

RESEARCH ARTICLE

Children's individual interests are sustained across development and predict later vocabulary development

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Abstract

While previous studies highlight the role that children's interest in natural categories predicts their learning of new label-object associations in these categories, the long-term implications of such a relationship – the extent to which children's interest shapes lexical development – remain unclear. The current study examines whether children's interests in different natural object categories predict their subsequent interest and the number of words children know in those categories 6 months later. Using data from 67 children tested at 18 and 24 months of age, we found that parents' estimates of interest in natural object categories at 18 months predicted their reports of their child's interests at 24 months. Parent interest reports at 18 months also predicted the number of words that children are reported to know in that category at 24 months. Taken together, this study documents the longitudinal relationship between children's interests, parents' awareness of their children's interests, and later vocabulary development.

Keywords: vocabulary development; longitudinal study; eye-tracking; category interest; parent questionnaires

1. Introduction

Young children frequently become fascinated with certain items or objects in their environment, and often display extensive knowledge about these objects (e.g., Chi & Koeske, 1983; DeLoache et al., 2007). Children's individual interests have been shown to boost learning and retention of novel word-object associations (Ackermann et al., 2020, 2023) as well as influence the quality of parent–child interactions (Madhavan & Mani, 2024). While such individual interests have been documented from around 2 years of age, the development, consistency, and impact of such individual interests in early development remain to be determined. Against this background, the current study aims to document the development of infants' interests and their relationship to longitudinal vocabulary development, that is, to examine the extent to which emerging

interests at an early stage in life predict the establishment of later documented well-developed interests and interest-specific vocabulary knowledge. In what follows, we first define what we mean by the term interest and how children's interests have been, thus far, documented to influence cognitive and social development, followed by a short review of children's vocabulary development and variability in children's lexical knowledge.

1.1. Defining interest and its role in infant development

The definition of the term interest in cognitive science is quite varied; indeed, oftentimes, the term interest has been used interchangeably with the concept curiosity (Bowler, 2010; Grossnickle, 2016). In keeping with definitions of interest as a key motivational variable (Hidi, 2006), we define interest as a psychological state whereby an individual repeatedly engages and interacts with an object or an object category, characterised by increased attention, knowledge, positive affect, and a sustained relationship with this object. The four-phase model of interest (Hidi & Renninger, 2006) suggests that sustained interaction between an individual and their item of interest develops in four stages, the first of them being a state of triggered situational interest. Here, an individual's interest in an item is triggered by certain characteristics of that item in their environment (e.g., the novelty of the item), which prompts the individual to initially engage with it. This is followed by a state of maintained situational interest, wherein the individual continues to engage with the object beyond their initial focus on it. On repeated engagement with this item over a longer period of time, the individual gathers more knowledge about it, and their interactions with this item are sustained not by the characteristics of the item, but their internal motivation, which characterises the third stage of emerging individual interest. The fourth stage of well-established individual interest is attained when individuals gather extensive knowledge about this item and begin to feel more positive affect during their interactions with the item of interest.

Well-developed individual interests in children have been showcased by studies examining extremely intense interests, or EII, in children. Here, children display a sort of single-minded interest in certain objects, where they continue to engage with these items over extended periods in time, eventually also showing generalisability in their interests, that is, becoming interested and engaging with items that closely resemble the original object of interest (DeLoache et al., 2007). Older children also show sustained interest in certain conceptual domains, which are categorised by deep concept-specific knowledge (Alexander et al., 2008; Johnson et al., 2004). With respect to the emergence of such interests, most research has derived this information from parent reports of their children's interests. Such work generally pinpoints the emergence of interest in specific objects or object categories around the age of 18 months; with parents reporting that such interests are firmly established, or have become more intensive at around 24 months (Burrows et al., 2021; DeLoache et al., 2007). By 24 months, children's interests in specific object categories also modulate the quality of parent-child interactions, with caregivers and children being more enthusiastic, engaging more, and attending more when reading books that contain content reported to be interesting to the child, compared to content reported to be less interesting (Madhavan & Mani, 2024). Importantly, as we discuss next, children's interests in specific objects or object categories can also drive their learning about these categories, especially with regard to vocabulary development.

1.2. Children's interests shape early language development

Infants, on average, learn words at a similar pace, which sharply increases towards the end of their second year (Hamilton et al., 2000). Although there are similarities in the number of words that children know, there are differences between individuals with regard to the individual words that individual children know. For example, while infant vocabularies appear to share many words in the early months, we see more variation in their lexicon as they grow older, which then stabilises further with age (Mayor & Plunkett, 2014). While models of early vocabulary development account for some of this variation by proposing that children are more likely to learn words that are (phonologically or semantically) related to words in the child's environment (Kalinowski et al., 2024; Kalinowski et al., 2025) or words the child already knows, they do not explain how initial differences in category-specific vocabulary size emerge.

Research into children's role as active participants in their own learning may shed more light on these differences in individual vocabularies observed in young children. For example, infants are shown to vocalise towards their caregiver, and actively point and gesture at novel objects in the surroundings, in a bid to have their caregiver label these objects (Begus & Southgate, 2012; Goldstein et al., 2010). Children's active pointing and gesturing towards various objects in the environment (and the caregiver's contingent labelling of them) is also shown to facilitate children's learning of these novel word-object associations (Begus et al., 2014; Lucca & Wilbourn, 2018). Older children in tablet-based learning tasks also show better learning when they are allowed to actively choose what to learn, compared to children who are not given a choice (Partridge et al., 2015). Therefore, young children's desire and readiness to learn can play a role in shaping their lexical acquisition.

More recently, children's individual interests in certain natural object categories have been shown to shape their learning of novel words from these categories. Here, 24- to 30-month-old children show improved recognition of the labels for objects belonging to categories they were reported to be more interested in (Ackermann et al., 2020). Furthermore, this effect of children's individual interest in different object categories shapes not just their immediate learning and recognition but also their retention of these label-object associations 5 minutes and 24 hours later (Ackermann et al., 2023). This line of research supports the possibility of a sustained relationship between children's interests and vocabulary acquisition, both in the short term and the long term. Indeed, there is a powerful association between interest and knowledge acquisition, with a meta-analytic correlation coefficient of .31 between interest and academic achievement at school age (Schiefele et al., 1992). At the same time, while interest is also related to prior knowledge (e.g., the number of words a child knows in a category that the child is interested in, c.f., Ackermann et al., 2020, 2023), only around 20% of the variance in the relationship between interest and learning is explained by what pre-existing knowledge the individual already has of the topic of interest (Tobias, 1994). Therefore, there seems to exist an almost truistic association between individual interest, pre-existing category-specific vocabulary knowledge, and subsequent lexical acquisition within that category in early development.

1.3. Measuring children's interests and vocabulary knowledge

Vocabulary knowledge of children is generally measured using parental reports, and indeed, parent-reported vocabulary measures such as the MacArthur-Bates Communicative

Development Inventory (MBCDI) have been used extensively in developmental research, and are purported to be highly reliable (Fenson et al., 2007; Frank et al., 2017; see also Madhavan et al., 2024). Studies examining category-specific vocabulary knowledge have typically examined either relative or absolute category knowledge, in terms of the number of words in the CDI pertaining to a specific natural category, for example, animals, vehicles, that a child is reported to know – and find strong associations between current category-specific knowledge and learning of new category members (Ackermann et al., 2020; Borovsky et al., 2016).

Children's interests, on the other hand, have been examined using a multitude of measures, including (a) parental reports of how interested their child is in a range of natural object categories, for example, animals, vehicles (Ackermann et al., 2020; Burrows et al., 2021; DeLoache et al., 2007; Madhavan & Mani, 2024), as well as (b) children's pupillary arousal to presentation of images of objects from those categories on screen (Ackermann et al., 2020; Kang et al., 2009). However, an examination of different measures of children's interests shows that, out of four measures of children's interest, there was limited convergent validity across measures, such that the different measures may index different aspects or dimensions of the definition of interest (Madhavan et al., 2024). Thus far, however, there is limited examination of the reliability of these measures of children's interests. Therefore, by including multiple measures and examining their relationship longitudinally, our study seeks to yield insights into the validity and reliability of measures of children's interests while also quantifying the relationship between the development of children's interests in various object categories and the evolution of their category-specific vocabulary knowledge acquisition across development.

1.4. Current study

Against this background, the current study examined the development of children's interest in specific natural categories longitudinally (between 18 and 24 months of age) and the extent to which children's interest in these categories at 18 months predicts category-specific vocabulary knowledge later in development, that is, at 24 months. In particular, we examine the extent to which children's interests sustain across development in terms of whether (1) parental reports of children's interest in natural object categories early in development are associated with their reports of their child's interests 6 months later; (2) children's pupillary arousal to objects from different natural categories, as an index of their interest in these categories, early in development predict pupillary arousal to the same objects later in development. Furthermore, against the background that children's pupillary arousal may capture children's implicit interests in objects that may be unbeknownst to their caregivers, we examined whether (3) children's pupillary arousal to objects from different natural categories early in development predicts parental reports of their child's interest in those categories later in development. Finally, we examine the relationship between emerging interests and later vocabulary development by (4) examining whether children's category-specific vocabulary knowledge later in development is predicted by children's interests in the category earlier in development.

2. Methods

We report our preregistered sample size, prerequisites for data exclusions, our inclusion/exclusion criteria, whether inclusion/exclusion criteria were established prior to data

analysis, all manipulations, and all measures in the study, either in our preregistration (<https://osf.io/p2k3e>, more details in Preregistration) or in the data pre-processing section of our paper. All data and corresponding analysis scripts required for the replication and substantiation of all our analyses can be found on the OSF study page (<https://osf.io/k4ybg>).

2.1. Ethics

Ethics approval was granted by the Psychology Institute's Ethics committee, and all parents provided informed written consent prior to their children's participation in the study. Children were given a book of their choice as a token of appreciation.

2.2. Preregistration

We preregistered a sample size of 30, along with our predictor and response variables, hypotheses, and planned analyses on the Open Science Framework (<https://osf.io/p2k3e>) prior to data analysis. This preregistration also contains information about other analyses that we do not address in this paper, as they would be beyond the scope and ideology of this paper. The datasets and analysis scripts can be found on the OSF page of the project (<https://osf.io/k4ybg>).

2.3. Participants

All participants were invited to attend two testing sessions. Participants during the first testing session were monolingual children aged between 16 and 20 months ($M_{age1} = 17.33$, $SD_{age1} = 0.93$) who were carried to full-term with no diagnosed developmental disorders. The second testing session took place 5–7 months later, with participants now aged between 22 and 26 months ($M_{age2} = 23.66$, $SD_{age2} = 1.08$). Participants were only included in the final sample if they attended and completed all tasks at both timepoints. At each visit, parents were asked to provide informed consent on behalf of their child.

A total of 88 children took part in the first testing session, and a total of 67 children took part again in the second testing session. Note that this is higher than our preregistered sample size of 30, as we expected a higher dropout for a longitudinal study during the pandemic and tested many more children in the first testing session. The rest of the children could not participate in the second testing session either due to the unavailability of time or due to COVID-19 restrictions. Not all children provided data for all tasks for both sessions. Therefore, we report the final sample size in the respective analyses.

2.4. Procedure

Children were invited on two separate occasions, once at around 18 months and again at around 24 months. The procedure at each time point was identical, where the participating families were first sent two questionnaires to complete in the week leading up to the appointment, and were required to have completed them before commencing the study. At the lab appointment, the children completed two eye-tracking tasks (the second of which is not addressed in this study). Our task of relevance was the first task, a category interest task, where we presented children with images and labels of objects for the six

different categories in isolation and measured their pupillary dilation to the presentation of an unscrambled image of the object. However, different exemplars of the category objects were used at each time point to ensure children were not accustomed to these images during their second visit. Gaze and pupil data were recorded using a Tobii X3-120 eye tracker with a gaze sampling rate of 60 Hz. Stimuli were presented on a 40-inch screen with a resolution of 1920×1080 pixels. The images were presented in the centre of the screen during the task.

2.5. Stimuli

Object categories tested in the study. We used six categories of items: animals, body parts, clothing, food, furniture, and vehicles. These categories were chosen based on previous research (c.f., Ackermann et al., 2020; Borovsky et al., 2016; Madhavan et al., 2024), aside from our choice of the category “furniture” instead of “drinks.” This change was made given that drinks are likely to reflect category membership primarily through the receptacle they are presented in. In contrast, there is greater variability in the furniture category, yet adequate perceptual consistency for children to successfully categorise items from this category. Our vocabulary and interest questionnaire contained questions pertaining to these six categories (see *Parent Questionnaires* below). For our eye-tracking task (see also *Lab eye-tracking task* below), six items from each category assumed to be familiar to children by the age of 18 months were chosen as familiar items from each of these categories.

Parent questionnaires. *Vocabulary questionnaire:* We utilised the FRAKIS vocabulary inventory, which is a German adaptation of the MacArthur Bates Communicative Development Inventory (MBCDI), that contains a total of 600 words, to measure children’s vocabulary size (Szagun et al., 2009). From the FRAKIS questionnaire, we curated a subset of words for our adapted version of the vocabulary questionnaire by specifically selecting the subcategories of words that corresponded to the six object categories being tested in the study (see Stimuli section). Parents were instructed to mark whether their child understood/produced the word by filling in a circle printed next to the word, and if they did not know the word, they were asked to leave it blank. Thus, we obtained estimates of the number of words from each category (included in the FRAKIS) that each child was reported to know of all the words in that category (included in the FRAKIS).

Interest questionnaire: Parents were also asked to complete an additional questionnaire to provide an estimate of how interested their child was in each of the six object categories. The questionnaire contained four sub-questions (with an answer row for each object category), and parents were instructed to answer them in a 7-point Likert scale (1 = not at all, 7 = extremely). The four sub-questions were a) how curious their child was about object categories, b) how much enjoyment their child gets from these object categories, c) how many questions their child asks about these object categories, and d) how much time their child spends with these object categories.

Lab eye-tracking task. *Audiovisual stimuli:* For the eye-tracking task, photorealistic images of the familiar items were used as visual stimuli. Images were obtained from a variety of sources: where possible, images were taken from normalised databases, including the Bank of Standardized Stimuli (Brodeur et al., 2014) and the Moreno-Martínez and Montoro (2012) database, to ensure their recognisability. The remaining images were sourced from Google Image searches. Each image was edited to be identical in size as

follows. We reduced the size of each image – pasted against a grey background (1920×1080 pixels) – such that the area covered by the image (in pixels) was approximately 10% of the screen size. This size was deemed to be large enough for children to view comfortably on the screen provided.

During the task (see below), the images were first presented as scrambled transformations of the real image for 2000 ms, which renders an image unidentifiable whilst preserving, as much as possible, the original image's perceptual features (Stojanoski & Cusack, 2014). Consequently, the scrambled image is comparable to the original in terms of colour and luminosity, minimising the incidental effects on the pupil, which is sensitive to changes in such properties (Hepach & Westermann, 2016). Following this, the unscrambled image was presented for 4000 ms, along with audio of the label of the object (see Figure 1). The audio labels were recorded by a female native speaker of German in an infant-directed speech register with their appropriate definitive article: “der,” “die,” or “das.” These clips were processed in Goldwave, where the volume was normalised to 70 dB and filtered for noise.

In addition, to maintain attention between and during trials, we also used four different attention getters of animated images paired with an attractive tone.

2.6. Lab session

During the eye tracking task, children were tested in a quiet room whilst sitting in a car seat or, alternatively, on their parent's lap. Children were seated approximately 60 cm from the monitor where the visual stimuli were presented. Audio stimuli were presented at an appropriate volume through two loudspeakers situated above the monitor. Stimuli

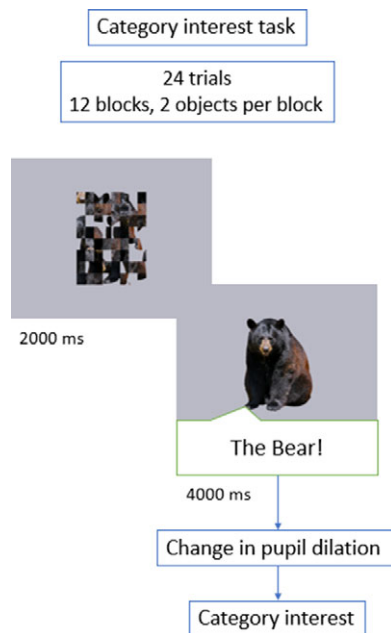


Figure 1. Progress of one trial in the category interest task.

were presented and recorded using Tobii Pro Lab. In this task, infants' pupillary response to familiar images from the different categories was measured using a similar method to Ackermann et al. (2020). In particular, participants were presented with each of the familiar images in isolation along with its label. This provided us a measure of each participant's pupillary arousal following presentation of four images from each of the six different categories, that is, 24 images altogether. We decided to present only four pictures, even though we had selected six objects for each object category, as including all six objects in the task would have significantly lengthened the task. Especially considering the fact that children in the first testing session were much younger than in other studies that have used the same methodology before, we deemed it prudent to reduce the number of trials. However, we created three different stimulus sets for this task, and, therefore, we utilised all six objects across children.

Participants were presented with 12 blocks, with each block consisting of two trials – therefore, 24 trials in total. Each block was category-specific, that is, only items from one category, with two such blocks (presenting different images) for each category. One block from each category was presented before categories were repeated, with the ordering of items in the blocks and the ordering of the blocks counterbalanced across participants. Thus, each trial presented one item, with each item only presented once to participants. As mentioned above, trials began with a scrambled image of the object presented for 2000 ms, followed by the unscrambled image of the object presented for 4000 ms. Then objects were labelled such that the onset of the object's label was exactly at 4000 ms (see Figure 1). Blocks were interspersed by an attention-grabbing stimulus, and the next trial began only once the experimenter indicated that the child was attending to the screen. The ordering of trials was counterbalanced across participants. This task took approximately 4 minutes.

2.7. Pre-processing

Children's vocabulary size measure. For the vocabulary questionnaire completed by the parents, if parents indicated that the word was known to the child, the word was scored with a 1, and a score of 0 was given if the row was left blank. We calculated our final vocabulary score for each object category as the number of words that the parents reported the child to know in the category and divided by the total number of words present in the object category that were included in the questionnaire. This resulted in a vocabulary size score between 0 and 1 for each category for each child.

Children's interest measures. *Parent estimates of children's category-specific interest:* Using the data from the interest questionnaire, for each category, we first averaged the score reported by parents for that category in each of the four interest dimensions (i.e., joy, familiarity, curiosity, questioning, see Methods). This score was then normalised by subtracting 1 from it and dividing that resulting score by 6 (which is the highest score possible, subtracted by 1). This resulted in an interest score between 0 and 1 for each category for each child.

Children's pupillary dilation as a measure of interest: For the category interest task, the eye-tracker provided us with data on where children were looking on the screen at a sampling rate of 60 Hz, that is, one data point approximately every 16 ms. These data were coded with regard to the pixel coordinates of the objects presented on the screen, in order to calculate the amount of time children spent looking at each individual object on the screen. For pupillary activity data, we only included data from fixations, which were

defined by the Tobii eye-tracker's default (>100 ms), and when the eye-tracker was able to report the gaze behaviour with high validity, that is, at least data from one eye labelled, "valid").

For each time bin, we exported the size of the left and right pupils only when the child was looking at the object on the screen (i.e., there were fixations towards the object). We then filtered the pupil data using a threshold filter (separately for both eyes), which calculated the difference in pupil size between two adjacent samples and excluded the top 10 percent of differences within the pupil size. We did this in order to exclude large deviations in pupil size from one sample to the next, which most likely are artefacts. Following this, we interpolated any missing data points with a sample size of 4 (Hepach et al., 2012) and then calculated the average pupil size of both eyes.

Following other studies (Ackermann et al., 2020, 2023; Kang et al., 2009), we also performed a baseline correction on the pupillary data, where we subtracted the averaged pupillary diameter of our baseline window of last 500 ms of the scrambled phase from our target window, which was the last 2000 ms of the unscrambled phase (during label onset). We then averaged the baseline-corrected data across the six different object categories to obtain a single response for each category.

2.8. Model construction for analysis

Association between parent reports of children's interests at 18 and 24 months. To estimate the extent to which our predictor, parent estimates of children's interest in the object categories at the first testing (18 months) predicted our response, parent estimates of their child's interest in the same object categories 6 months later (24 months), we fit a Generalised Linear Mixed Model (GLMM; Baayen, 2008) with a beta error structure and logit link function (Bolker, 2008; McCullagh & Nelder, 1989). We chose the beta error structure, since our response variable was transformed during pre-processing (see above), which resulted in a value between 0 and 1, and the beta error distribution is recommended in such cases, as it has precisely these limits. Our response variable was the parent estimate of interest at 24 months. Our main fixed effects predictor was parents estimates of interest at 18 months. We also included two other fixed effects predictors, children's age (in days) at the time of the first testing, as well as the time difference (in days) between the first and second testing, to control for these variables.

Apart from our fixed effects predictors, we also included random effects intercepts for participant ID and object category. Random intercepts account for the possibility of non-independent observations of our response variable made within the same level of each random effect (e.g., for each participant ID), and help avoid pseudo-replicability (Hurlbert, 1984). Additionally, we also included random slopes for parent interest estimates at 18 months within participant ID, age of participants, and time between testings within object category. Random slopes help keep the type I error rates at a nominal level, and neglecting them may lead to inflated type I error rates (Barr et al., 2013; Schielzeth & Forstmeier, 2009). We originally included correlations between random slopes and intercepts, to account for the possibility that random intercepts and slopes may be correlated. However, as these appeared to be essentially 1, we excluded them from the final model. The response was not overdispersed given the model (dispersion parameter 0.73). The sample analysed with this model comprised a total of 372 observations for 62 children for six categories. To avoid cryptic multiple testing (Forstmeier &

Schielzeth, 2011), we compared this full model with a reduced model lacking our main fixed effects predictor of the parent estimate of interest at 18 months.

While the above model is capable of examining the association between parent estimates of their child's interests in natural object categories at one point in time and their estimates of the child's interests in the same categories 6 months later, it fails to account for potential relationships between parent estimates of children's interests and children's category-specific vocabulary size. Previous studies examining the relationship between interest and vocabulary have shown these to be closely related (Ackermann et al., 2020; Madhavan et al., 2024). Therefore, it is necessary to control for the effects of category-specific vocabulary size when examining the relationship between parent estimates of children's interests longitudinally. This is especially so since children's category-specific vocabulary size was associated with parents' estimates of their children's interests at each time point (see [Supplementary materials; S2 and S3](#)).

We, therefore, fit another Generalised Linear Mixed Model with a beta error structure and logit link function. Here as well, our response variable was parent estimates of their children's interests at 24 months. We included two additional fixed effects predictors of category-specific vocabulary size at the first testing and the second testing, alongside our control predictors of age (in days) at the first testing and time difference (in days) between the two testings. Random effects included random intercepts of participant ID and object category, as well as random slopes of our three main fixed effects predictors within participant ID and random slopes of all five predictors within object category. We removed correlations between random slopes and intercepts, as the model including them did not converge. The response was not overdispersed given the model (dispersion parameter 0.74). The sample analysed with the model comprised 372 observations from 62 participants for six object categories.

We compared this model to a reduced model that only included our control variables of age at first testing and time difference between the two testings, and all of our random effects.

Association between children's category-specific pupillary arousal at 18 and 24 months. To examine the extent to which children's pupillary arousal to familiar objects on screen – as an index of children's interest in the category the object belongs to – at 18 months predicted their category-specific pupillary arousal at 24 months, we fit a Linear Mixed Model (LMM) with a Gaussian error distribution and identity link function and using maximum likelihood. Our response variable was the baseline-corrected pupillary arousal at the second testing, that is, at 24 months. Our fixed effects predictors included our main predictor of baseline corrected pupillary dilation at 18 months, as well as our control predictors of age (in days) and time difference between testings (in days). We included random effects intercepts of participant ID and object category. Additionally, we included random effects slopes of our main fixed effects predictor (pupillary dilation at 18 months) within participant ID and all three main fixed effects predictors (pupillary dilation at 18 months, age at first testing, and time difference between testings) within object category. We originally included correlations between random intercepts and slopes; however, since the correlations within object category were all essentially 1, and the difference between the loglikelihoods between the model containing all correlations and the model without correlations for object category was not significantly different, we report the results of the model without the correlations. The sample analysed with the model comprised 274 observations for 54 participants for six categories.

We compared this model to a reduced model that only included our control predictors of age at first testing and time difference between the two testings, and all of our random effects.

Predictive validity of children's category-specific pupillary arousal at 18 months and parent reports of children's interests at 24 months. Past research has examined the association between parents estimates of children's interests and children's category-specific pupillary arousal at a given point in time, and found no significant association between them (no convergent validity; Madhavan et al., 2024). The absence of a relationship between these two measures of interest may be explained by suggesting the two measures may tap into different aspects, timescales, or dimensions of interests. In particular, while parent estimates of interest may tap into past or well-developed interests of their child, the pupillary measure may tap into children's current or emerging interests (Ackermann et al., 2020; Madhavan et al., 2024).

To investigate this possibility, we examined the association between children's category-specific pupillary arousal at 18 months of age and parent estimates of children's interest at 24 months. To this extent, we fit a Generalised Linear Mixed Model (GLMM) with beta error distribution and logit link function, for the same reasons as the above model. Our response variable was the parent estimates of children's interests at 24 months, and our main fixed effects predictor was children's baseline-corrected pupillary arousal during the first testing, that is, at 18 months. We also included our control predictors of the age of the child during the first testing and the time difference between the two testings. We originally included all possible random effects intercepts, slopes, and correlations between random intercepts and slopes into the model. However, given convergence issues, our final model included the random effects intercepts of participant ID and object category, plus a random slope of our main fixed effects predictor (pupillary arousal at 18 months) within participant ID and a random slope of time difference between testings within object category. The sample analysed with this model comprised 287 observations from 56 participants for six categories. The response was not over-dispersed given the model (dispersion parameter 0.73).

We compared this model to a reduced model containing only our control predictors and the random effects.

The relationship between children's interests and later vocabulary development. To examine the extent to which our measures of children's interests predicted children's category-specific vocabulary size 6 months later, we fit a Generalised Linear Mixed Model with a beta error structure and logit link function. This was a deviation from our preregistration, where we stated we would fit a binomial model instead. We changed this, as the required transformations of our response variable would not be consistent with previous studies that have utilised this measure (Madhavan et al., 2024) and, therefore, restrict the interpretation of the results. Our response variable was the category-specific vocabulary size of children at 24 months, and our two main fixed effects predictors were our parent estimates of children's interests at 18 months and children's category-specific pupillary arousal at 18 months. We included control variables of the age of the child at the first testing, as well as the time difference between the two testings. We included random effects intercepts of participant ID and object category, as well as random slopes of our two main fixed effects predictors within participant ID, and children's pupillary arousal, age at first testing, and time difference between two testings within object category. We excluded all other possible random slopes as well as correlations between random intercepts and slopes due to convergence issues. The sample analysed with this model

comprised 281 observations from 56 participants for six categories. The response was slightly overdispersed given the model (dispersion parameter 1.13).

We compared this model to a reduced model containing only our control predictors and random effects.

3. Results

Please note that since our analyses include predictors and responses where data were collected at two different points in time, that is, at 18 months and 24 months of age, we refer to these measures as “variable at 18 months” and “variable at 24 months” respectively.

3.1. Descriptive statistics

Here, we provide the descriptive statistics (median and quartiles) for the three measures utilised in this study (for each of the two testing timepoints), pooled by the six different categories, in the form of plots. The means and standard deviations for each variable for each model will be slightly different from the ones we provide below, since the plot descriptives represent all the data we have for each of the variables (Figure 2).

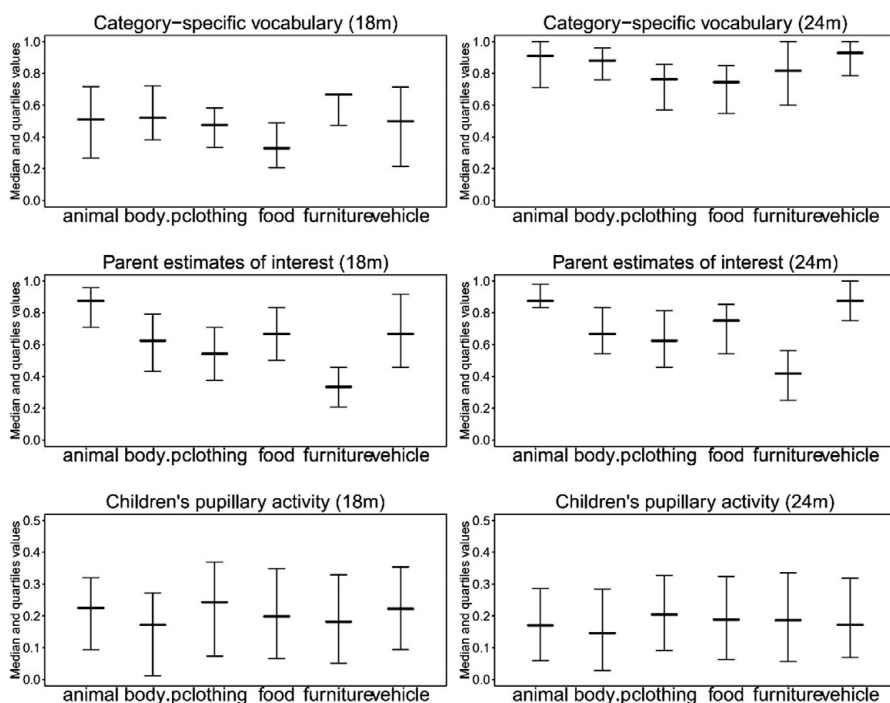


Figure 2. Median and quartiles of the measures (y-axis) with respect to the six different categories (x-axis) for each of the three variables. Timepoint 1 (18 months) on the left side, and timepoint 2 (24 months) on the right side. The x-axis label body.p refers to the object category of body parts. The horizontal line depicts the median, while error bars depict quartiles. Please note that the y-axis scale for the last two plots (pupillary arousal) is different from the rest of the plots, for ease of interpretation.

3.2. Parent reports of children's interests at 18 and 24 months

The results presented in the following tables present estimates of the fixed effects only; the estimates of random effects for all models can be found in the [Supplementary materials \(S1\)](#).

Our first analysis examined the relationship between parent estimates of children's category-specific interests at 18 and at 24 months. The full-null (reduced) model comparison was significant ($\chi^2(1) = 15.56$, $p < 0.001$), suggesting that parent estimates of their child's interest in natural object categories at 18 months significantly predicted their estimates of their child's interest in the same object categories 6 months later, that is, at 24 months. Specifically, when parents estimated their child's interest in certain categories to be high at 18 months, they reported their child to be highly interested in this category 6 months later ([Table 1](#); [Figure 3](#)).

Our second analysis examined the association between parent estimates of children's interests at 18 months and the same measure at 24 months, while controlling for children's category-specific vocabulary at the two time points. The full-null (reduced) model comparison was significant ($\chi^2(3) = 23.35$, $p < 0.001$). We conducted a drop1 analysis, which cycled through the individual predictors, excluding them one at a time. The drop1 analysis underscored the significant relationship between parent estimates of their children's interests at 18 and 24 months, despite controlling for variation in category-specific vocabulary size at the two ages. Indeed, there was no significant effect of category-specific vocabulary size at 18 months on parent estimates of their child's interests at 24 months. We only found a relationship between parent estimates of their child's category-specific vocabulary size at 24 months and their estimates of their child's interests at the same age. Thus, parent estimates of children's interests at 18 months successfully predict parent estimates of the child's interests 6 months later, even after accounting for the already-established relationship between parent estimates of children's interests and children's category-specific vocabulary size ([Table 2](#); [Figures 4–6](#)).

3.3. Children's category-specific pupillary arousal at 18 and 24 months

There was no significant difference between the full and null (reduced) model ($\chi^2(1) = 1.12$, $p = 0.29$). Thus, we found no evidence for an association between children's pupillary arousal to objects from specific categories at 18 and 24 months ([Table 3](#); [Figure 7](#)).

Table 1. Results of the GLMM examining parent estimates of interest at two timepoints

	Parent estimates of children's interests at second testing (24 months)							
Predictors	Estimate	se	χ^2	df	p	CI	min	max
(Intercept)	1.034	0.262				0.508–1.523	0.866	1.203
Parent estimate of interest at 18 m	0.503	0.075	15.566	1	<.001	0.361–0.649	0.477	0.563
Age (days)	0.117	0.078	2.199	1	.138	−0.035 – 0.278	0.083	0.152
Time b/w testings	0.039	0.079	0.246	1	.620	−0.103 – 0.185	0.016	0.066

Note: All predictors were transformed to a mean of 0 and standard deviation (SD) of 1. The original means and SD of predictors are: Parent estimate of interest at 18 m – 0.60 and 0.26, age (days) 519.03 and 26.50; time between testing 190.79 and 20.30. For this and following tables, indicated in the table are estimates, together with standard errors, significance values, 95% confidence intervals, and minimum and maximum of model estimates after excluding random effects one at a time.

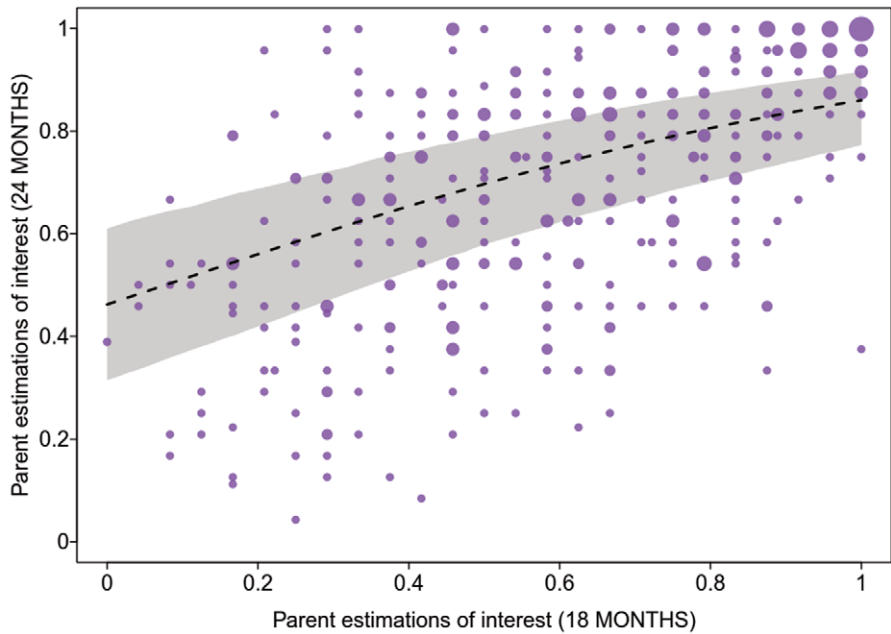


Figure 3. Parent estimates of their child’s interests at 24 months as a function of their estimates of the child’s interests 6 months earlier. For data visualisation purposes, dots show observations whereby the size (or area) of the dots shows the number of observations with the exact same value in both variables (range 1–12). The dashed line and grey polygon depict the fitted model and the 95% confidence intervals.

Table 2. Results of the GLMM examining parent estimates of interest at second testing

Predictors	Parent estimates of children’s interests at second testing (24 months)						
	Estimate	se	χ^2	df	p	CI	min max
(Intercept)	1.037	0.275				0.506–1.555	0.896 1.233
Category-specific vocabulary at 18 m	0.076	0.087	0.757	1	.384	–0.102 – 0.241	–0.012 0.117
Category-specific vocabulary at 24 m	0.189	0.081	5.584	1	.018	0.042–0.339	0.124 0.242
Parent estimate of interest at 18 m	0.444	0.082	13.446	1	<.001	0.286–0.608	0.402 0.515
Age (days)	0.035	0.089	0.154	1	.694	–0.131 – 0.196	–0.004 0.083
Time b/w testings	0.045	0.086	0.269	1	.604	–0.116 – 0.207	0.013 0.075

Note: All predictors were transformed to a mean of 0 and standard deviation (SD) of 1. The original means and SD of predictors are: category-specific vocabulary at 18 m – 0.47 and 0.26; category-specific vocabulary at 24 m – 0.80 and 0.20; parent estimate of interest at 18 m – 0.60 and 0.26; age (days) 519.03 and 26.50; time between testing 190.79 and 20.30.

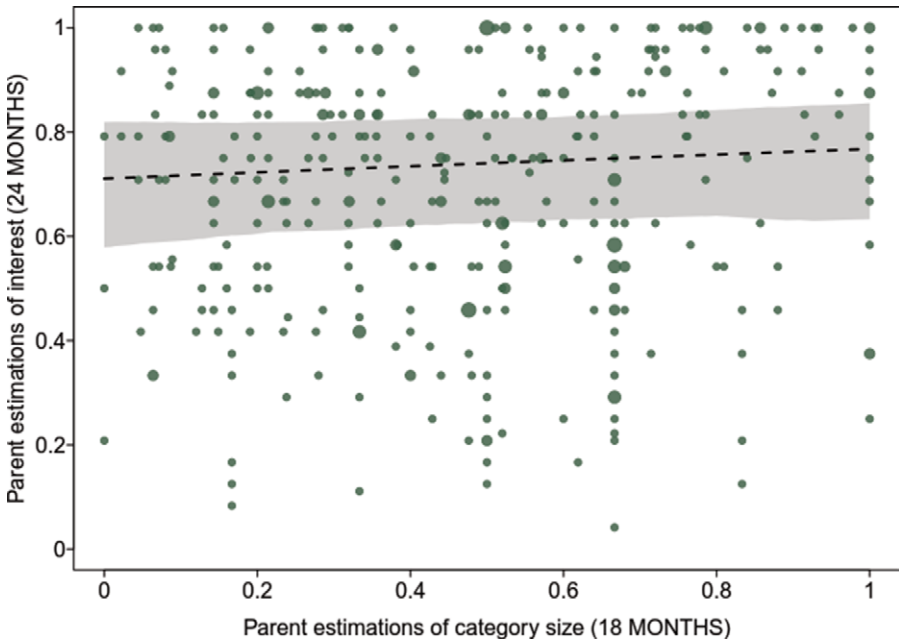


Figure 4. Parent estimates of children's interests at 24 months as a function of parent estimates of the child's category-specific vocabulary size at 18 months. Dots show observations whereby the size (or area) of the dots shows the number of observations with the exact same value in both variables (range 1–4). The dashed line and grey polygon depict the fitted model and the 95% confidence intervals.

3.4. Children's category-specific pupillary arousal at 18 months and parent reports of children's interests at 24 months

The comparison of the full model with the reduced (null) model showed no significant difference between the two models ($\chi^2(1) = 0.39$, $p = 0.53$). In other words, we found no evidence for an association between children's interests at 18 months, as indexed by the more implicit pupillary arousal measure, and parent estimates of their child's interests at 24 months (Table 4; Figure 8).

3.5. The relationship between children's interests and later vocabulary development

The full-null (reduced) model comparison was significant ($\chi^2(2) = 11.85$, $p = 0.002$). Following this, we conducted a drop1 analysis, which cycled through the individual predictors, excluding them one at a time. This showed that parent estimates of the number of words their child knows in a category at 24 months were significantly predicted by parent estimates of their child's interest in that category 6 months earlier. There was no significant association between parent estimates of children's category-specific vocabulary size at 24 months and children's pupillary arousal 6 months earlier. This suggests that when parents report higher interest in certain object categories at an earlier time point, there is a corresponding increase in vocabulary size for those specific categories at a later time point (Table 5; Figure 9).

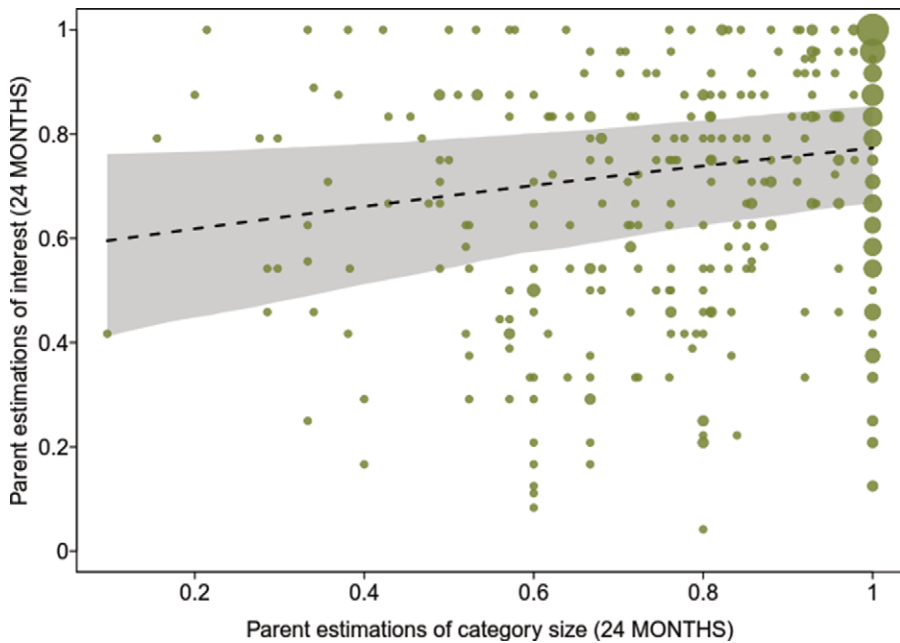


Figure 5. Parent estimates of children's interests at 24 months as a function of parent estimates of the child's category-specific vocabulary size at 24 months. Dots show observations whereby the size (or area) of the dots shows the number of observations with the exact same value in both variables (range 1–20). The dashed line and grey polygon depict the fitted model and the 95% confidence intervals.

4. Discussion

The current study investigated the extent to which children's interests at 18 months predict their interests at 24 months, speaking to both the emergence of well-developed individual interests in various natural object categories in young children as well as the reliability of our measures of children's interests. In addition, we examined the extent to which these emerging interests shape children's future vocabulary, in terms of whether children's interest in a category at 18 months predicts the number of words they know in that category 6 months later. We utilised two different measures of children's interests at both time points, namely parent estimates of children's interests in natural object categories as well as children's pupillary response to objects from these natural object categories. We estimate children's category-specific vocabulary size using a standardised parent vocabulary questionnaire.

First, we found that parent estimates of children's interests at 18 months significantly predict parent estimates of children's interests 6 months later, and that this effect persists even after controlling for differences in children's vocabulary size at the two time points. Second, we found no evidence that children's category-specific pupillary arousal at 18 months predicts children's category-specific pupillary arousal 6 months later. Third, we examined whether children's category-specific pupillary arousal at 18 months predicted parent reports of children's interest in those categories 6 months later. The rationale for this analysis was that the more implicit pupillary measure may tap into children's emerging interests, while parents may only be able to report on their children's

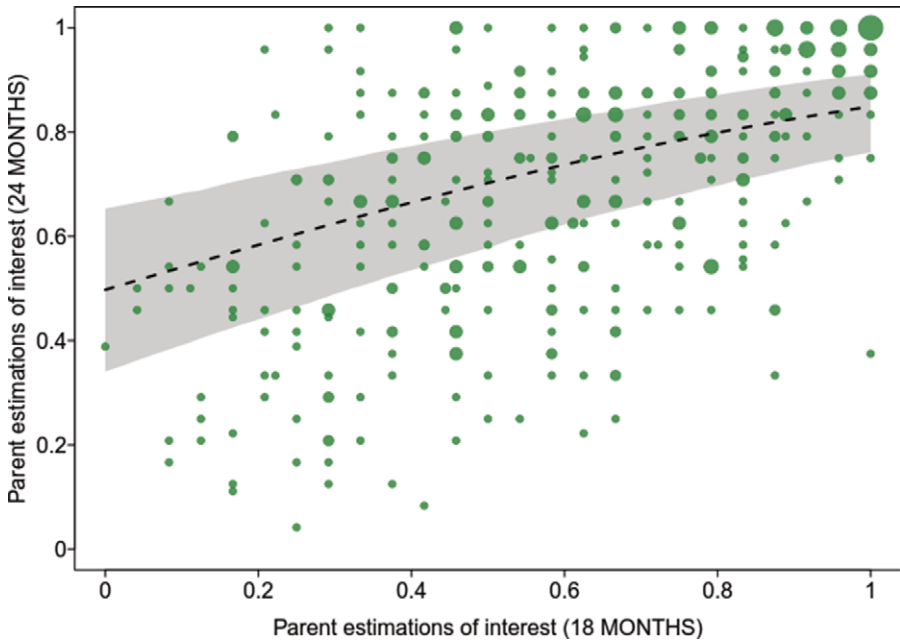


Figure 6. Parent estimates of children's interests at 24 months as a function of parent estimates of children's estimates at 18 months, after controlling for category-specific vocabulary size at each time point. Dots show observations whereby the size (or area) of the dots shows the number of observations with the exact same value in both variables (range 1 to 12). The dashed line and grey polygon depict the fitted model and the 95% confidence intervals.

Table 3. Results of the LMM examining pupillary arousal at two time points

Predictors	Children's category-specific pupillary arousal at second testing (24 months)							
	Estimate	se	df	t	p	CI	min	max
(Intercept)	0.168	0.013	46.484	12.588		0.142–0.193	0.162	0.173
Pupillary arousal at 18 m	0.011	0.010	31.159	1.061	.297	–0.009 – 0.032	0.005	0.019
age (days)	0.009	0.014	21.818	0.635	.532	–0.019 – 0.038	0.003	0.014
time b/w testings	–0.017	0.014	19.236	–1.249	.227	–0.044 – 0.011	–0.025	–0.012

Note: All predictors were transformed to a mean of 0 and standard deviation (SD) of 1. The original means and SD of predictors are: Pupillary arousal at 18 m – 0.19 and 0.17; age (days) 522.57 and 29.17; time between testing 188.80 and 19.24.

established interests (Ackermann et al., 2020; Madhavan et al., 2024). Here, too, we found no significant relationship between the two measures of interest at the two different time points. Finally, we found that parent estimates of children's interests in specific categories at 18 months predict their estimates of the number of words their child knows in that category 6 months later. In what follows, we discuss each of these results separately.

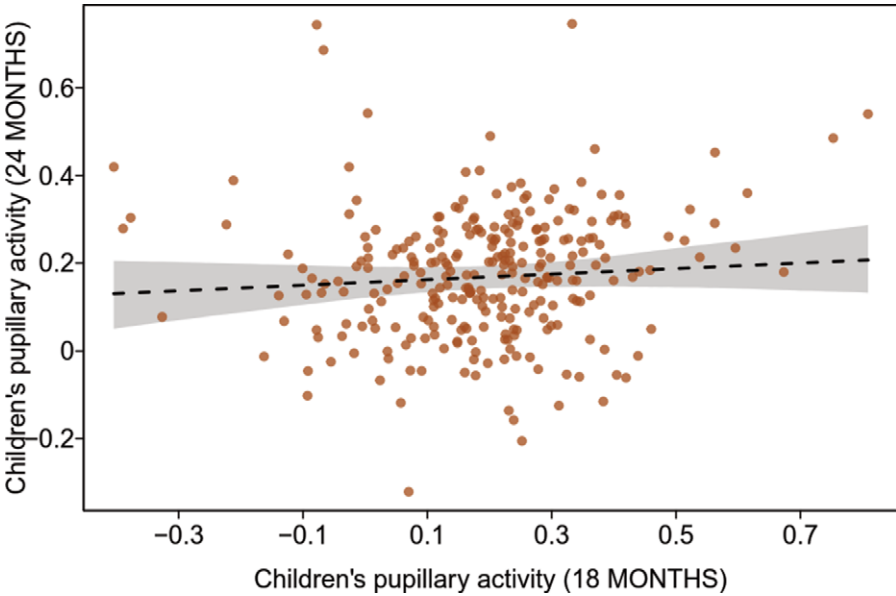


Figure 7. Children's baseline-corrected pupillary arousal at 24 months as a function of baseline-corrected pupillary arousal at 18 months. The dashed line and grey polygon depict the fitted model and the 95% confidence intervals.

Table 4. Results of the GLMM examining parent estimates of children's interests at 24 months and pupillary arousal at 18 months

Predictors	Parent estimates of children's interests at second testing (24 months)							
	Estimate	se	χ^2	df	p	CI	min	max
(Intercept)	1.342	0.328				0.712–1.964	1.136	1.569
Pupillary arousal at 18 m	−0.034	0.055	0.394	1	.530	−0.150 – 0.078	−0.082	−0.006
age (days)	0.137	0.088	2.405	1	.118	−0.026 – 0.318	0.088	0.171
time b/w testings	0.038	0.104	0.135	1	.714	−0.161 – 0.243	−0.039	0.078

Note: All predictors were transformed to a mean of 0 and standard deviation (SD) of 1. The original means and SD of predictors are: Pupillary arousal at 18 m – 0.19 and 0.17; age (days) 521.39 and 27.77; time between testing 190.03 and 19.60.

4.1. Parent estimates of children's interests at 18 and 24 months

We found that parents' estimates of children's interests at 18 months was positively associated with their estimates of children's interests 6 months later; that is, when parents report increased interest in certain object categories on their child's part when their child was 18 months old, they report a higher estimate of their child's interest in the same object categories approximately 6 months later. Furthermore, we found that the longitudinal consistency of parent estimates of their children's interests persisted even after accounting

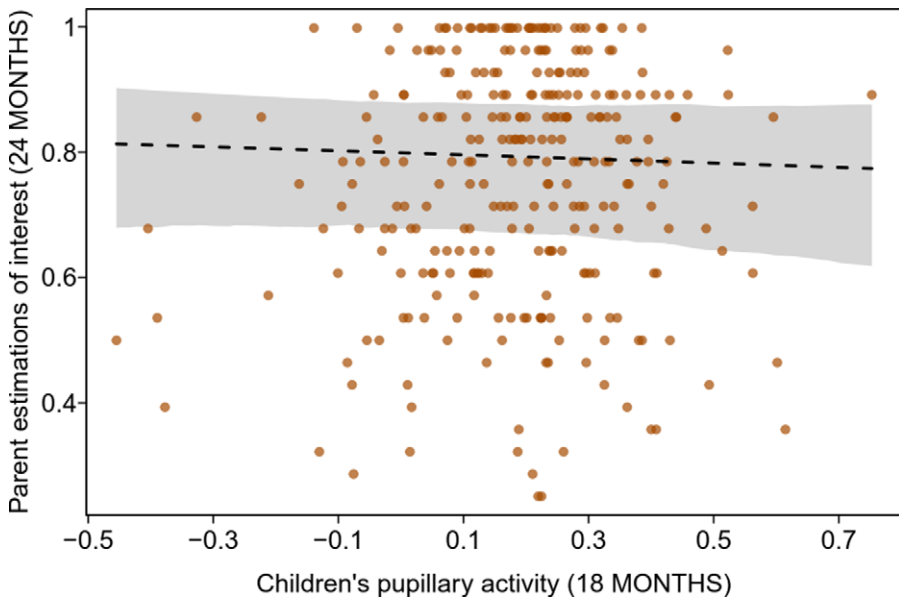


Figure 8. Parent's estimates of children's interests at 24 months as a function of children's baseline-corrected pupillary arousal at 18 months. The dashed line and grey polygon depict the fitted model and the 95% confidence intervals.

Table 5. Results of the GLMM examining children's category-specific vocabulary size at the second testing

Predictors	Parent estimates of children's category-specific vocabulary size at second testing (24 months)							
	Estimate	se	χ^2	df	p	CI	min	max
(Intercept)	1.914	0.248				1.377–2.277	1.840	2.004
Parent estimate of interest at 18 m	0.289	0.086	11.434	1	0.001	0.121–0.439	0.265	0.326
Pupillary arousal at 18 m	–0.091	0.070	1.710	1	0.191	–0.215–0.046	–0.118	–0.072
age (days)	0.479	0.121	14.157	1	0.001	0.246–0.692	0.434	0.531
time b/w testings	0.187	0.114	2.659	1	0.103	–0.046–0.385	0.121	0.232

Note: All predictors were transformed to a mean of 0 and standard deviation (SD) of 1. The original means and SD of predictors are: Parent estimate of interest at 18 m – 0.69 and 0.21; Pupillary arousal at 18 m – 0.20 and 0.16; age (days) 522.23 and 28.87; time between testing 187.55 and 18.21.

for children's vocabulary size at the two time points of testing. Thus, while parents' perception of the number of words their child knows in a category and their child's interest in that category are closely related, vocabulary size alone does not capture parents' intuition of what their child is interested in across development.

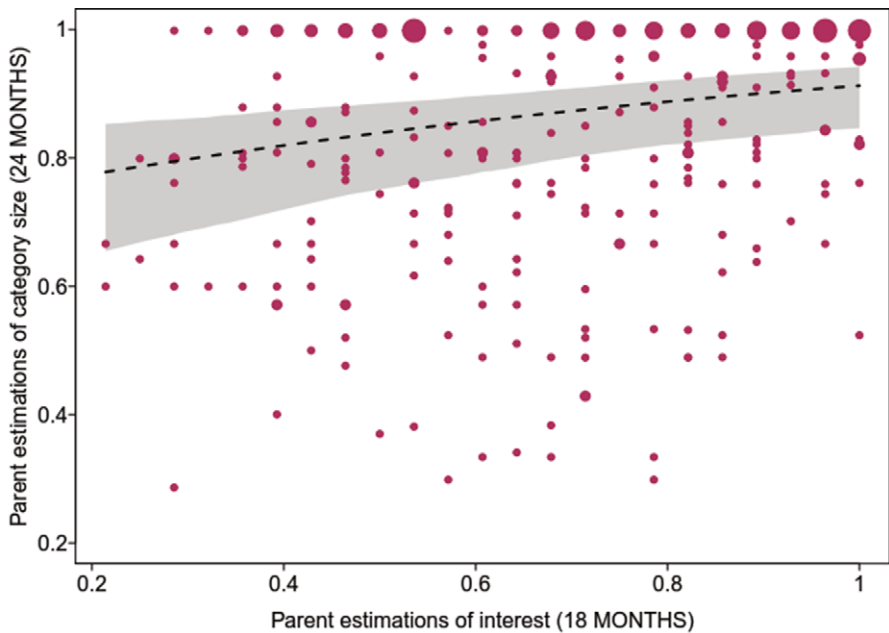


Figure 9. Parent estimates of children's category-specific vocabulary size at 24 months as a function of parent estimates of children's interest in that category 6 months earlier. Dots show observations whereby the size (or area) of the dots shows the number of observations with the exact same value in both variables (range 1–11). The dashed line and grey polygon depict the fitted model and the 95% confidence intervals.

These results speak to the reliability of measures of children's interests commonly used in developmental research. The reliability of a measure is typically examined by examining the replicability and consistency of the results at different time points, under similar conditions. The significant association between the parent measures of interest at the two timepoints indicates that this measure may have internal reliability. However, we note that evidence of the validity of these estimates is still lacking in terms of the extent to which this measure taps into children's interests. While other findings suggest that children's engagement and attentiveness during shared book reading do correlate with parent estimates of their child's interest in the content of the book (Madhavan & Mani, 2024), which may indicate that parents may be able to accurately predict their children's categorical interests, future research ought to investigate this in further detail.

4.2. Children's category-specific pupillary arousal at 18 and 24 months

Our second research question examined pupillary dilation as an index of children's interests in our chosen object categories across two different points in time: once around 18 months and later around 24 months. We found no significant relationship between children's category-specific pupillary arousal at 18 months and the same measure at 24 months.

The lack of evidence for such an association is in direct contrast to the results reported above, and may, as suggested by Ackermann et al. (2020) and Madhavan et al. (2024), be due to pupillary arousal indexing children's current or fleeting interests. This is typically

referred to as situational interest in the four-phase model of interest (Hidi & Renninger, 2006). Here, a temporary and fleeting response, be it arousal or engagement, is triggered by the presentation of a stimulus, which need not necessarily index a sustained or well-developed interest in the object on the part of the individual. Thus, the child may be aroused or intrigued by the presentation of images of animals at the first testing point at 18 months of age, either due to child-specific or stimulus-specific factors, such as greater engagement prior to the session, or greater familiarity with certain objects from certain categories. This fleeting engagement would, nevertheless, explain previous results of improved encoding and learning about these objects at that time point (Ackermann et al., 2020, 2023; Kang et al., 2009), despite not proving to be reliable across development.

Nevertheless, this suggests the need for some caution in the use of pupillary arousal in such tasks to index children's interests, at least in terms of more emerging and well-developed interests. At the very least, we note that children's category-specific pupillary arousal did not predict parents' estimates of children's interests, suggesting that the two measures have limited convergent validity and may not tap into the same construct of interest (see also Ackermann et al., 2020; Madhavan et al., 2024).

4.3. Predictive validity of children's category-specific pupillary arousal at 18 months and parent reports of children's interests at 24 months

We also examined whether children's pupillary arousal towards certain object categories at 18 months predicts parent estimates of children's interests in those categories 6 months later. We did not find any evidence of this relationship; indeed, the pupillary measure was not in any way significantly associated with parent estimates of children's interests or parent estimates of children's vocabulary size. The lack of evidence for such a relationship could be attributed to many different factors. On the one hand, it may be, as discussed above, that the pupillary measure may not index interest *per se*, and, therefore, cannot predict parents' perception of these interests later in development. At the same time, we note that, especially with young children, it is difficult to obtain an estimate of what they are actually interested in, since they cannot provide a subjective report of their interests. It, therefore, remains to be seen whether the pupillary measures or other measures under examination truly capture children's interest in different natural categories. At the very least, we suggest that the mounting evidence of lack of convergent validity between the pupillary measure and other measures of interest highlights the need for caution in *sole* use of this measure in studies on children's interests.

Alternatively, it may be that the interests indexed by the pupillary measure at 18 months may not yet be as well established at 24 months for parents to be able to perceive them. However, given that there was no correlation between the pupillary measure at 18 and at 24 months, it is unlikely that the absence of a correlation between the pupillary measure at 18 months and parent reports at 24 months is due to factors other than the questionable validity of the pupillary measure as an index of children's interests.

4.4. Relationship between category-specific vocabulary size and individual interest

Our final analysis examined the relationship between children's category-specific vocabulary size at 24 months and children's interest in those categories, indexed by either (a) parent estimates or (b) children's pupillary arousal, 6 months earlier. We found that parent estimates of children's interests in specific categories at 18 months predict the

number of words children know in that category 6 months down the line. That is, when parents report their child to be more interested in certain object categories at around 18 months, children also seem to know more words in those categories at around 24 months of age. This suggests the possibility of a longitudinal relationship between children's interests and vocabulary knowledge: when children have a well-developed interest in certain categories, they gather more and more knowledge over time about this category, which is reflected in their category-specific vocabulary size when they are older. This is typical of the phases outlined by the four-phase model of interest: when an individual's interest becomes established, their interactions and desire to know more about certain topics become stronger and internally regulated, such that they acquire more information about that category (Hidi & Renninger, 2006).

Might the results, however, be simply explained by children's knowledge about the object categories? Indeed, both the current study and previous research have shown that there exists a robust relationship between knowledge and interest (Madhavan et al., 2024, see [Supplementary materials](#); S2 and S3). We note, however, that the relationship between parent estimates of children's interests at 18 months and the same measures at 24 months was sustained even after controlling for children's category-specific vocabulary size at 18 months (as seen in the second analysis of R.Q.1). Given the significant relationship between parent estimates of children's interests at 24 months and their children's category-specific vocabulary size at 24 months (in [Supplementary materials](#) S3), this would suggest a relationship between early interests and later vocabulary development that goes beyond simple preferential acquisition due to early vocabulary (Kalinowski et al., 2024, 2025).

We suggest caution, however, in attributing directionality to this relationship – in terms of whether interest drives knowledge acquisition, or whether pre-existing knowledge of certain object categories drives interest in them. Additionally, the only measures supporting the interest-knowledge link were the parent reports: we find only that parent reports of category-specific knowledge are associated with parent estimates of children's interest. While this may reflect the accuracy and knowledge of parent with regard to their children's interests and language development, it is still skewed towards what parents perceive these to be. Furthermore, considering that both the parent measures of children's interest and vocabulary knowledge were implemented simultaneously (with parents receiving the questionnaires and completing them at home), it is possible that the nature of the measures (being parent questionnaires) and the timing of the measures being implemented may have influenced the significant association found here. Notably, children's pupillary arousal to objects from the different categories at 18 months of age did not predict their vocabulary knowledge in these object categories at around 24 months of age. Considering the (lack of) significant relationship between our pupillary measure and other measures reported in this study, these results are not surprising.

Our research is not without its limitations. Due to the age group of our participants, particularly at the first time point of testing, the number of stimuli presented to children in the pupillary task was limited. Not only were children at this age unlikely to be able to attend to this task for extended periods of time, their vocabulary knowledge is also limited, thereby limiting the number of words likely to be known and could be presented in the pupillary task. And while our results suggest the sustained nature of early interests in children across development as well as the longitudinal relationship between interest and later vocabulary, we cannot interpret these findings further due to the limitations in our knowledge of the directionality of the relationship.

In conclusion, our findings highlight the following: first, we find that parent estimates of children's interest in specific object categories sustain across early development. Not only does this speak to the consistency of early interests by as early as 18 months of age, but this finding also adds to developmental research by providing evidence for the internal reliability of parent estimates of children's interests. Conversely, the lack of relationship between the pupillary arousal measure across two timepoints questions the reliability of this particular measure, and warrants further research on this measure and the actual construct it measures. Finally, children's vocabulary development was linked to the development and maintenance of sustained individual interests, which suggests at least a dynamic mutual relationship between interest and knowledge in young children. Future studies can further examine the emergence of such interests by observing even younger children and whether parents are able to reliably predict and trigger their children's interests at an earlier developmental stage. The role of parents in maintaining children's interests and furthering their vocabulary must also be closely studied by examining the nature and function of parent-child interactions during daily activities, and identifying the role of parent and child, respectively, in the acquisition of word knowledge in young children.

Supplementary material. The supplementary material for this article can be found at <http://doi.org/10.1017/S0305000925100378>.

Data availability statement. All data and corresponding analysis scripts required for the replication and substantiation of all our analyses can be found on the OSF study page (<https://osf.io/puk6e/>).

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Competing interests. The authors state that there are no competing interests.

Ethics statement. Ethics approval was granted by the ethics committee for Psychology at the University of Göttingen.

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