# Children's scale errors and object processing: early evidence for cross-cultural differences

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## Highlights

- We examined the relationship between children's scale errors and their categorization ability in Japan and UK.
- UK children who showed greater local processing made more scale errors.
- Japanese children, who overall showed greater global processing, showed no such relationship.
- Suppression of scale errors in children may emerge not from attention to size *per se*, but from an integration of global and local information during object processing.

Abstract

Scale errors are observed when young children make mistakes by attempting to put their bodies into miniature versions of everyday objects. Such errors have been argued to arise from children's insufficient integration of size into their object representations. The current study investigated whether Japanese and UK children's (18 to 24 months old, $N$ = 80) visual exploration in a categorization task related to their scale error production. UK children who showed greater local processing made more scale errors, whereas Japanese children, who overall showed greater global processing, showed no such relationship. These results raise the possibility that children's suppression of scale errors emerges not from attention to size *per se*, but from a critical integration of global (i.e., size) and local (i.e., object features) information during object processing, and provide evidence that this mechanism differs cross-culturally.

Keywords: scale error, cultural differences, categorization, object processing, cognitive development.

## 1 Introduction

How infants and toddlers integrate feature information in object learning has attracted considerable attention in developmental psychology (e.g., Cohen et al., 2002; Mareschal et al., 1999; Chen & Westermann, 2018). Infants' ability to individuate featural information such as shape, size, and color develops substantially in early infancy (Wilcox & Biondi, 2016). For example, by 4.5 months infants can reliably represent shape and size information, and by 11.5 months they can detect color information and use this information to individuate objects (Wilcox, 1999). However, early in development toddlers' ability to integrate featural information with spatio-temporal information remains limited, presumably because young children have difficulty in maintaining representations of multiple object features (Bertenthal, 1996; Johnson & Mareschal, 2001). For example, infants within the first year of life are not able to represent featural and spatial information simultaneously, despite being able to process both types of information individually (Bremner et al., 2006; Oakes et al., 2006). Further, dissociations between perceived information and subsequent action are evident at these early stages of development; for example, 18- to 24-month-old children fail to integrate perceptual information with appropriate action responses (e.g., searching; Nardini et al., 2008).

The challenge of integrating perceptual information with the appropriate action representation is illustrated by an intriguing phenomenon known as the *scale error* (e.g., DeLoache et al., 2013; DeLoache et al., 2004; Rivière, Brisson & Aubertin, 2020). When making a scale error, young children make mistakes by attempting to put their bodies into miniature versions of everyday objects (Arterberry et al. 2020). For example, children have been observed trying to get into a miniature sized car, just as they would do with a normal sized car. An example of a child performing such a scale error is depicted in Figure 1. Children's scale errors were first reported in laboratory settings, where children were exposed to miniature toys immediately after interacting with a appropriate-sized toy. In the first of these studies, DeLoache and colleagues (2004) demonstrated that approximately half of their sample of 18- to 30-month-old children performed at least one scale error. Subsequent studies have revealed that scale errors are also observed in the classroom (Rosengren, Carmichael et al., 2009) and in the home (Rosengren, Gutiérrez et al., 2009) without immediate prior exposure to corresponding real-sized objects. Importantly, then, scale errors are a real-world phenomenon that do not depend on a controlled lab environment for its elicitation (see also DeLoache et al., 2013), but whose prevalence is also marked by substantial individual differences between children (e.g., Rosengren et al., 2010).

*Figure 1*. A child attempting to get into a miniature car.

Several mechanisms have been proposed as the potential cause of scale errors, most notably the immaturity of the brain network which governs object recognition/action planning (processed by the ventral stream) and online action control (processed by the dorsal stream; Glover 2004). Specifically, DeLoache et al. (2004) suggested that when children see a miniature replica of an object their mental representation of the corresponding real-size object is activated together with the motor routines associated with that real-size object. Typically, these motor routines are then inhibited, and an action plan based on the miniature category exemplar is executed instead, leading to size-appropriate behaviors such as pretending (as opposed to earnest attempts to carry out the action). However, in some cases this inhibition fails and a scale error is performed.

Several studies have explored the possibility that children's failure to inhibit size-inappropriate motor routines may be associated with their insufficient encoding of size information when encountering miniature objects. For example, DeLoache and Uttal (2011) reported that some children in their study were not aware of the change in object size from normal to miniature. Related work has revealed that the occurrence of scale errors was negatively associated with children's concept of size as measured using a parental questionnaire (Ishibashi & Moriguchi, 2017). In other work, using a looking time task designed to assess whether children could detect the appropriate or inappropriate object size for a particular tool, Grzyb et al. (2017) demonstrated that children who had exhibited scale errors were less likely to detect size changes than those who had not. Moreover, Grzyb and colleagues (2019) suggest that children's lack of attention to object size may stem from their emerging shape bias: as children learn new words, they also learn that words tend to refer to category exemplars that share a shape, but that size is less relevant for category membership (Landau, Smith & Jones, 1988).

Taken together, these studies support accounts that assume that scale errors stem from an insufficient processing of size information when encountering objects with an atypical size (i.e., miniature replicas of larger real-world objects). Individual differences in the frequency of scale errors might on this account point to variation in the ability to integrate local (i.e, recognizing elements of object features; car door) and global features (i.e., recognize the whole object configuration; size or shape) in object processing.

Nevertheless, in studies using hierarchical patterns in which local features are arranged in global patterns (such as Navon figures in which e.g., a large T is made up of many small Es), infants as young as 3 to 4 months have been shown to be able to process both local and global information (Ghim & Eimas, 1988), with a processing advantage for global information (Frick et al., 2000), although there are considerable individual differences between infants (Guy et al., 2013). In addition, as attentional selection develops, children learn to inhibit irrelevant information, successfully focus their attention on relevant information (Krakowski et al., 2016; Krakowski et al., 2018), and flexibly switch from global to local target information (Zappullo et al., 2020).

However, although the ability to process both global and local elements individually emerges early on, the ability to *integrate* local with global information shows a more protracted development. This ability has, for example, been investigated in the context of infants' formation of object categories. In a seminal study, Younger (1985) designed a set of eight line-drawn imaginary animals with four distinctive features (length of the neck and legs, thickness of the tail, distance between the ears) so that the features were correlated (e.g., a shorter legs would always co-occur with a thicker tail). If infants were able to detect these correlations they would form two categories based on correlated feature clusters. Younger (1985) found that 10-month-olds indeed formed two categories, indicating that they were able to encode the global feature relations across the stimuli. Nevertheless, follow-on studies have again found substantial individual differences between infants, with some infants categorizing on the basis of overall similarity and others on the basis of feature correlations (see Westermann & Mareschal, 2004), indicating that the ability to integrate local and global object information follows highly individual developmental trajectories.

Differences in global/local processing have not only been reported within homogeneous participant groups, but also on a larger scale between members of different cultures. Specifically, a substantial body of research has shown that members of Eastern cultures such as Japan and China show more holistic, global processing than members of Western cultures such as the US (Chua et al., 2005; Kelly et al., 2010; Masuda et al., 2014). For example, in tasks using Navon figures, East Asian adults showed a strong global advantage compared with Westerners in detecting target letters (McKone et al., 2010). Relatedly, several studies have shown that when viewing scenes containing local objects on a complex background, Westerners tend to look more at the local objects than East Asians (e.g., Chiu, 1972). Furthermore, when subsequently describing such scenes East Asians described surrounding information such as the color of water in an aquarium containing fish, whereas US participants' descriptions related more directly to the objects, for example describing their motion (Masuda & Nisbett, 2001). Similar differences in processing have also been observed in abstract tasks. For example, in the Framed Line Task, in which participants are asked to judge the length of a line drawn inside a square, Japanese participants showed fewer errors when making judgements based on the length of the line relative to the background information (i.e., the size of the square), whereas US participants showed fewer errors when judging absolute length, irrespective of the square size (Kitayama et al., 2003; for a review, see Nisbett & Miyamoto, 2005).

Related results from the developmental literature suggest that children from Eastern and Western cultural backgrounds also show differences in processing. For example, like adults, Japanese children aged 6 to 13 years demonstrate heightened attention to context in the Framed Line Task compared with their US peers (Duffy et al., 2009). Differences have also been observed in children as young as 3, with Japanese children recognizing objects holistically whereas US children identified them locally (Kuwabara & Smith, 2016). In Kuwabara and Smith's (2016) study, US children relied on low-level features for object identification, whereas Japanese children showed more evidence of configural processing when the overall shape of an image was masked.

It is an open question whether scale error production is related to specific object processing strategies and thus, to cultural differences. In particular, although scale errors have been shown to be a robust phenomenon across cultures (in Western countries, e.g., Brownell, et al., 2007; in Asian countries, e.g., Ishibashi & Moriguchi, 2017), the encoding processes by which children integrate local features of object properities (e.g., car door) into their global features (e.g., size, shape) may operate differently across different cultural backgrounds. On one hand, given that Western children pay more attention to local features, they may be better able to encode specific object properties. On the other hand, given that East Asians show stronger effects of an object's surrounding environment on its encoding it is also possible that these children specifically encode global elements such as size more robustly than Western children. Irrespective of culture, we would expect children who show better object processing to be less likely to commit scale errors.

The current study explored these possibilities by examining the relationship between scale error production and object processing ability in 18- to 24-month-old Japanese and UK children. To index object processing, we tested infants in a categorization task. In a typical task, infants are presented with a series of pictures from one category during a familiarization phase, followed by a test phase in which a novel exemplar from the familiarized category is paired with an out-of-category exemplar. Infants' longer looking at the out-of-category exemplar is taken as evidence that they have learned the category comprising the familiarization items and the within-category test item, and therefore show a novelty response to the out-of-category item. A rich body of work has shown that even young infants can succeed in such tasks and that they form categories on-line on the basis of the perceptual features of the presented items (e.g., Quinn et al., 1993; Younger & Cohen, 1986).

In the current study, we presented children with the categorization task used by Althaus and Westermann (2016). In this study, infants were familiarized with a novel category of morphed, cartoon animal stimuli, in which perceptual features (e.g., body morphology, posture; see Fig. 2) changed gradually along a continuum. Test stimuli consisted of three novel exemplars: a prototypical stimulus drawn from the averaged familiarization stimuli, a peripheral stimulus taken from the extreme end of the familiarization category, and a completely novel stimulus drawn from a novel category. Infants saw paired test stimuli across three types of test trial: novel/prototypical, novel/peripheral, and prototypical/peripheral. We took children's preference for the more novel exemplar on each type of test trial as an index of their novelty preference and hence, their object processing.

To elicit scale errors, we presented Japanese and UK children with the scale error task employed by DeLoache and colleagues (2004), with the addition of an extra set of stimuli (shoes) for Japanese children to acknowledge cultural norms (Ishibashi & Moriguchi. 2017). We hypothesized (a) that due to different culture-specific object processing strategies we would find differences in the prevalence of scale errors between Japanese and UK children, and (b) that children who showed a stronger novelty preference in the categorization task, indicating more robust encoding of object features, should make fewer scale errors.

## 2. Methods

### 2.1 Participants

Participants were 40 typically-developing Japanese-learning children living in Japan (*M* = 19.73 months, *SD* = 1.63, 17 girls, range = 18.21 - 24.74 months) and 40 typically-developing English-learning children living in the UK (*M* = 19.75 months, *SD* = 1.86, 23 girls, range = 18.02 - 23.90 months). Sample sizes were determined *a priori* to reflect those in previous studies which were sufficient to detect scale errors (e.g., Ware et al., 2006).

From the UK sample, an additional nine children were excluded due to fussiness (as defined by crying, or refusing to take part in either phase of the study; *n* = 4), eye-tracker sample rate of less than 20% (*n* = 4), and experimenter error (*n* = 1). Note that the differences in the rate of exclusion due to fussiness between countries (JPN, *n* = 0; UK, *n* = 4) may be shaped by differences in parenting practices (e.g., Pinquart & Kauser, 2018; see Discussion).

Participants were recruited from a database of parents who had expressed an interest in participating in developmental research. Children were from white and predominantly middle-class backgrounds. The purpose of the study was explained to the parents both verbally and in a written document and parents provided informed consent for their children to take part. Parents received £10 to reimburse travel expenses and children received a book for participating.

No children were excluded from the Japanese sample, under exclusion criteria identical to the UK sample. Japanese children were recruited via flyers placed in nurseries or e-mail invitation from a database of participants whose parents had expressed an interest in participating in developmental research. Children were from predominantly middle-class backgrounds. The purpose of the study was explained both verbally and in a written document and parents provided informed consent for their children to participate. Parents received 1000 yen and travel expenses for participating.

## 2.2 Materials

### 2.2.1 Categorization task.

Categorization stimuli are depicted in Figure 2. Drawn from Althaus and Westermann (2016), they consisted of images of a category of novel animals with 19 equally spaced exemplars. As in the original study, a subset of the exemplars (1, 3, 5, 7, 13, 15, 17, and 19) served as familiarization stimuli. Exemplars were presented individually centered on a white background. At test, children saw three new images. Exemplar 10 served as a category central prototype and exemplar 4 as a category peripheral item; both the prototype and peripheral exemplar shared features with the familiarization items but were novel to children (see Figure 2). Finally, a completely novel image drawn from a new category served as the novel item. This image differed from the familiarization stimuli in individual components (i.e. tail, head, design on tummy, wings, feet).

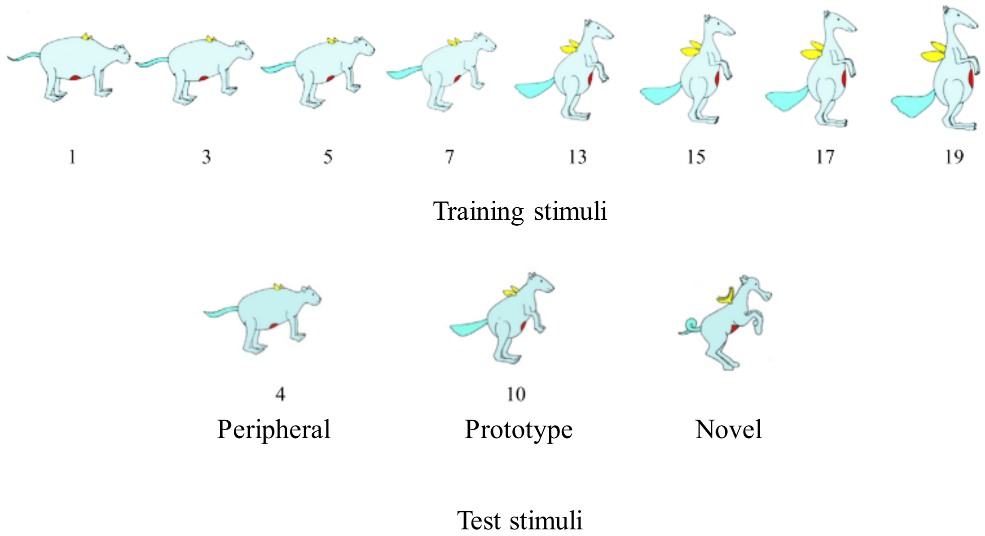


*Figure 2*. Stimuli used in the categorization task. The upper panel depicts training stimuli, and the lower panel depicts test stimuli.

2.2.2 Scale error task

A slide, a car, and a desk set (chair and table) were used for children from both countries, however different (but similar) car and slide stimuli were used for availability reasons. All items are commonly encountered in each culture, and access to toys during childhood is characteristic of both cultures (e.g., Mori et al., 2013). In addition, Japanese children also saw child-sized (their own) and miniature size shoes, because in line with cultural norms they were asked to remove their shoes in the play room before the study began. Approximate dimensions of the toys are provided in Table 1. The typical shoe size for children of around 18 to 24 months is provided for reference. Figures 3 and 4 depict the child-sized and miniature toys used in the scale error tasks.

*Table 1*. Dimensions of toys in used in the scale error task in Japan and the UK .

| Country | Toy | Dimensions (L x W x H; cm) | |
|---|---|---|---|
| | | Child-size | Miniature-size |
| Japan | Slide | 46.0 x 110.0 x 72.0 | 5.0 x 21.0 x 14.0 |
| | Car | 58.0 x 37.5 x 35.5 | 7.0 x 6.0 x 10.0 |
| | Chair | 35.5 x 28.5 x 32.0 | 8.0 x 10.0 x 10.0 |
| | Table | 61.0 x 41.0 x 47.5 | 10.0 x 18.0 x 15.0 |
| | Shoes | (7.0 x 12.0 x 4.0) | 4.0 x 7.0 x 2.0 |
| UK | Slide | 51.0 x 33.5 x 150.0 | 3.5 x 6.0 x 8.5 |
| | Car | 74.9 x 41.9 x 85.1 | 6.0 x 3.0 x 6.5 |
| | Chair | 35.5 x 28.5 x 32.0 | 8.0 x 10.0 x 10.0 |
| | Table | 61.0 x 41.0 x 47.5 | 10.0 x 18.0 x 15.0 |

*Figure 3*. Child-sized and miniature sized toys used in the Japanese scale error task.

*Figure 4*. Child-sized and miniature sized toys used in the UK scale error task

## 2.3. Procedure and design

For both samples, parents were present at all times; however, they were requested not to interact with their child during the categorization task, and not to mention the size of the objects during the scale error task. The two tasks were conducted in fixed order (categorization, scale error) because we assumed that the stimuli of the scale error task were more salient than those of the categorization task, which could make the children less attentive during the categorization task if it was performed second.

2.3.1. Japanese sample.

The categorization task and scale error task were conducted in the same quiet, child-friendly room. All toys used in the scale error task were hidden behind two partitions in the corner of the room until the scale error task began. Thus, children did not see either the child-sized or the miniature toys during the categorization task. After the experimenter had explained the purpose and procedure of the study and obtained consent, the categorization task began. Once the categorization task was complete, parents and participants left the room whereas the toys used in the scale error task were placed in the center.

2.3.2. UK sample.

After the experimenter had explained the purpose and procedure of the study and obtained consent, parents and participants were escorted to a quiet, dimly-lit room to take part in the categorization task. Next, the scale error task was conducted in a separate, brightly-lit, child-friendly room. Again, children did not see either the child-sized or the miniature toys during the categorization task.

2.3.3. Categorization task.

The procedure for the categorization task was identical for Japanese and UK children. The child was seated on his/her parent's lap opposite a computer screen in a dimly-lit room. A screen-mounted Tobii eyetracker (Japan: X2-30; UK: X120; display size 1920 x 1080 pixels) was situated under the screen and recorded the location and duration of the child's gaze. Stimuli were presented in Tobii Studio (Japan: V3.1.1; UK: V.3.2). Before the experiment began we used the five-point infant-specific calibration procedure available in Tobii Studio to calibrate the eye-tracker. The calibration stimulus was an animal or toy which appeared at five locations (top left, top right, bottom left, bottom right and center), accompanied by child-friendly sound (e.g., a jingling noise). This process was repeated up to three times if the calibration had not captured all five points. No child required more than three attempts at calibration.

During the familiarization phase children saw the eight familiarization stimuli presented individually on the screen. Half of the children saw stimuli that faced left, and half of the children saw stimuli that faced right. Order of presentation of stimuli was randomized across children, with the same randomization orders used for the Japanese and UK children. Each familiarization trial consisted of a static image displayed for ten seconds in silence. Between familiarization stimuli children saw attention grabbing videos consisting of a small, moving cartoon animal accompanied by a child-friendly sound.

Immediately following familiarization, children were presented with six test trials. Again, stimuli were presented for ten seconds in silence. Children saw three types of test trial, each of which consisted of two test exemplars presented side by side: a novel/prototype trial, a novel/peripheral trial, and a prototype/peripheral trial. Again, half of the children saw stimuli that faced right, and half of the children saw stimuli that faced left, with the constraint that test trial exemplars faced in the same direction as familiarization exemplars. Each test trial was seen twice; order of presentation of test trials was randomized across children (randomization was identical for the Japanese and UK children).

#### 2.3.4. Scale error task.

Following the categorization task, the child participated in the scale error task (DeLoache et al., 2004). The child played freely with the child-sized stimuli for approximately five minutes. If the child did not interact with any of the objects, the experimenter encouraged them to do so. Then, the child and parent left the play room. Meanwhile, the experimenter replaced the toys with the miniature versions. Then, the child and the parent returned to the play room, and the child's behavior was observed for five minutes. This task was also videotaped for later coding. The whole procedure took no longer than 30 minutes. Although the scale error task and the categorization task were conducted in different rooms in the UK and in the same room in Japan, the procedure was the same in Japan and the UK.

### 2.4. Data Coding and Analysis

#### 2.4.1. Categorization task.

Data cleaning and coding were identical for Japanese and UK samples. Gaze position was calculated automatically in Tobii Studio by taking the average gaze position of both eyes. Timestamps (the time window during which the eyetracker sampled an individual gaze point) for which the eye-tracker did reliably not detect an eye were discarded (Japan: 30.99%; UK:

32.91%). Test AOIs were centered on and closely bounded the stimuli, and measured 1151 by 673 pixels. Background looks were discarded, leading to a final Japanese dataset of 30,852 timestamps and a final UK dataset of 69,851 timestamps (note that the sample rate of the UK eyetracker was twice that of the Japanese eyetracker). On the novel/prototype test trials and novel/peripheral test trials, looks to the novel stimulus were coded "1", and looks to the prototype were coded "0". On peripheral/prototype trials, looks to the peripheral stimulus were coded "1", and looks to the prototype were coded "0".

#### 2.4.2. Scale error task.

The actions children performed on the miniature sized toys in the scale error task were coded based on criteria from DeLoache et al (2004), as follows: (a) whether the child attempted to interact with the miniature toy(s) in the same way he or she had acted on the child-sized objects (0, 1); (b) whether the appropriate part(s) of the toys were touched with the child's appropriate body part(s) (0, 1); (c) how clearly deliberate the behavior was (five-point scale; 1: definitely serious; 2: probably serious; 3: not clear, 4; probably pretending; 5: definitely pretending). Only behaviors which scored 2 or under on criterion (c) were classed as scale errors. Repeated attempts with the same object in succession were counted as a single scale error (Rosengren et al., 2010). For example, we coded a single scale error if a child attempted to sit on the chair multiple times in a row. Twenty-five percent of each sample was coded by a secondary coder naïve to the experimental hypothesis. Cohen's Kappa indicated that inter-rater reliability was high (Japan: $k = .74$; UK: $k = .74$).

## 3. Results

All analyses were performed in R Studio (v. 3.4.2; R Studio Team, 2015); linear mixed effects models were conducted in lme4 (v. 1.1-15; Bates et al., 2015).

### 3.1 Categorization results

To test whether children in Japan and the UK learned categories, for each test trial type we submitted proportion target looking (time looking to target AOI / total AOI looking) to two-sided, one-sample *t*-tests against chance (0.5). Results are depicted in Figure 5.

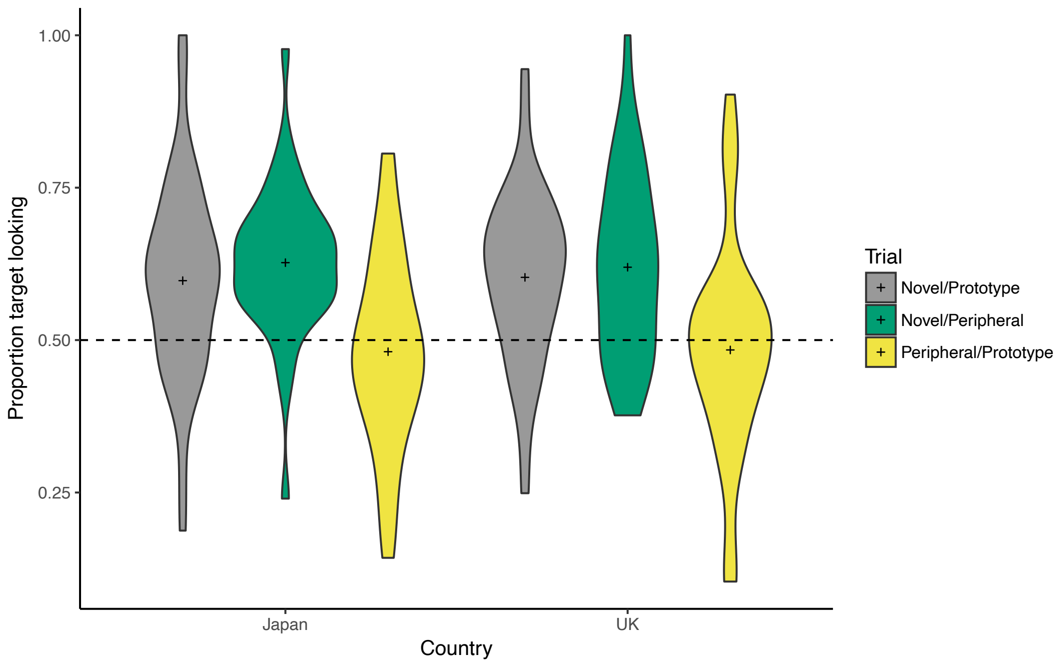


*Figure 5*. Results from test trials. + indicates mean. Dashed line indicates chance.

On novel/prototype trials, we treated the novel stimulus as the target. Children in both Japan and the UK looked for longer at the target than expected by chance (Japan: $M = 0.60$, $SD = 0.16$, $t(38) = 3.83$, $p < .001$, 95% CI[0.55, 0.65]; UK: $M = 0.60$, $SD = 0.14$, $t(36) = 4.48$, $p < .001$, 95% CI[0.56, 0.65]). Next, on novel/peripheral trials, we also treated the novel stimulus as the target. Again, children in both Japan and the UK looked for longer at the target than expected by chance (Japan: $M = 0.63$, $SD = 0.12$, $t(39) = 6.70$, $p < .001$, 95% CI[0.59, 0.67]; UK: $M = 0.62$, $SD = 0.15$, $t(37) = 4.96$, $p < .001$, 95% CI[0.57, 0.67]). Finally, on peripheral/prototype trials, we treated the peripheral stimulus as the target. Neither Japanese nor UK children looked for longer at the target than expected by chance (Japan: $M = 0.48$, $SD = 0.16$, $t(39) = -0.77$, $p = .44$, 95% CI[0.43, 0.53]; UK: $M = 0.48$, $SD = 0.17$, $t(37) = -0.57$, $p = .57$, 95% CI[0.43, 0.54]). Thus, children learned categories that excluded the novel exemplar, but included the peripheral exemplar, and this finding was replicated across countries.

#### 3.1.2. Relationshiop between trial type (novel/prototype, novel/peripheral, peripheral/prototype) and country

Next, we submitted proportion target looking to a linear mixed effects model (henceforth *LMEM*) with fixed effects of trial type (novel/prototype, novel/peripheral, peripheral/prototype) and country (Japan, UK) and their interaction, by-participant random slopes for trial type and by-item random slopes for country (this was the maximal random effects structure that converged; Barr et al., 2013). The model revealed a significant effect of trial type ($\chi^2(2) = 15.88$, $p < .001$; novel/prototype: beta = -0.040, $SE = 0.041$, $t = -0.96$; peripheral/prototype: beta = -0.15, $SE = 0.041$, $t = -3.72$). Post-hoc Tukey comparisons confirmed that overall, participants looked less at the target on peripheral/prototype trials than on either novel/prototype trials ($z = -3.87$, $p < .001$) or novel/peripheral trials ($z = -4.72$, $p < .001$), with no difference in looking between these two trial types ($z = -0.82$, $p = .69$). We found no difference in performance between countries (beta = -0.011, $SE = 0.039$, $t = -0.28$, $\chi^2(1) = 0.016$, $p = .90$) and no interaction between trial type and country ($\chi^2(2) = 0.28$, $p = .87$; country by novel/prototype: beta = 0.030, $SE = 0.057$, $t = 0.52$; country by peripheral/prototype: beta = 0.014, $SE = 0.057$, $t = 0.25$). Thus, children exhibited evidence of category learning on novel/peripheral trials, suggesting that their more mature object processing abilities enabled them to detect the more subtle differences between these two stimuli. However, we did not find any differences between Japanese and UK children's performance on the categorization task.

### 3.2. Scale error task

Results from the scale error task are provided in Table 2. Children from both countries made scale errors. In line with existing work, rates of scale error production are overall relatively low, with 20/40 Japanese and 15/40 UK children producing errors. However, we found no evidence of a difference in scale error production between countries ($t(77.00) = 0.75$, $p = .45$, 95% CI[-0.45, 1.00]). Thus, we found similar results in the occurrence of scale errors between two countries. These results are in line with previous studies that used a similar procedure across cultures (e.g., 25/40 in Western countries, [DeLoache et al., 2004]; 26/54 in Asian countries [Ishibashi & Moriguchi, 2017]).

*Table 2*. Rates of scale error production for Japanese and UK children.

| Number of scale errors | Number of children | |
|---|---|---|
| | Japan | UK |
| 0 | 20 | 25 |
| 1 | 8 | 5 |
| 2 | 3 | 5 |
| 3 | 5 | 2 |
| 4 | 1 | 1 |
| 5 | 2 | 1 |
| 6 | 1 | - |
| 7 | - | 1 |

3.3. Relationship between children's scale errors and categorization ability

To address the question of whether children with better object processing abilities (as indexed by their novelty preference at test in the categorization task) were less likely to make scale errors, we analyzed the relationship between scale errors, novelty preference and country. We submitted the number of scale errors children made during the free play task to a linear regression with country and proportion target looking (i.e., aggregating the novelty preference on novel/prototype, novel/peripheral, and prototypical/peripheral trials) and their interaction as predictors (note we used a regression analysis here due to non-convergence of an LMEM with the same predictors). The regression revealed an interaction between country and proportion target looking ($\beta$ = 85.17, $SE$ = 24.75, $t$ = 3.44, $p$ = .0063), but neither of these variables independently predicted the number of scale errors made by children (proportion target looking: $\beta$ = -20.75, $SE$ = 11.40, $t$ = -1.82, $p$ = .099; country: $\beta$ = -0.75, $SE$ = 1.04, $t$ = -0.72, $p$ = .49). To explore the interaction, we ran two further regressions, using proportion target looking to predict scale error frequencies for each country separately. These analyses revealed that whereas there was no relationship between proportion target looking and scale error production for the Japanese children ($\beta$ = -20.75, $SE$ = 12.95, $t$ = -1.60, $p$ = .17), there was a relationship in the UK children ($\beta$ = 64.41, $SE$ = 18.51, $t$ = 3.48, $p$ = .018).

To eliminate the possibility that inclusion of the shoe stimuli for the Japanese children affected their rates of scale error production, we also conducted the analysis excluding the scale errors made with the shoes by Japanese children. There was no difference in scale error production between countries ($t(59.53)$ = -1.27, $p$ = .21). In line with the regression on the full dataset, we found a significant interaction between country and proportion target looking ($\beta$ = 91.51, $SE$ = 23.71, $t$ = 3.86 , $p$ = .006), but no independent effect of either variable (proportion target looking: $\beta$ = -27.09, $SE$ = 17.13, $t$ = -1.58, $p$ = .16; country: $\beta$ = 1.34, $SE$ = 1.00, $t$ = .23).

Again, we ran two further regressions to explore the interaction. We found no relationship between scale errors produced and proportion target looking for Japanese children ($\beta$ = -27.09, $SE$ = 9.60, $t$ = -2.83, $p$ =.11), whereas there was a significant relationship in the UK children ($\beta$ = 64.42, $SE$ = 18.51, $t$ = 3.48, $p$ = .018). Thus, the overall pattern of results did not change when scale errors produced with the shoe stimuli by Japanese children were excluded.

In short, UK children with better object processing abilities were more – not less – likely to produce scale errors. We return to this surprising finding in the Discussion.

### 3.4. Exploratory analyses

Overall, while we did find a relationship between children's object processing and scale error production, this relationship was not in line with our original hypotheses. Specifically, we found no difference between Japanese and UK children in object processing performance in our categorization test. This null result could be due to insufficient statistical power to detect a difference. Equally, it is possible that Japanese and UK children may process images differently, but these two different mechanisms nonetheless lead to successful categorization. Based on the existing literature, Japanese children's global processing and UK children's local processing may both lead to category formation. However, this account predicts that during familiarization, Japanese children's looking should be more broadly distributed across the screen, whereas UK children's looks should be more closely centered on the AOI (which contained all local stimulus features). Thus, we carried out a post-hoc exploratory analysis to examine this possibility. To this end we calculated the total proportion of AOI looking out of all screen looks during the familiarization phase for each familiarization trial for each child. A two-tailed, independent samples *t*-test confirmed that UK children spent a greater proportion of the familiarization phase looking at the AOI than at the background than Japanese children (Japan: $M = 0.62$, $SD = 0.17$, UK: $M = 0.79$, $SD = 0.18$, $t(78) = -4.47$, $p < .001$, 95% CI[-0.23, -0.10]). Thus, children's looking behavior during familiarization is compatible with the assumption that children from Eastern cultures show global processing, whereas children from Western cultures show local processing (e.g., Masuda et al., 2014). Since this finding did not form part of our initial hypotheses and was exploratory, it should be interpreted with caution. Nonetheless, it is in line with results from similar work with adults (Chua et al, 2005) and sheds some light on our intriguing cross-cultural finding that there was a relationship between category learning and scale error in the UK children but not the Japanese children: on the assumption that UK children process local rather than global features, it may be that the extent to which children rely on a combination of local and global processing could underlie their scale errors. We discuss this possibility in further detail below.

## 4. Discussion

The purpose of this study was to examine whether children's scale errors were associated with their categorization ability, and if so, whether this relationship differed between Japanese and UK children. In particular, we reasoned that culture-specific differences in object processing may result in differences in category learning; specifically, we predicted that UK children's local object processing would lead to better category learning. Further, we reasoned that because children who performed better in the categorization task were better at encoding category exemplars, they should also show fewer scale errors. To explore this possibility we indexed children's object processing using a looking time task taken from Althaus and Westermann (2016). Then, we asked whether this ability related to children's scale error production, and whether there were cultural differences in performance of scale errors between Japanese and UK children.

First, we discuss children's categorization performance. Then we discuss our main results: whether object processing is associated with the scale error and how scale error performance related to category learning between the two cultures.

4.1. Categorization results

Our results replicated Althaus and Westermann's (2016) findings that 10-month-old infants showed a novelty preference on novel/prototype test trials, and additionally on novel/peripheral test trials. Overall, these results expand on the findings of Althaus and Westermann's (2016) study, extending them to an older age group and across cultures. Increased target looking on the novel/prototype trials replicated the behavior of infants in the original study. Unlike those 10-month-old infants, however, children aged 18 to 24 months in the present study exhibited evidence of category learning on novel/peripheral trials, suggesting that their more mature object processing abilities enabled them to detect the more subtle differences between these two stimuli. Not surprisingly, then, our older children's object processing abilities were more sophisticated than those of the 10-month-old infants in the original study. However, like the infants, children did not prefer the peripheral stimulus on the peripheral/prototype trials. Importantly, these results offer no evidence that low-level visual categorization abilities differ in Japanese and UK children.

We did not find any differences between Japanese and UK children's performance on the categorization task. Thus, in the current study we found no evidence for cross-cultural differences in category formation – at test. Nonetheless, our exploratory analysis revealed a difference in visual processing during familiarization: similarly to a study with Chinese and US adults (Chua et al, 2005), whereas Japanese children distributed their attention broadly across the screen, UK children focused more on the objects. Thus, Japanese children looked more at the non-target aspects of the stimuli such as the background, in line with global processing, whereas UK children looked more at stimulus features, in line with local processing. Previous studies indicate that when viewing video clips of fish swimming in an aquarium, East Asians describe surrounding information, whereas US participants' descriptions related more directly to the objects (Nisbett & Miyamoto, 2005). Relatedly, Eastern children have been shown to recognize objects holistically whereas Western children identified them locally (e.g., Kuwabara & Smith, 2016). We therefore tentatively conclude that our results are consistent with existing evidence that Westerners tend to look more at local-features than East Asians (e.g., Masuda & Nisbett, 2001).

Although exploratory, this finding is supported by the literature on children's object processing and raises the possibility of cultural differences in the category learning task; importantly, however, we did not find that UK children showed stronger categorization than Japanese children, suggesting that although visual processing differs cross-culturally, both local and more global processing can lead to successful category formation. Further work is necessary to explore in detail such cross-cultural differences in visual encoding in categorization tasks..

### 4.2. Relationship between children's scale errors and categorization ability

The current investigation of children's scale error production is the first to compare children from different cultural backgrounds from the same age group in the same task. It indicates that the scale error is a robust cross-cultural phenomenon, in line with existing work that has studied these groups separately (e.g., DeLoache et al., 2004; Ishibashi & Moriguchi, 2017). Whereas we found no overall differences in scale error production in Japanese and UK children, we did find a critical cross-cultural difference: UK children who showed stronger categorization made more scale errors, but we found no such relationship in Japanese children. This finding contradicted our hypothesis that children who showed a stronger preference for the novel stimuli in the categorization task (i.e., were more sophisticated category learners) should produce fewer scale errors.

We account for this surprising finding as follows. If, as suggested by the existing literature and supported by our exploratory analysis, UK children process objects locally, a greater focus on object features might lead to object representations that emphasize local over global features. In the looking time task, then, children who pay more attention to local features may form a more detailed category representation, and therefore find it easier to detect differences between that representation and the novel test items. Thus, in the scale error task, focusing more on local object features (e.g., car door) may lead children to a less effective encoding of global features – in particular, size. Here, we offer a new perspective: UK children's scale errors may emerge from a trade-off between local and global processing.

We found no evidence for a similar relationship in Japanese children; however, these children nonetheless made scale errors at equal rates to UK children. Based on the preceding account we would expect to find cross-cultural differences in scale error production, but in fact, we found no evidence for differences in scale error production between the two groups. As noted, the possibilily that this null result stems from a lack of statistical power is an important one, and our interpretations must remain speculative. Nonetheless, whereas increased local processing in UK children may cause them to make scale errors, it does not necessarily follow that increased global processing should lead to a reduction in scale error production. Rather, we contend that motor planning involves integration of local and global featural information;

*appropriate* motor planning therefore involves an optimal balance between local and global encoding such that representations of the specific object properties and its size are both sufficiently activated. In particular, in our scale error task, local processing is required to recognize the object features, whereas global processing is required to notice the size change. From this perspective, UK children who looked longer at the AOI might have overemphasized local features, while Japanese children's processing might have overemphasized global features. Neither of these processing styles led to optimal integration of local and global information, leading to scale errors. Only UK children who spent more time engaged in global processing may generate the balance between local and global processing necessary for the suppression of scale errors. However, this account is only partially supported by our exploratory analysis, which does not involve a task specifically designed to capture differences in local and global processing, and requires direct replication. Thus, the current study raises the possibility for future work that using a more direct measurement of local/global processing (e.g., Masuda & Nisbett, 2001) may address whether scale errors stem from differences in local/global information integration.

Importantly, what might underlie the differences in processing between the Japanese and UK children? It has been reported that individualistic cultures dominate in Western countries, whereas collectivist cultures are dominant in Eastern countries (Haslam et al., 2020). Differences in parenting styles have been found between Eastern and Western cultures

(Pinquart & Rubina, 2018). Parenting in individualistic cultures focuses on child autonomiy, independence, and assertiveness, whereas parenting in collectivist cultures focuses on duty, obedience, and interdependence (Haslam et al., 2020; Triandis et al., 1990). Such cultural values persist when individuals narrate a story to others; for example US participants created stories based on individualstic values whereas Japanese people created stories based on collectivistic values  (Imada & Yussen, 2012). Also, it has been reported that children's culturally specific attentional styles come to reflect those of their parent over time (Masuda, 2017). Senzaki et al (2016) revealed that when parents describe objects to their chidren, Western parents tend to discuss local objects, whereas Asian parents tend to discuss contextual information. It has also revealed that children aged 4 to 9 years do not show culturally specific attentional styles when they are engaged in a task alone (Senzaki et al., 2016). However, when working on a task with their parents, older children (ages 7 to 9 years) do demonstrate culturally specific attentional styles (i.e., local attention in Western/global attention in Eastern). Thus, it is possible that children gradually develop a dominant attentional style based on their daily parental interactions (Lee et al., 2017). In the current context, we hypothesize that these differences in attentional styles influence variation in the ability to integrate local features (recognizing elements of an object's features; car doors) and global features (recognizing the configuration of the entire object; size and shape) in object processing. Taken together, it is possible that the resulting disparity of different attentional strategies in children’s daily experiences through culturally unique parenting style could give rise to differences in processing. However, to our knowledge the cross-cultural effect of parenting and attentional style on low-level object processing has yet to be directly investigated.

Importantly, as DeLoache et al. (2013) note, there may be several factors that contribute to children's scale error production. Specifically, the phenomenon is likely influenced by mechanisms other than local/global processing, for example immaturity of inhibitory control (Ware et al., 2006), lack of body-size awareness (Brownell et al., 2007), or/and misunderstanding of the object function (Casler et al., 2011). Moreover, Grzyb et al. (2017; 2019) suggest that scale errors may relate to children's shape bias; that is, their tendency to attend to objects' shape when generalizing novel labels to new category exemplars. More broadly, Arterberry et al (2020) proposed that scale errors stem from failure to fully integrate action, perception and cognition. Clearly, future work should identify and explore potential cross-cultural differences in the relative contribution of these mechanisms. Nonetheless, our results are consistent with a new, testable theoretical prediction: heavy reliance on either local or global processing – irrespective of cultural background – should be associated with more scale errors, whereas errors should be reduced in children who show both processing styles. Empirical work is currently planned to test this prediction. Overall, however, this study is the first to directly compare scale error production cross-culturally, and the first to demonstrate a relationship between the scale error and children's categorization ability, shedding new light on our understanding of the complex mechanisms underlying this fascinating phenomenon.

## 5. Conclusion

This study offers a new perspective on the mechanisms underlying the intriguing phenomenon: children's suppression of scale errors emerges not from attention to size *per se*, but from a critical integration of global and local information, and provides evidence that this mechanism may differ cross-culturally.

MI was affiliated with the Department of Psychology at Ochanomizu University until the submission of this work and is currently affiliated with Center for Baby Science at Doshisha University.

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