DOES CHILDREN’S SCALE ERROR RELATE TO A FAILURE TO DETECT SIZE CHANGE?

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The scale error is a phenomenon in which young children try to perform impossible actions on miniature versions of objects. Previous work (Grzyb et al., 2017) indicates that children’s errors in the scale error task were associated with a failure to notice object size changes in a 2D looking time task. Here we extend this work to a more naturalistic environment, asking whether failure to detect size changes can be observed in the scale error task itself. Results revealed that the duration of children’s object exploration differed when the objects’ size changed from child-sized to miniature-sized. In particular, children who produced scale errors decreased contact time with the miniature sized objects more rapidly than those who did not. These results therefore offer the first evidence from an ecologically valid task that that scale errors may arise from a failure to detect changes in object size.

Key words: scale error, change detection, cognitive development

INTRODUCTION

The scale error is a phenomenon in which young children attempt to perform impossible actions on miniature sized objects without taking into account their own body size (DeLoache, Uttal, & Rosengren, 2004), for example attempting to climb into a miniature car, or to sit on a miniature chair. In the canonical scale error experimental paradigm, children’s scale errors are observed when they are exposed to miniature toys after interaction with versions of the same toys which were appropriate for their body size (e.g., DeLoache et al., 2004, Ishibashi & Moriguchi, 2017). Several studies document the scale error from as early as 12 months, with a peak around the second year of age (DeLoache et al., 2004; however see, Grzyb, Cangelosi, Cattani, & Floccia, 2019), and decreasing at 36 months (Rosengren, Schein, & Gutiérrez, 2010; Ware, Uttal, & DeLoache, 2010; although scale errors have also been observed in adults; Casler, Hoffman, & Eshleman, 2014).

While research into the roots of this fascinating phenomenon began relatively recently, there are four possible underlying mechanisms, namely, action planning and immaturity of inhibitory control, immaturity of children’s body size awareness, imbalance

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of lexical development, and immaturity of the perceptual system have been proposed. In particular, immaturity of integration of size information in action planning and immaturity of inhibitory control (DeLoache, LoBue, Vanderborght, & Chiong, 2013) is the most supported theory of the mechanisms. With respect to this theory, seeing the miniature objects activates children’s category representations for the previously-seen child-sized objects together with its associated motor plan. However, size information fails to become integrated into the activated motor routine, leading to a scale error (DeLoache et al., 2004; but see also Ishibashi & Moriguchi, 2017). Earlier studies offered that some children might not notice the change of an object’s size from child-appropriate to miniature (DeLoache & Uttal, 2011). Experimental evidences that scale error may be stem from the understanding of the size information were also conformed (Ishibashi & Moriguchi., 2017).

Other accounts have been offered for the possible mechanisms behind the scale error. For example, Brownell, Zerwas, and Ramani (2007) revealed a negative relationship between scale error occurrence and children’s performance in a body size awareness task. In this task, children were required to choose one of two doors in order to approach their parent, who was behind the doors; one door was too narrow to pass through for their body size, and the other was a body-appropriate size. Children were considered to have made a body size error when they attempted to get through the too-narrow door. Children with better performance in this body awareness task made fewer scale errors in a subsequent scale error task, indicating that the scale error may stem from immaturity of children’s own body size awareness.

In addition, scale errors can be mediated by children’s imbalance lexical development (Grzyb, Cattani, Cangelosi, & Floccia, 2014; Hunley & Hahn, 2016). For example, children with medium sized vocabularies performed scale errors more frequently than those with lower and larger vocabularies (Grzyb et al., 2014). According to the researchers, children’s action selection may be mediated by the semantic system. When children start learning object names, action selection may be more likely to be affected by the semantic system (e.g., “car”), not by the perceptual information (i.e., actual size information). For children who do not have sufficient lexical knowledge, action selection process sometimes can fail to integrate their semantic system into the perceptual information, leading to scale error as a result.

Recently, immaturity of the perceptual system has also been suggested as a potential underlying mechanism and we examined this possibility in this study. Grzyb, Cangelosi, Cattani, and Floccia (2017) examined whether scale error stem from the immaturity of the perceptual system experimentally. In this study, children were presented with a serious of performances, in which an actor performed actions with appropriately or inappropriately sized (i.e., too big/too small) objects for a given task followed by the actor performed actions with the appropriate sized object, to examine how their scale errors related to their size perception. The authors used children’s increases in looking times to actions performed with inappropriately sized objects relative to actions performed with appropriately sized objects as their index of size change detection. Thus, whether children discriminate between the miniature- and large-sized objects was
measured by their looking time. Children then took part in a typical scale error task. Results showed that children who did not show scale errors significantly increased their looking times when the object size changed compared with those who did show scale errors. Thus, children who produced scale errors were less likely to pay attention to size changes than those who did not produce scale errors. The authors concluded that the scale error can occur when children neglect to attend to size, suggesting that perceptual immaturity (i.e., immaturity in the ability to detect object size information) underlies the scale error.

However, Grzyb and colleagues (2017) only examined how children detected changes in object size when observing an actor’s behavior displayed in 2D on a computer screen, in an experimental context that is necessarily considerably constrained relative to their everyday learning environment. Additional research is needed to clarify whether children also fail to detect object size when engaged in the more naturalistic scale error task. In the context of the evidence presented by Grzyb and colleagues (2017) that the scale error is associated with a failure to detect size information, children who produce scale errors may also be unaware that the child-sized object has changed to the miniature sized object after the brief interval in the scale error task. Here, then, we directly examine whether size change detection during the scale error task itself contributes to the occurrence of a scale error in order to extend existing work to a more ecologically valid setting, asking whether children’s contact time with the objects related to their rate of scale error production.

Generally, infants show a preference for new information, whereas their attention decreases when they have sufficiently encoded a stimulus (Fantz, 1958). Importantly, attention has been used as an index of infants’ object encoding in both visual and manual habituation tasks (e.g., Quinn, Eimas, & Rosenkrantz, 1993; Oakes, Madole, & Cohen, 1991; Shinskey & Munakata, 2005). In particular, manual habituation/dishabitation has been used to examine children’s attentional processes and object encoding. Specifically, the duration of children’s spontaneous object exploration provides an index of whether they have discriminated a novel object from a familiarized category (Oakes et al., 1991; Ross, 1980; Ruff, 1984). In this procedure, children are allowed to repeatedly explore toy category exemplars during a familiarization phase. Then, at test, children are presented with two new toys: one from the familiarized category and one from a novel category. If children spend more time exploring the novel toy than the familiarized toy, it is assumed that they have discriminated between the novel and familiarized toy, suggesting that they formed a category during the familiarization phase. Conversely, if children show no preference for the novel toy (i.e., if they spend the same amount of time exploring both familiarized and novel toys), it is assumed that they have failed to discern the different properties of the known and novel toys (Oakes et al., 1991).

Critically, this paradigm can be adapted to the scale error task: whether children discriminate between the child- and miniature-sized objects can be indexed via their duration of exploration: if object exploration increases after the child-size objects have been exchanged for their miniature counterparts, an increase in exploration time would indicate that children have successfully detected the change; conversely, a decrease in
exploration time would indicate that children have not detected the change. Thus, analyzing contact time in this way offers a measure children’s change detection ability, allowing us to associate this index with their scale error production.

In the present study, then, as in several other studies we presented children with a scale error task based on DeLoache and colleagues’ (2004) procedure. We analyzed the children’s object exploration during the scale error task itself, looking for differences in contact time between child-sized and miniature objects. We then asked whether contact time related to children’s scale error production during that task. We predicted that contact time to the miniature toys compared to the child-sized toys should decrease in children who showed scale errors relative to those who did not.

**Method**

**Participants**
Fifty-one typically developing children (M = 24.33 months, SD = 5.42, 21 girls, range = 18.00–37.00 months) and their parents participated. Five additional children were excluded from the analysis; Two children (girls = 15, 19 months) were excluded due to fussiness as defined by crying or refusal to play with the toys. Three additional children were (boys = 16, 19, 24 months) excluded because they made scale errors only with the shoe stimuli (see Stimuli section; n = 3). The purpose of the study was explained to parents both verbally by the experimenter and in a written document. Informed consent for children to participate was obtained from the parent. This project was approved by the Ethics Committee, Joetsu University of Education.

**Materials and Procedure**
The scale error task was conducted in a university play room. Children freely interacted with their parents during the session. Two video cameras were used to record children’s behavior for subsequent analysis.

**Stimuli.** Based on the original study (DeLoache et al., 2004), we used a slide, a car, a desk set (desk, chair, and book), and shoes. Although shoes were not used in the original study, this stimulus was added as it has been shown to be successful in eliciting the scale error in this population of children (Ishihashi & Moriguchi, 2017). For each stimulus both child- and miniature-sized toys were used, with the exception of shoes, for which only the miniature-sized stimuli were used since the child took off their own shoes when they arrived at the lab. Stimulus dimensions were presented in Table 1 and Fig. 1.

**Procedure.** Before the experiment began, the child-sized slide, desk set and car were placed in the

| Toy  | Dimensions (L x W x H; cm) |
|------|-----------------------------|
|      | Child-size                  | Miniature-size            |
| 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| –                           | 4.0 x 7.0 x 2.0           |
Fig. 1. Child-sized and miniature-sized toys used in the scale error task

play room. In the task, children freely played with these items for approximately five minutes. If the child showed little interest in a particular object, the experimenter drew attention to it. The child was encouraged to interact with each toy at least twice. Then, the child and his or her parent left the play room. Meanwhile, the experimenter replaced the toys with their miniature versions and added the miniature shoes. Then, the child and his or her parent re-entered the room. Again, the child’s behavior was observed for approximately five minutes. The child was allowed to interact with his or her parent but the parent was asked not to mention the size of the miniature toys.

Date Coding and Analysis

Scale error coding. Children were considered to have made a scale error if their behaviours towards the child-size objects met the following criteria, taken from DeLoache et al. (2013): (a) the child attempted to perform part or all of an earlier action toward the child-sized object, for example, the child touched their foot to the miniature slide’s ladder; (b) the correct part(s) of the miniature object was contacted with the child’s correct body part(s); and (c) the child’s effort toward the miniature object was serious. In terms of (c), a 5-point scale was used to judge children’s seriousness (1: definitely serious–5: definitely pretending). Twenty-five percent of data were coded by a secondary coder with high inter-rater reliability (κ = .91).

Size change detection coding. To provide an index of size change detection, manual contact time during object exploration for each object was calculated to examine whether children with/without scale errors showed different examining time for the child-sized and miniature-sized toys. Specifically, we defined object contact as the duration of touching for both child- and miniature-sized objects. Children’s contact time with the child-sized and miniature versions of each object (the slide, car, and deskset) were recorded. Proportion of object contact time was calculated separately for the miniature and child-sized versions of each object, by dividing the contact time for each object by the duration of total time of the session. For example, proportion of contact time for the miniature car was calculated by dividing the total contact time for the miniature-sized car by the total time for the session. This is because the length of the scale error task had differed among children (approximately three to five minutes).

RESULTS

We first present the results from the scale error task, followed by the proportion of contact time results and their relationship to children’s scale errors.

Scale Error Production

Twenty-three out of 51 children performed scale errors, which were classified into the “with scale error” group (i.e., produced at least on scale error) and 28 into the “without scale error” group (i.e., produced no scale error; see Grzyb et al., 2017, for a similar approach). The mean occurrence of scale errors for three miniature-sized toys was 1.39 (SD = 1.93). This rate of scale error production is in line with previous studies
in this population (e.g., Ishibashi & Moriguchi, 2017). There were no significant age and gender differences between children with scale error and without scale error groups (age: \(t(49) = 1.29, p = .20, d = 0.36, 95\% \text{ CI } [-1.09, 5.00]; \) gender: \(\gamma(1) = 0.09, p = .76, \varphi = 0.04\)). Therefore, we did not consider age and gender variables in further analyses.

**Proportion of Contact Time in the Scale Error Task**

To address the possibility that scale errors relate to a failure to discriminate object size changes, children’s contact time to both child- and miniature-sized toys during the scale error task were analysed. We first present results for the proportion of contact time for each object (i.e., slide, car, and desk set) between children with and without scale error, followed by the proportion of the total contact time (i.e., sum of the slide, car, and desk set). The descriptive results of each object and total are presented in Table 2.

Next, we analysed the relationship between object contact time, scale error production and object type. We submitted proportion of contact time to a 2 x 2 x 3 mixed analysis of variance (ANOVA) with main effects of group (with scale error, without scale error), object size (child- or miniature-size), and object (slide, car, desk set) and all interactions. We found no significant main effects of group \(F(1,49) = 0.12, p = .73, \eta^2_p = 0.002\), suggesting that there was no difference in size change detection between children with and without scale error. However, we did find a significant main effect of size \(F(1,49) = 76.99, p < .001, \eta^2_p = 0.61\): overall, children spent longer playing with child-sized toys \((M = 20.30, SD = 0.05)\) than miniature-sized toys \((M = 0.10, SD = 0.08)\). The ANOVA also revealed a significant main effect of object \(F(2,98) = 30.12, p < .001, \eta^2_p = 0.38\): children spent more time engaged with the car \((M = 0.25, SD = 0.20)\) than slide \((M = 0.11, SD = 0.11)\) and than the deskset \((M = 0.10, SD = 0.12)\). Interestingly, we found a marginal interaction of group and size \((F(1,49) = 3.49, p = .07, \eta^2_p = 0.07)\), although since this result does not reach significance it should be interpreted cautiously. An analysis of simple main effects confirmed that children with scale error had shorter contact time with the miniature-sized objects compared with that with the child-sized objects \((F(1,22) = 63.19, p < .001, \eta^2_p = 0.74)\). In addition, children without scale error also had shorter contact time with the miniature-sized objects than those with the child-sized objects \((F(1,27) = 23.01, p < .001, \eta^2_p = 0.46)\). While both groups spent

| Object  | Children with scale error | Children without scale error |
|---------|---------------------------|-----------------------------|
|         | Child-size | Miniature-size | Child-size | Miniature-size |
| Slide   | .14 (.09) | .06 (.06) | .12 (.09) | .13 (.17) |
| Car     | .35 (.19) | .16 (.14) | .31 (.24) | .17 (.15) |
| desk set| .15 (.12) | .04 (.04) | .16 (.16) | .05 (.07) |
| Total   | .21 (.17) | .09 (.10) | .20 (.19) | .11 (.14) |

*Note. Total represented the mean proportion of sum of the slide, car, and desk set.*
more time interacting with the larger objects and both appeared to decrease contact time with the objects in the second phase of the scale error task, children with scale error group showed relatively larger decreases than the children without scale error group (mean decrease, with scale error = 0.12; mean decrease, without scale error = 0.09; see also Table 2). Thus, although our results do not offer conclusive evidence that children’s ability to detect size changes, as indexed by object interaction time, is related to their scale error, the larger decrease in interaction time in the scale error group than the no scale error group is in the direction predicted by this hypothesis, offering converging evidence with Grzyb et al. (2017) that size change detection plays a role in scale error production.

Quality of Children’s Behavior

In order to determine whether children detected the object size change, we conducted an additional analysis, where we classified children’s behaviors when they contacted with the miniature objects right after the object had changed. Two children were excluded because it was unclear when exactly the child entered the play room. Children’s behaviors were classified by the previous study (Ishibashi & Uehara, 2020): (a) “touching” referring to usual play except for pretense and scale error behavior, such as putting the car on the chair or slide and touching, (b) “pretending” referring to pretend play such as pushing a car on the floor to run fast, (c) “scale error” as referring to the definition of DeLoache et al. (2004).

Table 3 described that the children’s behavioral pattern for the first object touching between children with and without scale errors. Of the scale error group, 10 children committed scale error to the first object touching. Children’s behavioral patterns (touching vs. pretending) were not differed in between children with and without scale errors ($\chi^2(1) = 2.62, p = .11, \phi = 0.26$). In addition, onset latency when the child entered the play space to the first object touching was calculated. We assumed that delayed onset latency might be one of the measurements of the size change detection (i.e., if the children surprised the object size change, then their onset latency may be delayed). However, the results showed that there was no differences in the onset latency between two groups ($t(47) = 0.66, p = .51, d = 0.19, 95\% \ CI [-11.78, 23.32]$; Children without scale error: $M = 20.47$ s., $SD = 37.84$, Children with scale error: $M = 14.69$ s., $SD = 17.07$).

Table 3. The number of children’s behavioral pattern for the first time object touching between children with and without scale errors

| Group                  | Touching | Pretending | Scale error |
|------------------------|----------|------------|-------------|
| No-scale error ($n = 27$) | 11        | 16         | –           |
| Scale error ($n = 22$)   | 8         | 4          | 10          |
DISCUSSION

The goal of the present study was to test whether the occurrence of scale errors in young children was associated with their discrimination of object size, extending Grzyb et al.’s (2017) findings to a naturalistic situation, more closely reflecting children’s real-world learning environment. To this end, we implemented a novel adaptation of the manual habituation methodology (e.g., Oakes et al., 1991). Specifically, we focused the decrease in children’s contact time with the miniature-sized objects relative to the child-size objects as an index of habituation. We hypothesized that children who show scale errors should be less able to discriminate between the two sizes of objects, and should therefore decrease contact time with the miniature objects, while children who did not show scale errors should notice the size change and maintain interest (as measured by contact time) in the smaller objects.

Overall, contrary to our hypothesis, children both with and without scale error decreased the contact time with the miniature-sized objects. However, children with scale error decreased the objects’ contact time more quickly than children without scale error, and the interaction between scale error group approached significance. Although these marginal results did not offer conclusive support for our hypothesis, our findings were in line with previous work which demonstrated that children who show scale errors paid less attention to size changes in a 2D screen-based task than those who do not show scale errors (Grzyb et al., 2017). Our evidence, although not strong, could support these findings: children who made scale errors may have done so due to lack of ability to detect object size change. However, the additional task demanded (e.g., presence of other toys, presence of parent and experimenter and social interaction) in our 3D task relative to the simplified environment in the previous 2D task may have introduced additional noise, making detection of statistical differences between attention to child- and miniature-sized objects more difficult. This result underscores the difficulty of cross-paradigm comparisons, and future replication of the current work with a larger sample should be undertaken to further explore the role of size change detection in children’s scale error production. Thus, our result provided weak supporting evidence in favor of Grzyb and colleagues’ study, and did so by extended their paradigm, examining children’s behaviors in a naturalistic learning environment. Overall, we cautiously interpret these findings as consistent with accounts which assume that the scale error may partially explained by a failure to detect size changes.

Importantly, the scale error task involves a short delay in which no objects are present before the object size change takes place. Thus, children may be unaware of the size changes due to forgetting during this brief interval, which may lead them to produce a scale error. If so, the scale errors as elicited in this task may relate to change blindness, a phenomenon in which individuals fail to notice large perceptual changes that normally would be easily perceived (Simons & Rensink, 2005). Adults sometimes fail to detect changes in color, object position, or object size between two images when the images are separated by a brief interval (e.g., 100 ms; Burmester & Wallis, 2011; Grimes, 1996; Simons & Levin, 1998; Rensink, O’Regan, & Clark, 1997). Importantly, however,
change blindness is experienced by not only adults but also infants and children (Farzin, Rivera, & Whitney, 2011; Fletcher-Watson, Collis, Findlay, & Leekam, 2009; Shore, Burack, Miller, Joseph, & Enns, 2006). Although change blindness in object size has not been reported in young children, it is well known that size perception is still developing at this age (Kavšek & Granrud, 2012; Pillow & Flavell, 1986; Zeigler & Leibowitz, 1957). Given the evidence, in scale errors, children may fail to detect changes in the size of objects because they have to leave room for more time than 100 ms while the child-sized object is replaced with the miniature-sized object. In other words, taken together with the change blindness literature, this study and related work raise the important possibility for future work that the mechanisms underlying change blindness may relate to the mechanisms underlying children’s scale errors. Examining the relationship between children’s performance on a change detection task and scale error production would further expand our understanding of the perceptual immaturity hypothesis.

Further, size information is also affected by the functional information about the objects (Casler, Eshleman, Greene, & Terziyan, 2011; Casler et al., 2014). Casler (2014) demonstrated that children at 24 months of age have a functional bias which novel tool consider exclusively one function. Such “one tool, one function” bias may also be affected by the perceptual information. Particular purpose (e.g., “pen is for writing”) can lead to neglect the perceptual information, leading to scale errors as a result (Casler et al., 2011). Thus, children’s functional bias may be important factor for considering the mechanism behind the scale errors.

Two possibilities above, however, do not explain the fact that children who do not show scale error also decrease the contact time for objects. In fact, in Grzyb et al. (2017)’s study, they did not obtain the prominent looking-time differences between children with scale error and without scale error when the objects’ size had changed from child-sized to miniature-sized. From this result, they suggested that children tend to prefer to large objects and perceptual saliency in small objects is lower than those in big objects. In our study, it may be possible that both children with and without scale error may be less attentive in the small-sized objects, not because of the failure to detect the size changes. Therefore, we concluded that the perceptual immaturity only partially explained the scale errors.

In the additional analysis, we classified number of behavioral patterns between children in scale error and without scale error. Although we could not find any behavioral differences and onset latency between two groups, such behavioral differences (e.g., pretending or touching) may bring the suggestion whether children detect the object size change. To examine the further possibility of the perceptual immaturity, qualitative analysis, how children performed the object after changed the size of the toys, is clearly important. Another work is currently planned to examine this analysis.

In conclusion, this study suggested that scale errors may stem from the failure of detection of the change of size, extending this finding from the controlled empirical task employed by Grzyb and colleagues (2017) to an ecologically valid task which closely resembles children’s natural learning environment. This study therefore contributes converging evidence that one possible mechanism underlying children’s scale errors is
their proficiency in processing and retaining size information, both in experimental settings and in the real world.

AUTHOR’S CONTRIBUTION

M.I. and Y.M.: Substantial contributions to the conception or design of the work; or the acquisition, analysis, or interpretation of data for the work. M.I. and Y.M.: Agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

CONFLICT OF INTEREST

The authors declare no conflicts of interest associated with this manuscript.

REFERENCES

Brownell, C. A., Zerwas, S., & Ramani, G. B. (2007). “So Big”: The development of body self-awareness in toddlers. *Child Development, 78*(5), 1426–1440. doi: 10.1111/j.1467-8624.2007.01075.x

Bermester, A., & Wallis, G. (2011). Thresholds for the detection of changing visual features. *Perception, 40*(4), 409–421. doi: 10.1068/p6890

Casler, K. (2014). New tool, new function? Toddlers’ use of mutual exclusivity when mapping information to objects. *Infancy, 19*(2), 162–178.

Casler, K., Eshleman, A., Greene, K., & Terziyan, T. (2011). Children’s scale errors with tools. *Developmental Psychology, 47*(3), 857–866.

Casler, K., Hoffman, K., & Eshleman, A. (2014). Do adults make scale errors too? How function sometimes trumps size. *Journal of Experimental Psychology: General, 143*(4), 1690–1700.

DeLoache, J. S., LoBue, V., Vanderborgh, M., & Chiong, C. (2013). On the validity and robustness of the scale error phenomenon in early childhood. *Infant Behavior and Development, 36*(1), 63–70. doi: 10.1016/j.infbeh.2012.10.007

DeLoache, J. S., & Uttal, D. H. (2011). Gulliver, Goliath and Goldilocks: Young children and scale errors. In V. Slaughter & C. A. Brownell (Eds.), *Early development of body representations* (pp. 59–68). Cambridge, United Kingdom: Cambridge University Press.

DeLoache, J. S., Uttal, D. H., & Rosengren, K. S. (2004). Scale errors offer evidence for a perception-action dissociation early in life. *Science, 304*, 1027–1029. doi: 10.1126/science.1093567

Fanz, R. L. (1958). Pattern vision in young infants. *The Psychological Record, 8*(2), 43–47.

Farzin, F., Rivera, S. M., & Whitney, D. (2011). Resolution of spatial and temporal visual attention in infants with fragile X syndrome. *Brain, 134*(11), 3355–3368. doi: 10.1093/brainawr249

Fletcher-Watson, S., Collis, J. M., Findlay, J. M., & Leekam, S. R. (2009). The development of change blindness: Children’s attentional priorities whilst viewing naturalistic scenes. *Developmental Science, 12*, 438–445. doi: 10.1111/j.1467-7687.2008.00784.x

Grimes, J. (1996). On the failure to detect changes in scenes across saccades. In K. A. Akins (Ed.), *Perception. Vancouver studies in cognitive science* (Vol. 5, pp. 89–110). Oxford, United Kingdom: Oxford University Press.

Grzyb, B. J., Cangelosi, A., Cattani, A., & Flocchia, C. (2017). Decreased attention to object size information in scale errors performers. *Infant Behavior and Development, 47*, 72–82.

Grzyb, B. J., Cangelosi, A., Cattani, A., & Flocchia, C. (2019). Children’s scale errors: A by-product of lexical development? *Developmental Science, 22*(2), e12741.
Grzyb, B. J., Cattani, A., Cangelosi, A., & Flocia, C. (2014, Oct). Children in a wonderland: How language and scale errors may be linked. Paper presented at the Fourth International Conference on Development and Learning and on Epigenetic Robotics (ICDL-EpiRob), Genoa, Italy. doi: 10.1109/devlrn.2014.6982992

Hunley, S. B., & Hahn, E. R. (2016). Labels affect preschoolers’ tool-based scale errors. Journal of Experimental Child Psychology, 151, 40–50.

Ishibashi, M., & Moriguchi, Y. (2017). Understanding why children commit scale errors: Scale error and its relation to action planning and inhibitory control, and the concept of size. Frontiers in Psychology, 8, 826.

Ishibashi, M., & Uehara, I. (2020). The relationship between children’s scale error production and play patterns including pretending play. Manuscript submitted for publication.

Kavšek, M., & Granrud, C. E. (2012). Children’s and adults’ size estimates at near and far distances: A test of the perceptual learning theory of size constancy development. i-Perception, 3, 459–466. doi: 10.1068/i0530

Oakes, L. M., Madole, K. L., & Cohen, L. B. (1991). Infants’ object examining: Habituation and categorization. Cognitive Development, 6(4), 377–392.

Pillow, B. H., & Flavell, J. H. (1986). Young children’s knowledge about visual perception: Projective size and shape. Child Development, 57, 125–135.

Quinn, P. C., Eimas, P. D., & Rosenkrantz, S. L. (1993). Evidence for representations of perceptually similar natural categories by 3-month-old and 4-month-old infants. Perception, 22(4), 463–475. doi: 10.1068/p226463

Rensink, R. A., O’Regan, J. K., & Clark, J. J. (1997). To see or not to see: The need for attention to perceive changes in scenes. Psychological Science, 8(5), 368–373.

Rosengren, K. S., Schein, S. S., & Gutiérrez, I. T. (2010). Individual differences in children’s production of scale errors. Infant Behavior and Development, 33(3), 309–313.

Ross, G. S. (1980). Categorization in 1- to 2-year-olds. Developmental Psychology, 16, 391–396.

Ruff, H. A. (1984). Infants’ manipulative exploration of objects: Effects of age and object characteristics. Developmental Psychology, 20, 9–20.

Shinskey, J. L., & Munakata, Y. (2005). Familiarity breeds searching: Infants reverse their novelty preferences when reaching for hidden objects. Psychological Science, 16(8), 596–600.

Shore, D. I., Burack, J. A., Miller, D., Joseph, S., & Enns, J. T. (2006). The development of change detection. Developmental Science, 9(5), 490–497. doi: 10.1111/j.1467-7687.2006.00516.x

Simons, D. J., & Levin, D. T. (1998). Failure to detect changes to people during a real-world interaction. Psychonomic Bulletin & Review, 5(4), 644–649.

Simons, D. J., & Rensink, R. A. (2005). Change blindness: Past, present, and future. Trends in Cognitive Sciences, 9, 16–20. doi: 10.1016/j.tics.2004.11.006

Ware, E. A., Uttal, D. H., & DeLoache, J. S. (2010). Everyday scale errors. Developmental Science, 13(1), 28–36.

Zeigler, H. P., & Leibowitz, H. (1957). Apparent visual size as a function of distance for children and adults. The American Journal of Psychology, 70(1), 106–109.

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