{\beta} = 0.58$, 95% CI $[0.39, 0.77]$, $z = 6.03$, $p < .001$), and a main effect of format, such that children were more accurate in the object format than the black-and-white line drawing format ($\hat{\beta} = -0.48$, 95% CI $[-0.82, -0.14]$, $z = -2.74$, $p = .006$). There was a significant interaction between the

black-and-white line drawing format and age, such that the accuracy difference between the object and black-and-white line drawing formats was greater for older than younger children ($\hat{\beta} = -0.31$, 95% CI $[-0.56, -0.06]$, $z = -2.47$, $p = .014$). All other main effects and interactions were not significant (all p 's $> .20$).

Exploratory Analyses

Response accuracy was lowest in the black-and-white condition on only 6 out of 16 items, with extremely low response accuracy in the black-and-white condition on 3 out of 16 items (i.e., "book", "button" and "fork"; see Fig. 3). Thus, in order to explore the model using the maximal random effects structure accounting for more item-level variation, which did not converge in the preregistered regressions, we also conducted exploratory Bayesian analyses. We analyzed the data with the brms R package (Bürkner, 2017) using the default flat priors. Each model underwent a warm-up period of 1000 iterations, followed by four sampling chains with 2000 iterations each.

A first exploratory Bayesian mixed effects model was fit to the response scores (accurate/inaccurate), including fixed effects for format (object/photograph/cartoon/black-and-white line drawing), and random slopes for the effect of condition on each child, and condition on each item. The Bayesian model converged, Gelman-Rubin statistic = 1.00. There was no difference in performance between object and photograph formats ($\text{emmeans} = .13$, 95% credible interval $[-.75, 1.10]$), or object and cartoon formats, $\text{emmeans} = .54$, 95% credible interval $[-.20, 1.35]$.

We also ran a second exploratory Bayesian mixed-effects model including child age as an additional variable. This second mixed-effects model was fit to the response scores (accurate/inaccurate), including fixed effects for format (object/photograph/cartoon/black-and-white line drawing) and age (in years), and random slopes for the effect of condition on each child, and the three-way interaction between condition, age, and item. This Bayesian model also converged, Gelman-Rubin statistic = 1.00. Once again, there was no difference in performance between object and photograph formats, $\text{emmeans} = .15$, 95% credible interval $[-.78, .44]$, object and cartoon formats, $\text{emmeans} = .05$, 95% credible interval $[-.70, .74]$, or object and black-and-white line

	Target Item (Swahili)	Near Distractor	Random Distractor	Random Distractor
Set 1	Comb (Kichana)	Brush	Watch	Bracelet
	Shoe (Kiutu)	Sock	Medicine	Telephone
	Chalk (Chaki)	Crayon	String	Handkerchief
	Fork (Uma)	Spoon	Straw	Necklace
Set 2	Cup (Kikombe)	Bottle	Soap	Boots
	Shirt (Shati)	Hat	Eraser	Bucket
	Scissors (Makasi)	Knife	Bag	Bib
	Button (Kifungo)	Stone	Stick	Shovel
Set 3	Book (Kitabu)	Paper	Jeans	Coat
	Bowl (Bakuli)	Plate	Pants	Scarf
	Box (Sanduku)	Basket	Bottle Cap	Key
	Shorts (Kaptula)	Dress	Clock	Remote Control
Set 4	Ball (Mpira)	Balloon	Earring	Sandal
	Toothbrush (Mswaki)	Toothpaste	Mirror	Bead
	Sweater (Sweta)	Skirt	Glasses	Toilet Paper
	Pencil (Penseli)	Pencil Sharpener	Towel	Zipper

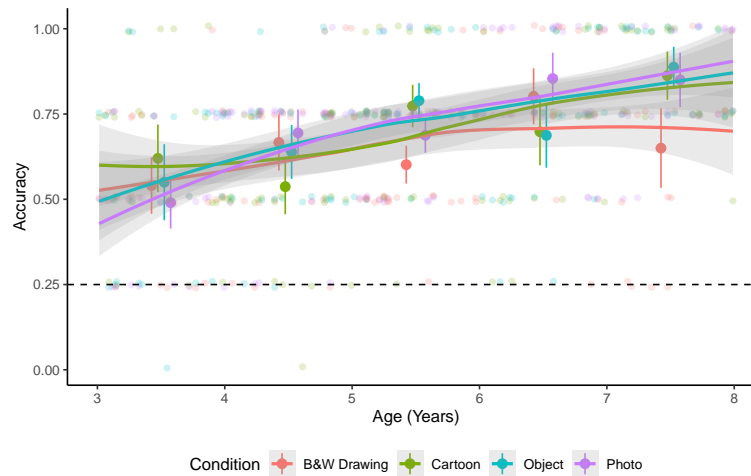


Figure 2: Proportion of accurate responses across conditions and age.

drawing formats, emmeans = .62, 95% credible interval [-.07, 1.31].

We then ran Bayesian analyses with the same random effects structure as the convergent preregistered models. Thus, a third exploratory Bayesian mixed effects model was fit to response scores (accurate/inaccurate), including a fixed effect for format (object/photograph/cartoon/black-and-white line drawing) and random intercepts for each child and item. The Bayesian model converged, Gelman-Rubin statistic = 1.00. There was no difference between object and photograph formats, emmeans = .0005, 95% credible interval [-.37, .34] or object and cartoon formats, emmeans = .12, 95% credible interval [-.22, .47]. However, there was a significant difference between object and black-and-white line drawing formats, emmeans = .45, 95% credible interval [.08, .80].

A fourth exploratory Bayesian mixed effects model was fit to response scores (accurate/inaccurate), including a fixed effect for format (object/photograph/cartoon/black-and-white

line drawing) and age (in years), and random intercepts for each child and item. This Bayesian model also converged, Gelman-Rubin statistic = 1.00. There was no difference between object and photograph formats, emmeans = -.02, 95% credible interval [-.37, .34] or object and cartoon formats, emmeans = .12, 95% credible interval [-.25, .46]. However, there was a significant difference between object and black-and-white line drawing formats, emmeans = .48, 95% credible interval [.15, .84]. Consequently, the difference between children's accuracy on objects and black-and-white line drawings is reliable, providing further support that the random effect structure changes the significance of the effect.

Discussion

The present experiment investigated whether young children in urban Kisumu, Kenya performed equally accurately on vocabulary assessments involving objects and three kinds of pictures (i.e., photographs, cartoons, black-and-white line

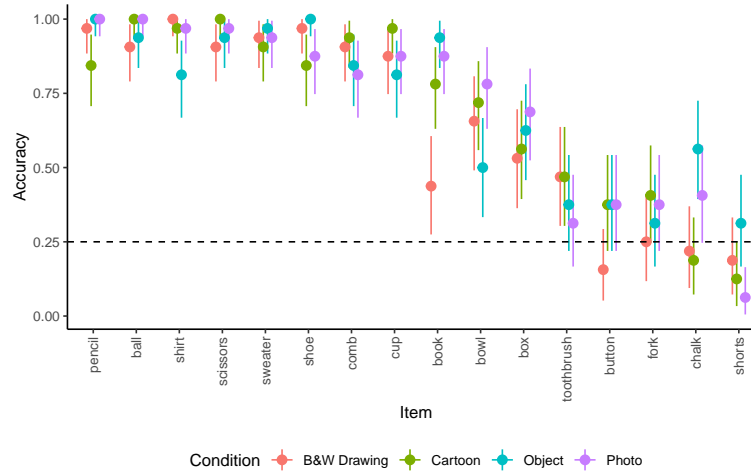


Figure 3: Response accuracy by item and condition. Error bars are binomial 95% confidence intervals.

drawings). Preregistered analyses suggest that young children in this context perform equally accurately on vocabulary assessments involving objects, photographs, and cartoons, but less accurately on assessments involving black-and-white line drawings. However, further exploratory Bayesian analyses with a full random effects model did not find significant differences in children’s response accuracy between vocabulary assessments involving objects, photographs, cartoons, and black-and-white line drawings. These exploratory analyses may suggest that the accuracy difference between object-based and black-and-white line drawing-based assessments is not consistent across items, but rather driven by specific items. Consequently, the present experiment tentatively suggests that assessments involving black-and-white line drawings may underestimate the capacities of Kisumu children already attending daycare or formal schooling, whereas cartoon- and photograph-based assessments may be valid assessments in this population.

More data and more item diversity are required in order to conclude that the accuracy difference between object-based and black-and-white line drawing-based assessments is generalizable. It is possible that this accuracy difference between objects and black-and-white line drawings only appears for some kinds of black-and-white line drawings (e.g., particularly ambiguous depictions), or that the black-and-white line drawings used in the present experiment were particularly difficult for an idiosyncratic reason. Thus, future research should attempt to replicate this accuracy difference between assessments involving objects and black-and-white line drawings with a new sample of items, to better understand whether the present finding is generalizable across items, or driven by stimulus specificity effects.

Furthermore, what variables might account for the differences between our present findings that Kisumu preschoolers perform equally accurately on object-, photograph-, and cartoon-based assessments, compared to previous find-

ings that Mombasa preschoolers, as well as toddlers and preschoolers in other global contexts, perform more accurately on object- than photograph- and cartoon-based assessments (Walker et al., 2013; Zhu et al., 2024)? One possibility is that formal schooling may drive the discrepancy between our present findings and previous findings. Many of the children in the present study already attend daycares and schools, and these additional learning contexts may provide children with more opportunities to access picture books and other kinds of visual media, or to discuss pictures and other kinds of visual media with teachers or peers.

Another possibility is that the children in the present study are simply older than in previous studies. Specifically, we worked with 3- to 7-year-olds, (average age of approximately 5.5 years), whereas other studies worked with 2-year-olds (Walker et al., 2013) and 2- to 7-year-olds, with an average age of approximately 4.5 years (Zhu et al., 2024). Older children may have more experiences with pictures overall, and thus perform more accurately on picture-based assessments.

A third possibility is that there is something distinct about Kisumu, such that work from other Kenyan contexts (i.e., Mombasa County) does not generalize to Kisumu. Indeed, Kisumu is substantially more urban than some, though not all, previously researched global contexts, such as rural India and Peru (Callaghan et al., 2011) and rural Tanzania (Walker et al., 2013). In general, we caution that not all global contexts are the same, and do not readily generalize to each other. Instead, it is more fruitful to articulate specific variables which may vary across and within contexts, and thus drive variation in behavior (Bohn, Fong, Pope-Caldwell, Stengelin, & Haun, 2024).

Thus, while the present research suggests that picture-based assessments are indeed valid measurements in some global contexts, future work should search for more detailed mechanistic explanations about the development of picture comprehension. Specifically, it is still unknown what quality and

quantity of picture experience training facilitates the development of picture comprehension.

Moreover, it is unclear whether U.S. children might perform similarly to their Kisumu counterparts across object- and picture-based conditions. Indeed, while previous research with toddlers and preschoolers in Berkeley, California suggest that high-income U.S. children perform equally accurately on vocabulary assessments involving objects and cartoons (Zhu et al., 2024), it is unclear whether high-income U.S. children also show no performance difference across other kinds of picture formats. Thus, more research on picture comprehension, and possible differences in performance across picture- and object-based tasks, is required not only in understudied global contexts, but also Western convenience samples.

Overall, the present findings contribute to more confidence in the current assessments used in global contexts, particularly contexts where children may possess highly variable amounts of picture experience. However, much more future research is required to determine in exactly which contexts picture-based assessments are valid or invalid. Ultimately, this research will contribute to the development of more inclusive and effective curricula for children worldwide, as well as more appropriate evaluation of policies and programs to improve early child outcomes and educational trajectories.

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