

An attentional learning account of the shape bias:  
Reply to Cimpian & Markman (2005) and Booth, Waxman & Huang (2005)

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## Abstract

Recently, this journal published two papers on the shape bias; both reject our previous proposals about the role of attentional learning in the development of a shape bias in object name learning. Cimpian & Markman (CM) do so by arguing that the shape bias does not exist but is an experimental artifact. Booth, Waxman, and Huang (BWH), in contrast, conclude that the shape bias (and its contextual link to artifact categories) does exist, but that the mechanisms that underlie it are conceptual knowledge and not attentional learning. In response, this paper clarifies the claims of the Attentional Learning Account and interpretations of the data under question. This paper also seeks to make explicit the deeper theoretical divide: cognition as sequestered from processes of perceiving and acting versus as embedded in and inseparable from those very processes.

Recently, this journal published two papers on the shape bias in early noun learning that conclude – on very different grounds – that our account of the phenomena is wrong. We were not called upon to comment on these papers in the review process and so do so now. Our goals are to clarify our account and open discussion of several issues in this contentious literature.

### **The Attentional Learning Account of Early Noun Learning**

The past 20 years of research on early noun learning provide a well-documented set of to-be-explained phenomena. In brief, the data are these: One-year-olds typically comprehend and produce a handful of object names. Two-year-olds, in contrast, comprehend and produce several hundred object names (e.g., Fenson et al, 1994). Moreover, in experimental tasks, children as young as two to two-and-a-half years of age show systematic attentional biases, exquisitely attending to different properties for different kinds – to the multiple similarities of animals, the shapes of artifacts, the material of substances, the colors of foods (e.g., Imai & Gentner, 1997; Soja, Carey & Spelke, 1993; Booth & Waxman, 2002; Jones & Smith, 2002; Macario, 1991).

Attention to the shape of artifacts is the most well-studied of these attentional biases. This “shape bias” is evident in quite young word learners but with age becomes more robust and more specific to things with the perceptual properties of artifacts (e.g., Hupp, 2004; Gershkoff-Stowe, 2004; Landau, Smith & Jones, 1988; Graham & Poulin-Dubois, 1999; Colunga & Smith, 2005; Jones, Smith & Landau, 1991), and to linguistic contexts indicative of artifacts rather than substances or animals (Soja, 1992; Gathercole, 1997; Booth & Waxman, 2002; Yoshida & Smith, 2001, 2003a). The shape bias is evident in children learning different languages, but the developmental trajectory and relevant contextual cues (both perceptual and linguistic) vary across languages (Gathercole, Thomas, & Evans, 2000; Imai & Gentner, 1997; Yoshida & Smith, 2003a; Colunga & Smith, 2005). Finally, biased attention to shape is weaker in children with language delay (Jones, 2003; Jones & Smith, 2005) and may be an early warning of a potentially significant developmental disorder (Thal & Katich, 1996; Rescorla, Roberts & Dahlsgaard, 1997).

The Attentional Learning Account (ALA) explains this full array of results through three major claims:

**Claim 1. The learning environment presents correlations among linguistic devices, object properties, and perceptual category organization.** We have provided support for this idea by

studying the statistical structure of the first 300 nouns in English and Japanese (Samuelson & Smith, 1999; Jones & Smith, 2002; Smith, Yoshida & Colunga, 2003; Colunga & Smith, 2005; see, also, Sandhofer, Luo & Smith, 2000). Among early-learned noun categories, artifacts tend to be rigid, angular, solid things in categories organized by shape. Animals have eyes, legs and heads, and are in categories organized by multiple similarities. Substances tend to be nonsolid and in categories organized by material. Thus, as illustrated in Table 1, there are correlations between the perceptual properties of individual things and the kinds of similarities characteristic of instances in a common noun category. Critically, languages also present *other words* (determiners, classifiers, verbs) that are, due to their use with nouns of different kinds, also correlated with perceptual properties, and the similarities characteristic of instances of a noun category.

**Claim 2: As children learn lexical categories, they learn these statistical regularities and the higher order generalizations that emerge from them, enabling the even more rapid learning of lexical categories.** Support for this *developmental* claim lies in a wide range of studies (see, Smith, 1999; Smith, Colunga & Yoshida, 2003 for reviews). The strongest evidence derives from: (1) longitudinal studies in which we show a tight *temporal* link between the particular nouns an individual child knows and that child's attentional biases in artificial noun-learning tasks, and (2) microgenetic studies in which we experimentally *accelerate* vocabulary growth. In one 6-month longitudinal study of children's acquisition of their first 100 nouns, Gershkoff-Stowe and Smith (2004) showed that the emergence of a robust shape bias in individual children coincided with an acceleration in that child's nominal vocabulary growth. In training experiments (Smith, Jones, Landau, Gershkoff-Stowe & Samuelson, 2002; Samuelson, 2002), 15- to 19-month-olds were taught lexical categories well organized by shape that they to novel categories. This training also caused an acceleration (relative to children in control conditions) in the rate of *real-word* vocabulary growth *outside of the laboratory*. These longitudinal and microgenetic studies demonstrate that attention to object shape in learning names for artifacts is relevant to the real life vocabulary development of young children.

**Claim 3: Children's learning of the statistical regularities and their *application of that learning* in the real-time task of generalizing a name to a new instance is mechanistically realized through learned associations that yield *contextually-cued shifts in attention*.** According

to ALA, the *system* of learned associations illustrated in Table 1 creates contextually-cued attentional biases. Children's attention is automatically directed -- in the moment of learning -- to similarities that have been systematically relevant in those linguistic and perceptual contexts in the child's past. The core mechanism, then, is the *top-down* control of attention by past knowledge (see especially, Smith, 2000; Yoshida & Smith, 2003a, b). The claim is that past learning, activated by cues in the context, modulates attention and, because these associations are over-learned, does so rapidly through automatic (rather than deliberative or executive) processes (see Smith, Jones & Landau, 1996). In this way, attention is dynamically bound to context, enabling the child to attend to the right similarities for the linguistic and perceptual task at hand. This is a potentially powerful learning mechanism because (1) it is exquisitely tied to and integrates multiple (perceptual *and* linguistic) contextual cues in the moment; (2) it enables the learner to attend to the same perceptual object in different ways depending on context (e.g., "a muffin" cues attention to shape but "some muffin" cues attention to material); and (3) attention and learning in the moment are strongly guided by the history of regularities in the learner's past. We have provided support for this mechanistic account in formal models of the attentional learning process and experimental tests of novel predictions from those simulation studies (Smith, 1995; Samuelson, 2002; Colunga & Smith, 2005), through demonstrations of word, property and task context effects (Yoshida & Smith 2003a, b; 2005), through cross-linguistic studies of children with different developmental histories (Yoshida & Smith 2001, 2003a), and through experimental training studies in which we teach new context cues and show that they modulate attention in noun learning tasks (Samuelson, 2002; Smith et al., 2002; Yoshida & Smith, 2005).

### **Cimpian & Markman: Is there really a shape bias?**

Cimprian and Markman (CM) acknowledge the evidence showing a shape bias. But argue against the conclusion that children "understand" names as applying to "classes of same-shaped things" (ms. Page 7). Instead, they propose that children understand names as being about "kinds." They provide evidence in experiments in which 3- to 5-year-old children were asked to learn new names for instances of well-known categories. For example, the child might be shown a detailed picture of a square-shaped purse (with handle, claps, etc. clearly depicted) and told that in "frog talk" it is called a "wug." The child was then asked which of the following was also a "wug" --- a

bedroom dresser (same square shape), saddlebag purse (same kind), or a paper bag (same superordinate category). CM found that in some conditions, children chose the shape match. but when contextual information was supplied, or when children were provided the choice of saying that the name did not extend to any of the alternatives, they did not systematically choose the shape alternative. CM take these results to indicate that the shape bias “is not a genuine word learning strategy” (pg 7). We strongly disagree. Three- to 5-year-olds learning “frog talk” for already known lexical categories is *not* “genuine” word learning in any sense. In contrast, the acquisition of the first 100 nouns by 15- to 24-month-olds (Gershkoff & Smith, 2004), the acceleration in the vocabulary growth of 17-month-olds (Samuelson, 2002; Smith et al, 2002), and the struggle of late-talkers to add new nouns to their productive vocabulary (Jones, 2003) are instances of genuine word learning, and in these cases, attention to shape matters.

Further, the ALA does not claim that children *always* or *only* attend to shape, even for artifacts, and especially *not* for well known artifact categories. In the General Discussion of a prior paper on the ALA (Yoshida & Smith, 2003c), we *predicted* CM’s results. As young children learn names for specific categories, they learn the *many* specific properties relevant to those categories; for purses, those characteristic properties may well include aspects of shape, material, latches, handles, having money inside, etc. Instances of basic-level categories commonly have much more in common than merely shape (Rosch & Mervis, 1975; Samuelson & Smith, 1999; Cree & McRae, 2003). Moreover, the similarities that characterize any category are *statistical* not necessary and sufficient. Thus, to use an example from one of our previous papers, most pickles may be green, bumpy and pickle shaped but not all pickles have *all* these properties. If children are associative learners, they should learn all the statistical regularities that characterize individual categories and these learned associations should modulate attention. But *–and this is the key claim–* children should also learn higher (second, third) order correlations that arise *over* the learned correlational patterns of *many different categories*. The shape bias is a higher order correlation. It is not a truth about a specific category but a regularity that emerges in a system of many categories.

In brief, children have category knowledge at multiple levels of abstraction, They should know the specific similarities that matter for specific categories (e.g., that pickles are pickle-shaped, green and bumpy) and the higher order regularities that should guide learning evening cases of novel

things about which children have little knowledge. To demonstrate this, Yoshida and Smith (2003c) presented children with *novel* 3-dimensional things that were not recognizable instances of any category known by the child. When labelled with a well-known name (e.g., *pickle*), children attended to the properties relevant to that particular category (e.g., *pickle* directed attention to color as well as shape). When labeled with a novel name, children attended exclusively to shape. According to the ALA, this is because the word “pickle” is a context cue that activates a web of specific associations about pickles and in so doing shifts attention weights to the properties that have been relevant to pickles in the past. In contrast, the novel noun “wug”, and the syntactic and social context in which it is embedded, is associated with (and thus activates to some degree) *all* known nominal categories, and thus directs attention to the similarity most pervasively and systematically relevant to *all* known noun categories—shape. Likewise, the ALA predicts that the highly recognizable pictures used by CM should activate children’s specific knowledge about specific categories and direct attention to the cluster of properties relevant to that particular category, not just shape.

In sum, the ALA does not claim that children only and always attend to shape; nor does it claim that they know nothing about other properties that are correlated with specific lexical categories. Rather, the ALA claims that children learn predictive relations between perceptible cues (words, properties, actions) and category organization, and that they learn those associations at lower and higher orders of generalization.

### **Booth, Waxman & Huang: Conception not perception**

BWH characterize the current state of the field as follows (page 492):

Most contemporary theories of word learning reflect this state of the evidence, claiming that in the process of word learning, infants weave together information from various sources, including perceptual, social, pragmatic, and conceptual resources...

However, this view has not been unilaterally [sic] endorsed. On the contrary, in an influential ongoing program of research, Linda Smith, Susan Jones and their colleagues have argued that word learning “primarily engages the perceptual systems and is immune to influences from general world-knowledge” (Landau, Smith & Jones, 1998, p. 20).

This nearly decade-old quote was snipped from context, distorting its meaning and misrepresenting our position. The full quote the first sentence of the General Discussion, was not in summary of our position or data but offered as a strong benchmark against which to discuss experimental results:

The present studies sought to determine whether early object naming primarily engages the perceptual systems and is immune to influences from general world-knowledge, and if so, how this might change developmentally. (Landau, Smith & Jones, 1998, p. 20).

BWH seek to show that more than perceptual information is relevant to children's noun extensions. In so doing, they concentrate on our previous findings showing that (1) the addition of eyes (or legs or shoes) to the named object shifts children's attention to multiple similarities (e.g., to texture jointly with shape) and (2) that this effect of eyes (or legs) on children's formation of lexical categories increases with age, and specifically with the number of animal names in children's vocabularies (Jones & Smith, 2002; Yoshida & Smith, 2001). The ALA explains these results in terms of learned associations between object properties and the perceptual similarities that characterize members of the same lexical category, the higher order generalizations that such a system of associations yields.

BWH report a set of experiments showing that the words experimenters used to describe objects (saying, for example, that the object is "happy") change children's name extensions – so that the presence of the words alone (no eyes, no legs) can bring about patterns of name extensions typical of animal categories, and they demonstrate this effect in children as young as 18 months. We we like the task and the results and have conducted nearly identical experiments showing that we can alter children's name extensions by merely changing the words we say (Yoshida & Smith, 2003a, b). Words (linguistic cues) have played an important role in the ALA since 1988 (c.f. Landau, Smith & Jones, 1988). Words are "in the task" contextual cues (like legs and eyes) dynamically organize attention weights.. Words are also important as elements in the system of learned associations (see especially, Yoshida & Smith, 2003 a, b, c, 2005; Colunga & Smith, 2005). Thus, ALA predicts and is supported by our studies of cross-linguistic differences. BWH's demonstration that linguistic cues affect children's noun extensions is not evidence against the ALA. The ALA is not a bottom-up theory of categories; instead, it is explicitly about how knowledge (learned associations among

words, perceptual properties, and category organization) exerts top-down control on perception through attention, and in so doing constrains learning in the moment.

BWH also misrepresent our work, and that of others, in their assertion that there have been “failures to replicate” (BWH, 493) a link between vocabulary growth and the shape bias. “Failure to replicate” implies that investigators have used our same experimental procedures to investigate the same empirical question and obtained different results. This is not the case. Diesendruck and Bloom (2003), cited as one such “nonreplication” did not test the relation between the shape bias and early vocabulary growth but instead showed that 2- and 3-year-olds’ attention to shape could be manipulated by aspects of the task context (which they interpret as indicating a conceptual rather than perceptual basis to the shape bias, but which we have interpreted in terms of a system of learned associations, see Samuelson & Smith, 2000b). Graham & Poulin-Dubois (1999), cited as the second “nonreplication”, used a preferential looking paradigm to examine 16- to 20-month-olds’ attention to shape versus color for pictures of animals versus artifacts. They found that children with both small and large vocabularies systematically attended to shape in both cases (not attending to color more for the animals than artifacts), a result consistent with our view of the greater statistical relevance of shape and the extremely limited statistical relevance of color to noun (see Samuelson & Smith, 1999). BWH’s assertion of “nonreplicability” with regard to these papers is disingenuous. Neither study attempted, nor was motivated as, a direct replication of any of our demonstrations of a link attention to shape and early vocabulary growth using longitudinal, correlational, and training studies with both typically developing children and children with language-delay (e.g., Gershkoff-Stowe & Smith, 2005; Smith, 1995; Smith et. al, 2002; Jones, 2003; Jones & Smith, 2005). Our data, along with that of Diesendruck & Bloom (2003), and Graham & Poulin-Dubois (1999) requires the unified explanation that the ALA offers, not dismissal. “Failure to replicate” is a misleading choice of words that does a disservice to scientific progress.

### **What is at stake?**

The present debate on the shape bias is so unclear that proponents of the different sides can conduct nearly identical experiments and see the same results as being both for and against the ALA (compare Cimprian & Markman to Yoshida & Smith, 2003a, Booth & Waxman 2002 to Yoshida &

Smith, 2003b, and Diesendruck & Bloom, 2003 to Samuelson & Smith, 2000b)! Just what is at issue here?

Traditional theories of cognition partition mental life into three mutually exclusive parts: sense, think, act (e.g., Fodor, 1983; Keil, 1994; Newell & Simon, 1972). Cognition under this framework is predominantly about the “think” part which mediates between perceiving and acting. Within this view, the knowledge which mediates between sensation and action is generally believed to be propositional and symbolic, and thus profoundly different from the processes that underlie perceiving, remembering, attending, and acting. Further, the central theoretical goal in this tradition is to specify knowledge structures. For this reason, sense-think-act theories of cognition are often amechanistic and not focused on the processes that underlie real-time performance. It is *under* this theoretical set of *assumptions* that the distinctions between competence versus performance, conception versus perception, and representation versus process make sense (see Thelen & Smith, 1994).

The ALA derives from entirely different assumptions. This newer idea – one with growing support from computational, behavioral, and cognitive neuroscience approaches to cognition – is that knowledge is *embedded* in, *distributed* across, and *inseparable* from the real-time processes of perceiving, remembering, attending, and acting (see Samuelson & Smith, 2000a). Cognition *just is* a set of internal processes bound to each other *and to the world through perception and action* in real-time with no fixed and segregated representation of anything. Thus, the ALA does not favor perception over conception, performance over competence, or process over representation because it makes *no such distinctions at all*. We also make no claims about children’s “understanding” of categories as a unitary process. Understanding is a momentary event embedded in real time processes of perceiving, attending, and remembering. Under this newer framework, the explanatory power attributed to concepts as unitary representational entities dissolves, as cognition is emergent in the task and the soft-assembly of many processes, each bound to each other and to the here-and-now of sensory-motor input (see, Thelen & Smith, 1994; Barsalou, 1993, 2003; Smith, 2005; Jones & Smith, 1993, O’Regan & Noe, 2001; Port & van Gelder, 1995; Smith & Samuelson, 1997; Gasser & Smith, 2005; Samuelson & Smith, 2000a).

What is at stake in these debates about the shape bias is the foundational nature of cognition itself. In this larger theoretical battle, our goal is to show how knowledge is embedded in processes such as attention, rather than fixed representational structures such as concepts. Attention is a potentially powerful repository of knowledge because it is a dynamic process shifting continually with changes in the immediate input and because it is informed by a system of learned associations that reflect the statistical regularities of the world, of language, and the social structure of discourse. Attention is a particularly powerful force on development because it selects and constrains what is learned in the moment, in the real time in which learning and development genuinely takes place.

Table 1. Examples of the kinds of correlations –among perceptual properties, linguistic cues, and category organization – that are characteristic of early noun categories.

	Perceptual properties	Linguistic cues	Category organization
Animates	Limbs, eyes, mouths	Adjectives: <i>happy, sad, kind</i> Verbs (subject of): <i>want, kiss, cry</i>	Multiple similarities (especially shape and texture)
Artifacts	Angular, complex parts	Adjectives: <i>broken, fixed</i> Verbs (object of): <i>break, made</i>	Shape
Substances	Rounded, flat, irregular, unique shape	Adjectives: <i>soft, hard</i> Verbs (object of): <i>squish, eat, spill</i>	Material

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