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Abstract

When young children interpret novel nouns, they tend to be very much affected by the perceptual features of the referent objects, especially shape. We investigated whether children might inhibit a prepotent tendency to base novel nouns on the shape of referent objects in order to base them on conceptual features (i.e. taxonomic object categories). We tested 3- to 5-year old children on a noun extension task, alongside a test of their inhibition and more general executive control ability. Noun extensions were related to inhibition ability, independent of age. Noun extensions were not related to individual differences in our general executive control task. This suggests a potential role for inhibition in extension which is independent of other aspects of cognitive development.

Keywords

Noun learning, inhibition, executive function, perceptual focus, shape bias

When children hear a novel noun (e.g. *kig*) used to label an object they need to decide what it is about that object that makes it a *kig*, and therefore what other objects are also *kigs*. Literature on the "shape bias" shows that (English-speaking) young children seem to have the tendency to extend a novel name to other objects primarily on the basis of shared shape with the original referent (e.g., Gentner, 1978; Landau et al., 1988; Merriman, Scott and Marazita, 1993; Samuelson & Smith, 1999; Gershkoff-Stowe & Smith, 2004). Such an early focus on attention grabbing perceptual properties seems to be beneficial and promotes generalisability and immediate productivity of newly-learned words (Smith, Jones, & Landau, 1996). This is evident in a strong link between shape recognition / shape bias and early vocabulary development (e.g. Borgström, von Koss Torkildsen, & Lindgren, 2015; Gershkoff-Stowe & Smith, 2004). Furthermore, training that facilitates development of a shape bias has been shown to have positive effects on word learning, both within and outside the laboratory (e.g. Samuelson, 2002; Smith et al., 2002; Perry, Samuelson, Malloy, & Schiffer, 2010).

Despite this benefit of focussing on perceptual features such as shape, it is not necessarily the best strategy because for adults the names of objects tend to be based on their function rather than on their appearance (e.g. Miller & Johnson-Laird, 1976). That is, a sponge shaped like an apple is a sponge, not an apple. Conversely, the literature on the shape bias shows that English-speaking young children tend to base their noun extensions on shared shape over shared function (e.g. Gentner, 1978; Merriman, Scott, & Marazita, 1993; Smith, Jones, & Landau, 1996; Graham, Williams, & Huber, 1999). This has been found even when the functions of the objects were emphasised (Graham, Williams, & Huber, 1999).

There is also evidence that young children can overcome their focus on shape in order to make adult-like noun extensions on the basis of features other than shape, including function. This seems to happen under the right circumstances, for instance, when allowed to

experience the function of objects for themselves, when objects possess a strong structure-function relationship, or when cues to the objects' function are provided (e.g. Booth, Waxman & Huang, 2005; Graham, Welder, Merrifield, & Berman, 2010; Kemler Nelson, 1995; Kemler Nelson, 1999; Kemler Nelson, Russel, Duke, & Jones, 2000; Kemler Nelson, Frankenfield, Morris, & Blair, 2000; Markson, Diesendruck, & Bloom, 2008; Tare and Gelman, 2010). Similarly, Kemler Nelson, Frankenfield et al. (2000) suggested that a shape bias can be overcome by exploration and mindful conceptual processing of stimuli, but this takes time. In their study, children's focus on shape was stronger when they were asked to respond immediately compared to after 10 seconds.

When considering factors that help children overcome a shape bias, it is useful to consider processes that have been associated with adults' noun extensions. Smith, Jones, & Landau (1996) suggested that adults might experience the same attentional pull to salient perceptual features of objects as children, but routinely inhibit this initial impulse in order to engage in more analytic processes. It is therefore possible that children might not engage as much as adults in these analytic processes because they do not possess the same level of inhibitory control ability as adults. It is well known that inhibition ability develops with age. It improves considerably between the ages of three and five years (Diamond, 1991; Carlson & Moses, 2001; Carlson, Moses, & Breton 2002; Carlson, Moses, & Claxton, 2004; Carlson, 2005; Jones, Rothbart, & Posner, 2003; Garon, Bryson, & Smith, 2008). Interestingly, this is a time during which the shape-bias in noun extension has been shown to decrease (e.g. Gentner, 1978; Merriman, Scott, & Marazita, 1993; Imai, Gentner & Uchida, 1994). Therefore, children's adult-like noun extensions on the basis of non-perceptual features might partly be related to the strength of their inhibition ability.

The importance of inhibition ability for disengaging from perceptual features would not be unique to noun extension and word learning. The same has been suggested for appearance-reality decisions, object categorisation, and analogical reasoning tasks. Bialystok and Senman (2004) found that inhibition ability correlated with the ability to overcome a focus on perceptual object features in 3- to 5-year-olds when they asked them to identify objects that appeared to be one thing, but were something else (e.g., an object that looked like a rock, but was a sponge). Fisher (2011) found evidence for a stronger attentional draw to perceptual features than taxonomic category membership in a categorisation task. She asked 3- to 5-year-olds to categorise objects first by perceptual similarity and then by taxonomic category membership, or vice versa. She found a larger switching cost when children first categorised objects by perceptual similarity and then by category membership compared to the other way around, suggesting that drawing attention away from perceptual features requires particularly strong inhibition.

The importance of inhibition of perceptual features has also been suggested in analogical reasoning tasks. It has been argued that responses in line with the featural match in analogical reasoning tasks must be inhibited in order to select a relational match over a more salient featural match (Morrison et al., 2004; Richland, Morrison, & Holyoak, 2006; Viskontas et al., 2004). For instance, in a study by Markman and Gentner (1993) participants were presented with a picture of a truck towing a car and a picture of a car towing a boat and asked what the car in the first picture ‘goes with’ in the second picture. In order to select the relational match to the car, i.e. the boat, which is also being towed, one needs to inhibit selection of the more salient featural match, i.e. the other car. Richland et al. (2006) found that the impact of featural distractions diminished with increasing age and therefore increasing inhibition ability of children. In addition, Morrison, Doumas, and Richland (2011) showed by

means of a computational model of analogical reasoning that improved ability to deal with featural distracters in analogical reasoning tasks can be explained by changes in inhibitory ability. Furthermore, it has been found that individuals with damage to the prefrontal cortex, a brain area strongly associated with executive functions including inhibition, demonstrate difficulties with ignoring more salient choices in order to select relational matches in analogical reasoning tasks (Krawczyk et al., 2008; Morrison et al., 2004; Waltz, Lau, Grewal, & Holyoak, 2000).

In the present study we aimed to provide empirical evidence for the suggestion that children's noun extension on the basis of non-perceptual features, such as taxonomic category, involves an inhibitory component. More concretely, we investigated whether children's ability to extend nouns on the basis of non-perceptual features was related to their inhibition ability. We assessed their inhibition ability with the Grass / Snow task (Carlson & Moses, 2001), a common measure of inhibition ability appropriate for our age range and found to be related to other cognitive processes such as theory of mind (Carlson, 2005). For the noun extension task we adopted a paradigm that pitched shape against taxonomic category of familiar objects (see also, e.g., Gentner & Imai, 1995; Gentner & Namy, 1999; Imai, Gentner, & Uchida, 1994). Despite the use of familiar objects, children still show a high proportion of shape-based responses in this paradigm. Importantly, children do not need to be taught novel functions on which they could base their noun extensions. We thus removed cognitive load that could have affected their responses and interfered with their inhibition ability.

When investigating correlations of task performance with inhibition it is important to be aware that an improvement in inhibition ability usually goes hand in hand with improvements in other cognitive abilities due to general cognitive maturation. In line with

this, executive functions such as inhibition, updating or working memory are often found to be correlated with each other (e.g., Hughes, 1998; Hughes & Ensor, 2011). Also, while historically executive function has been argued to be both a unitary construct and a collection of dissociable processes (Garon, Bryson, & Smith, 2008), more recently integrative frameworks have been suggested (Garon, Bryson, & Smith, 2008; Miyake et al., 2000). These frameworks consider executive function to be a general mechanism, but with partially dissociable components, for instance inhibition. We therefore tested whether children's improvements in noun extension were related to inhibition ability independently of a potential relation with a more general advance in executive function, which would be part of a general cognitive maturation of the children. General executive function ability was assessed with a task that places overall demand on executive control, namely an adapted version of the stationary boxes task used in Ewing-Cobb et al. (2004). This is a spatial self-ordered search task that makes use of strategic thinking, organisation of search behaviour, and information updating (Luciana, Conklin, Hooper, & Yarger, 2005). Since this task only captures part of the general cognitive maturation, we added another measure of general cognitive maturation into our analysis, namely age. We thus checked whether non-perceptually-based noun extension was related to inhibition ability independently of a relation with age. Apart from changes in cognitive functioning, the relation with age also captures any potential improvement in children's understanding of what features of objects they should focus on when figuring out what a novel noun might refer to: perceptual features or non-perceptual features. Note that the understanding that non-perceptual features are most important in noun extension can lead to non-perceptual responses without the involvement of inhibition. Inhibition is only needed if perceptual features strongly draw attention away from non-perceptual features.

We expected to find a relation between non-perceptually-based noun extension and inhibition ability independently of potential relations with age or with more general executive function ability. This would suggest that children might need to inhibit an attentional pull towards salient perceptual features in order to extend novel nouns on the basis of non-perceptual features. A relation of non-perceptually-based noun extension with performance in our general executive control task would be in accordance with a role of general executive function abilities on noun extension performance. A relation with age would specifically be in line with the notion that with increasing age children develop their understanding that non-perceptual features such as function are more important for naming objects than perceptual features. As noted, it is possible that noun extension is related not to inhibition ability, but to the emerging understanding of the importance of non-perceptual features such as function, or to the development of more general executive control abilities such as strategic thinking.

Method

Participants

Sixty participants, aged 3 to 5 years (mean age 53.7 months, *SD* = 9.7, 28 female) were recruited from nurseries and schools in the West Midlands area of the United Kingdom. These nurseries and schools served middle-class families of this region. Participants were predominantly (95%) White-British. Consent was granted by either the head teacher or nursery owner, or by parents when requested by the head teacher / nursery owner. All participants were native monolingual speakers of English.

Noun-extension task

Materials. We based our material on the single exemplar condition of the categorisation task by Gentner and Namy (1999), using the same categories and items such as an *apple*, a *balloon* and a *pear* (see Figure 1), but our own pictures of these items. This meant that we used ten sets of each three laminated cards displaying cartoon-style pictures of everyday objects

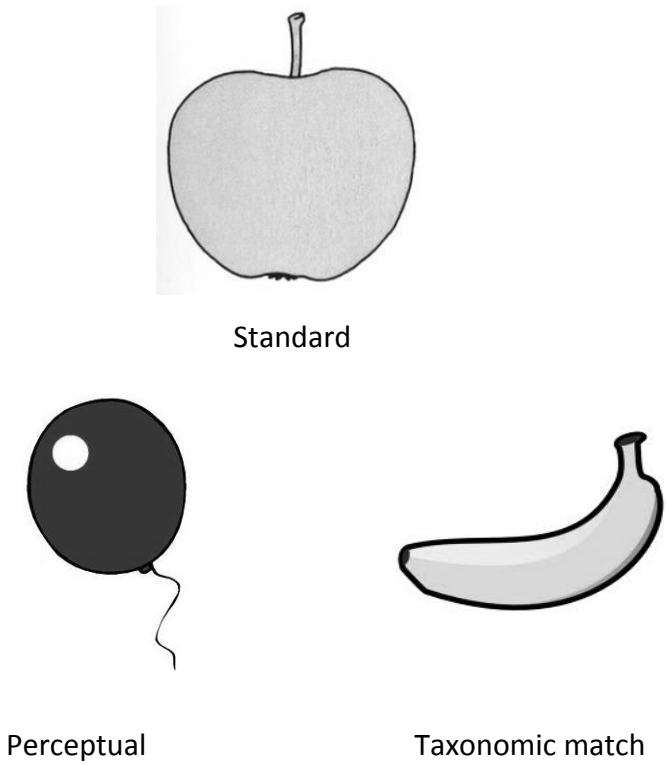

Figure 1. Example stimuli set for the noun-extension task.

that children would be familiar with. In each set, one object functioned as the standard, which was given a novel name (e.g. *kig*). Another object was from the same category as the standard (= taxonomic match) but differed from it in terms of shape, and the third object was from a different category, but was similar in shape to the standard object (= perceptual match). For a complete list see the Appendix. In order to choose the taxonomic match in this task, children needed to be familiar with the taxonomic category of an item. While we did not test this knowledge independently of our task for our participants, results by Gentner and Namy's (1999), who used the same items and categories as us, suggests that this was the case. In one

of Gentner and Namy's conditions they presented not one, but four standards, i.e. four exemplars of the same category (e.g., an apple, a pear, a watermelon slice, and a bunch of grapes) and referred to them with the same novel name. In this condition, four-year-olds extended the novel name to another taxonomic category member (e.g., a banana) in on average 84% of all trials, suggesting good knowledge of the categories. Also, this result likely rather underestimates children's knowledge of the categories due to the strong attentional pull of the shape match response. Thus, we have no reason to doubt that the children in our study are generally familiar with the categories.

Procedure. Participants were first introduced to the experimenter's puppet "Bear". They were told that Bear has special bear names for things which are different to the names we use and that they are going to hear some of Bear's special names for things. Participants received ten trials. In each trial, first the card displaying the picture of the standard object (e.g. an apple) was placed on the table in front of them. Below this card two more cards were placed side by side. One was the perceptual match, e.g. a balloon, and the other the taxonomic match, e.g. a banana (Figure 1). Which side the perceptual and taxonomic matches were placed on was randomised across trials. Participants then heard Bear's special name for the original object and were asked which of the other two objects they think also shares that name. For instance, the experimenter said "Bear calls this a blik (experimenter points to the apple with Bears hand). Which of these other two things would Bear also call a blik?" The child would then point at one of the cards. The number of taxonomic choices was used as a score for the analysis.

Grass / Snow task (inhibition ability)

Participants were told that they were going to play the ‘opposites game’. They were then asked “what colour is grass?” and “what colour is snow?” Once they had answered correctly, a green piece of paper and a white piece of paper were placed side by side in front of the participant. The experimenter then explained that because this is the opposites game when he says “grass” they need to point at the white piece of paper (demonstrating the pointing) and when he says “snow” they need to point to the green piece of paper (demonstrating the pointing). There were then four practice trials with the order ‘grass, snow, snow, grass’ to ensure the participant understood the task. Participants then progressed onto the main trials. For those, the participant was told that they should point as fast as possible when they hear the experimenter say one of the names. Seventeen trials were presented in the order ‘G, S, S, G, G, G, S, G, S, S, S, G, G, S, S, G, G’ (G = grass; S = snow). This order ensured an equal number of instances where the correct response changed (green following white) and when it stayed the same (green following green). After trial 8, participants were reminded of the rules of the game. The number of correct responses was entered into the analysis.

Stationary cups task (general executive control)

We adapted the stationary boxes task used by Ewing-Cobb et al. (1994). Nine opaque cups were placed mouth down in a 3x3 grid. Under each cup the experimenter placed one marble, while the participant was watching. The cups were then covered with an opaque box. Each time the box was lifted, the participant got to pick one cup to look for a marble. The cup was lifted and if a marble was underneath, the marble was removed, the cup placed back in its original location and the box placed back over the cups. The box remained on the cups for a ten second period between each choice. This was repeated until all marbles were found. Participants were told to find all the marbles in as few picks as possible. The number of

attempts to find all marbles was entered into the analysis. Spatial self-ordered search tasks, such as the one used here, are a frequently utilised measure, with a computerised version making up part of the Cambridge Neuropsychological Test Automated Battery (Cambridge Cognition, 2004).

Results

On average, children correctly extended the nouns to taxonomic matches in the noun-extension task 5.8 out of 10 times (SD = 1.9). They correctly responded in the Grass /Snow task (inhibition ability) for on average 12.4 out 17 trials (SD = 2.4), and they needed on average 11.2 (SD 2.3) attempts to find all marbles in the stationary cups task (general executive control ability). While inhibition ability was normally distributed, general executive control was positively skewed because a considerable number of children were able to solve the task within 9 moves (see Figure 2). General executive control was not correlated with inhibition ability ($r = .07$, $p = .62$), suggesting that these two executive function tasks largely measure different abilities. This means that any potential correlation of performance in the noun extension task with inhibition ability would not be confounded with a relation with the more general executive function ability of strategic thinking, organisation of search behaviour, and information updating. Correlation analyses showed that performance in the noun extension task was positively and moderately correlated with both age ($r = .46$, $p < .001$) and inhibition ability ($r = .37$, $p = .003$), but not with general executive control ($r = .00$, $p = .994$) (see Figure 2). Even when controlling for age, there was no significant relationship between noun extension task performance and general executive control ($r = .01$, $p = .963$). This suggests that abilities measured with our executive control task, i.e. strategic thinking, organisation of search behaviour, and information updating, did not play much of a role in the

noun extension task. Given the results of the correlation analyses, we conducted a regression analysis with age in months entered at step 1 and inhibition ability added at step 2. Results showed that both age in months and inhibition ability were significant predictors at step 2 (see Table 1). Age in months alone accounted for 21.3% of the variance in performance. Adding inhibition ability increased the explained variance to 31.8%.

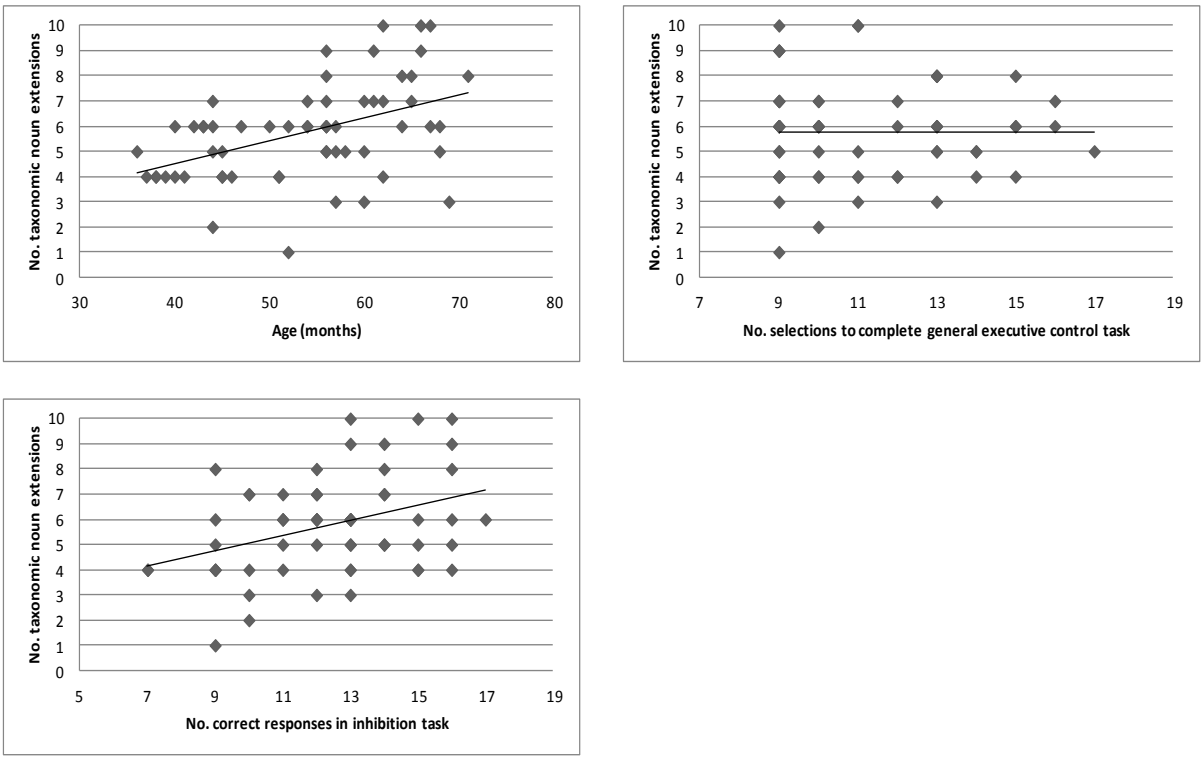

Figure 2. Relations of performance on noun extension task with age in months and inhibition ability, and the lack of such a relation with general executive control ability.

Table 1: Hierarchical regression analysis predicting noun extension task performance (N = 60)

Step	Variables entered	Cumulative R^2	R^2 change	B	Std. Error	Beta
1	Age in months	.213 ($p < .001$)	.213 ($p < .001$)	.092	.023	.462 ($p < .001$)
2	Age in months Inhibition ability	.318 ($p < .001$)	.105 ($p = .004$)	.085 .264	.022 .089	.427 ($p < .001$) .326 ($p = .004$)

Discussion

The current study aimed to provide evidence for a potential role for inhibition in non-perceptually based noun extension. This was achieved by determining whether children's non-perceptually based responses in a noun extension task might be related to their inhibition ability and/or general cognitive maturation. We found a positive relation between their inhibition ability and their taxonomic responses in a noun extensions paradigm that pitted shared taxonomic category membership against shape similarity. We also found a positive relationship between age and taxonomic responses in the noun extension paradigm. This suggests that as children mature, they tend to develop a more robust understanding that object function is likely to be a more important determinant of the object's name (i.e. category) than is object shape. The relation with inhibition ability was independent of the relation with age, with inhibition ability explaining an additional 10% of the variance. The relation with inhibition ability was therefore not confounded with general cognitive maturation. Furthermore, performance on our general executive control task was not related to performance on the noun-extension task. Thus, abilities inherent in this task such as strategic thinking and organisation of search behaviour do not seem to be very important for noun extensions, at least not for children of the ages tested here.

These findings are in line with the assumption that during noun learning young children's initial focus is drawn to salient perceptual features. They are also congruent with the attentional learning account (e.g. Colunga & Smith, 2008; Perry & Samuelson, 2011; Samuelson & Horst, 2008; Smith et al., 1996; Smith et al., 2002), which suggests that young children's attention during learning is pulled by object features based on statistical regularities, in this case object shape. The presence of a relationship between inhibition ability and noun extension may suggest that as children's inhibition ability improves, they are able to

inhibit this attentional focus in order to make extensions on the basis of conceptual similarities.

The additional relation between noun extension performance and age suggests that inhibition is not the only relevant factor when it comes to extending novel object names to new exemplars. As indicated, this relation might, for instance, reflect that general cognitive maturation or experience with how nouns map onto referents affects noun extensions. Children might learn that shape is not necessarily the most important factor, and other conceptual similarities such as function might be more important. Also, it is possible that a child's level of experience with superordinate categories and the terms used to label them may affect noun extensions. Their general intelligence may also play a role. Future research should investigate whether the relationship between inhibition and ability to suppress the role of perceptual similarity during noun extensions is still maintained when factors such as IQ and knowledge of the superordinate terms is controlled for.

As mentioned, previous research has shown that under particular circumstances even two-year-olds can move their focus away from shape, for instance, when they have prior experience with the function of the reference objects (e.g. Kemler Nelson, 1999) or the reference objects possess a stronger structure-function relationship (e.g. Kemler Nelson, 1995 Kemler Nelson, Frankenfield, Morris, & Blair, 2000). Furthermore, the addition of a generic statement about the word being extended, provision of information about the internal properties of the referent, the use of a familiar kind label when referring to the item, or the absence of a target photo all help to draw children's focus onto non-perceptual features (Tare & Gelman, 2010). All this additional information can shift children's attentional focus away from perceptual features to conceptual or 'kind' features. Future studies will need to investigate whether and, if so, how inhibition ability might interact with these other factors.

It also needs to be noted that the shape bias is not a universal phenomenon. Children's first language seems to determine whether or not they develop a preference for shape. Some studies have shown no shape bias for preschool aged children whose first language is not English (e.g. Gathercole & Min, 1997; Gathercole, Thomas, & Evans, 2000; Imai & Gentner, 1997). Similarly, it has been found that the strength of children's eventual focus on shape may be determined by first language (Hahn & Cantrell, 2012). Thus, linguistic factors such as experience of the syntax of one's language or differences in linguistic input might either prevent the development of a shape bias altogether or reduce it. Therefore, in an individual child, it is not just their inhibition ability and general cognitive maturation, but also linguistic factors that determine the strength of their shape bias.

We utilised familiar objects in order to avoid the cognitive load of remembering novel functions and its potential effect on the responses and, importantly, on the inhibition abilities of the children. Similarly to previous studies (e.g., Gentner & Namy, 1999; Imai et al., 1994), we did not find an overwhelming level of taxonomic responses, meaning that the shape-matched choice was still a strong competitor despite the knowledge of the objects. Future studies will need to investigate whether inhibition ability is also relevant for the extension of nouns for novel objects. For this purpose, it will be important to consider other factors that have been manipulated in previous noun extension tasks and shown to affect children's noun extension, for instance, whether children were able to experience the function of objects themselves or whether the objects were complex.

Our results are in line with the suggestion of a general importance of inhibition ability for disengaging from perceptual features in cognitive tasks, as shown for instance in appearance-reality tasks (Bialystok & Senman, 2004), object categorisation (Fisher, 2011) and analogical reasoning tasks (Morrison et al., 2004; Richland, Morrison, & Holyoak, 2006;

Viskontas et al., 2004). There is thus a growing consensus that in order to arrive at deeper conceptual insights, it is often necessary to inhibit more salient perceptual distracters. The results of these studies and our study might have broader implications. Children with a low level of inhibition ability might struggle more in tasks where looking past attention-grabbing perceptual features is required. As learning often involves looking beyond the surface level this would put these children at a disadvantage. Future studies will need to explore the extent to which children with low inhibition ability experience different learning outcomes.

In conclusion, we have presented findings that suggest a role for inhibition in noun learning, extending evidence for such a role in categorisation and reasoning tasks. Our finding that extension of nouns on the basis of non-perceptual features is related to inhibition ability in children is in line with the suggestion of Smith, Jones, and Landau (1996) that adults may still experience a strong attentional pull to perceptual features. In other words, the attentional draw of perceptual features may be a life-long phenomenon, and the development of inhibition ability might help older children and adults to focus on non-perceptual features. That said, the role of inhibition in early word learning is very much understudied. There is thus a need for future research into whether or how inhibition ability interacts with other factors relevant for word extensions.

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References

Bialystok, E. & Senman, L. (2004). Executive processes in appearance-reality tasks: the role of inhibition of attention and symbolic representation. *Child Development, 75*, 562-579.

Booth, A. E., Waxman, S. R., & Huang, Y. T. (2005). Conceptual information permeates word learning in infancy. *Developmental Psychology, 41,* 491-505.

Borgström, K., Torkildsen, JvK., & Lindgren, M. (2015). Event-related potentials during word mapping to object shape predict toddlers' vocabulary size. *Frontiers in psychology, 6*, 143. doi:10.3389/fpsyg.2015.00143

Cambridge Cognition. (2004). *The Cambridge Neuropsychological Testing Automated Battery (CANTAB) subject bibliography.* Retrieved from http://www.camcog.com.

Carlson, S. (2005). Developmentally sensitive measures of executive function in pre-school children. *Developmental Neuropsychology, 28*, 595-616.

Carlson, S., & Moses, L. (2001). Individual differences in inhibitory control and children's theory of mind. *Child Development, 72,* 1032-1053.

Carlson, S., Moses, L., & Breton, C. (2002). How specific is the relation between executive function and theory of mind? Contributions of inhibitory control and working memory. *Infant and Child Development, 11,* 73-92.

Carlson, S., Moses, L., & Claxton, L. (2004). Individual differences in executive functioning and theory of mind: An investigation of inhibitory control and planning ability. *Journal of Experimental Child Psychology, 87,* 299-319.

Clark, E. V. (1973). What's in a word: On the child's acquisition of semantics in his first language. In T. E. Moore (Ed.) *Cognitive development and the acquisition of language* (pp. 65-110). New York: Academic Press.

Cimpian, A., & Markman, E. M. (2005). The absence of a shape bias in children's word learning. *Developmental Psychology, 41*, 1003-1019.

Colunga, E., & Smith, L. B. (2008). Knowledge embedded in process: the self-organization of skilled noun learning. *Developmental Science, 11*, 195-203.

Diamond, A. (1991). Guidelines for the study of brain–behavior relationships during development. In H. Eisenberg (Ed.), *Frontal lobe function and dysfunction* (pp. 339-378). New York: New York University Press.

Diamond, A., Prevor, M. B., Callender, G., & Druin, D. P. (1997). Prefrontal cortex cognitive deficits in children treated early and continuously for PKU. *Monographs of the Society for Research in Child Development, 62*, 1-208.

Ewing-Cobbs, L., Prasad, M., Landry, S., & Kramer, L. (2004). Executive functions following traumatic brain injury in young children: A preliminary analysis. *Developmental Neuropsychology, 26*, 487-512.

Fisher, A. V. (2011). Processing of perceptual information is more robust than processing of conceptual information in preschool-age children: Evidence from costs of switching. *Cognition, 119*, 253-264.

Garon, N., Bryson, S. E., & Smith, I. M. (2008). Executive function in pre-schoolers: A review using an integrative framework. *Psychological Bulletin, 134*, 31-60.

Gentner, D. (1978). A study of early word meaning using artificial objects: What looks like a jiggy but acts like a zimbo? *Papers and Reports on Child Language Development, 15,* 1-6.

Gentner, D., & Imai, M. (1995). A further examination of the shape bias in early word learning. In *Proceedings of the Twenty-sixth Annual Child Language Research Forum* (pp. 167-176). Stanford, CA.

Gentner, D., & Namy, L. L. (1999). Comparison in the development of categories. *Cognitive Development, 14*, 487-513.

Gershkoff-Stowe, L., & Smith, L. B. (2004). Shape and the first hundred nouns. *Child Development, 75*, 1098-1114.

Graham, S. A., Welder, A. N., Merrifield, B. A. & Berman, J. M. J. (2010). Preschoolers' extension of novel words to animals and artifacts. *Journal of Child language, 37*, 913-927.

Graham, S. A., Williams, L. D., & Huber, J. F. (1999). Preschoolers' and adults' reliance on object shape and object function for lexical extension. *Journal of Experimental Child Psychology, 74*, 128-151.

Hughes, C., Graham, A., & Grayson, A. (2005). Executive function in childhood: Development and disorder. In J. Oates (Ed.), *Cognitive development* (pp. 205-230). Milton Keynes, UK: Open University Press.

Hughes, C., & Ensor, R. (2011). Individual differences in growth in executive function across the transition to school predict externalizing and internalizing behavoirs and self-perceived academic success at 6 years of age. *Journal of Experimental Child Psychology, 108*, 663-676.

Imai, M., Gentner, D. & Uchida, N. (1994). Children's theories of word meaning: The role of shape similarity in early acquisition. *Cognitive Development, 9*, 45-75.

Jones, L., Rothbart, M., & Posner, M. (2003). Development of executive attention in preschool children. *Developmental Science, 6*, 498-504.

Kemler Nelson, D. G. (1995). Principle-based inferences in young children's categorization: Revisiting the impact of function on the naming of artifacts. *Cognitive Development, 10*, 347-380.

Kemler Nelson, D. G. (1999). Attention to functional properties in toddlers naming and problem-solving. *Cognitive Development, 14,* 77-100.

Kemler Nelson, D. G., Frankenfield, A., Morris, C., & Blair, E. (2000). Young children's use of functional information to categorize artifacts: three factors that matter. *Cognition, 77,* 133-168.

Kemler Nelson, D. G., Russel, R., Duke, N., & Jones, K. (2000). Two-year-olds will name artifacts by their functions. *Child Development, 71,* 1271-1288.

Krawczyk, D.C., Morrison, R.G., Viskontas, I., Holyoak, K.J., Chow, T.W., Mendez, M., Miller, B.L., & Knowlton, B. J. (2008). Distraction during relational reasoning: the role of prefrontal cortex in interference control. *Neuropsychologia, 46,* 2020-2032.

Landau, B., Smith, L. B., & Jones, S. S. (1988). The importance of shape in early lexical learning. *Cognitive Development, 3,* 299-321.

Luciana, M., Conklin, H. M., Hooper, C. J., & Yarger, R. S. (2005). The development of nonverbal working memory and executive control processes in adolescents. *Child Development, 76,* 697-721.

Markman, A. B., & Gentner, D. (1993). Structural alignment during similarity comparisons. *Cognitive Psychology, 25,* 431-467.

Markson, L., Diesendruck, G., & Bloom, P. (2008). The shape of thought. *Developmental Science, 11,* 204-208.

Merriman, W. E., Scott, P. D., & Marazita, J. (1993). An appearance function shift in children's object naming. *Journal of Child Language, 20,* 101-118.

Miller, G. A., & Johnson-Laird, P. N. (Eds.). (1976). *Language & Perception*. Cambridge, MA: Harvard University Press.

Miyake, A., Friedman, N., Emerson, M., Witzki, A., Howerter, A., & Wager, T. D. (2000).

The unity and diversity of executive functions and their contributions to complex "frontal lobe" tasks: A latent variable analysis. *Cognitive Psychology, 41,* 49-100.

Morrison, R. G., Doumas, L. A. A., & Richland, L. E. (2011). A computational account of children's analogical reasoning: balancing inhibitory control in working memory and relational representation. *Developmental Science, 14,* 546-529.

Morrison, R. G., Krawczyk, D., Holyoak, K. J., Hummel, J. E., Chow, T., Miller, B., & Knowlton, B. J. (2004). A neurocomputational model of analogical reasoning and its breakdown in frontotemporal dementia. *Journal of Cognitive Neuroscience, 16,* 260-271.

Perry, L. K., Samuelson, L. K., Malloy, L. M., & Schiffer, R. N. (2010). Learn locally, think globally: exemplar variability supports higher-order generalization and word learning. *Psychological Science, 21,* 1894-1902.

Perry, L. K., & Samuelson, L. K. (2011). The shape of the vocabulary predicts the shape of the bias. *Frontiers in psychology, 2*: 345.

Petrides, M., & Milner, B. (1982). Deficits on subject-ordered tasks after frontal- and temporal-lobe lesions in man. *Neuropsychologia, 20,* 249-262.

Richland, L. E., Morrison, R. G., & Holyoak, K. J. (2006). Children's development of analogical reasoning: insights from scene analogy problems. *Journal of Experimental Child Psychology, 94,* 249-273.

Samuelson, L. K., & Horst, J. S. (2008). Confronting complexity: insights from the details of behavior over multiple timescales. *Developmental Science, 11,* 209-215.

Samuelson, L. K., & Smith, L. B. (1999). Early noun vocabularies: do ontology, category organization and syntax correspond? *Cognition, 73,* 1-33.

Smith, L. B., Jones, S. S., & Landau, B. (1996). Naming in young children: a dumb

attentional mechanism? *Cognition, 60,* 143-171.

Smith, L.B., Jones, S. S., Landau, B., Gershkoff-Stowe, L., & Samuelson, L. (2002). Object name learning provides on-the-job training for attention. *Psychological Science, 13,* 13-19.

Tare, M., & Gelman, S. A. (2010). Determining that a label is kind-referring: factors that influence children's and adult's novel word extensions. *Journal of Child Language, 37,* 1007-1026.

Viskontas, I. V., Morrison, R. G., Holyoak, K. J., Hummel, J. E., & Knowlton, B. J. (2004). Relational integration, inhibition, and analogical reasoning in older adults. *Psychology and Aging, 19,* 581-591.

Waltz, J. A., Lau, A., Grewal, S. K., & Holyoak, K. J. (2000). The role of working memory in analogical mapping. *Memory & Cognition, 28,* 1205-1212.