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In Defense of Core Competencies, Quantitative Change, and Continuity

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Abstract

Kagan (2008) urges contemporary developmentalists to (1) be cautious when attributing conceptual knowledge to infants based on looking-time performance, (2) constrain their interpretation of infant performance with multiple methodologies, and (3) reconsider the possibility that qualitative development may be the path by which perceptual infants become conceptual adults. This commentary outlines an account of conceptual development that adheres to two of the three Kagan provisos. It is (1) circumspect in the core competencies attributed to infants, and (2) grounded in convergent measures including looking time, ERPs, computational modeling, and eye tracking, but (3) maintains that the transition from the perceptually-based category representations of infants to the knowledge-rich concepts of adult is a continuous developmental process marked by quantitative change.

In a provocative article, Kagan (2008) has rebooted the vigorous debate that sprang up about a decade ago when Marshall Haith's (1998) article "Who put the cog in infant cognition? Is rich interpretation too costly?" was published by *Infant Behavior & Development*. The debate centers on the issue of what kinds of skills and knowledge can be attributed to infants based on their performance in experiments conducted with looking time methodologies. Kagan contends that one is unlikely to observe adult competencies in infants, and argues that looking time results offer multiple interpretations, which need to be verified with convergent methodologies. Kagan also argues that the extent to which infant performance falls short of adult-like levels of competence should point investigators towards re-embracing the notion of qualitative change as the path by which the nature of infant thought may be altered to attain the conceptual power of adult knowledge.

I agree with the argument that whatever mental structures are guiding infant performance in looking time experiments, their content is unlikely to match the richness of the mature semantic concepts underlying adult competence. In addition, I agree with the argument that the multiple interpretations of infant looking time need to be evaluated further with convergent methodologies. It also seems reasonable to suggest that a vocabulary for describing infant performance be adopted that respects the immaturity of the infant's mental structures relative to those of adults. However, to develop this vocabulary in such a way that it emphasizes dissociation between infants and adults may not be warranted, and to contend

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that qualitative change is the path to the end state of being fully developed may not be necessary. The remainder of the commentary will propose an account of early conceptual development that avoids rich interpretation of infant looking time performance and uses multiple methodologies to further constrain that interpretation. But the account also argues that much of conceptual development can be accounted for by core competencies that when put into operation in the developing infant can begin to yield functional knowledge in a short period of time, and that a continuous process of developmental enrichment marked by quantitative change may explain the transition from infant to child to adult concepts.

Perceptually Based Category Representations in Infants

Looking-time studies measuring the emergence of categorization during early development have demonstrated that young infants between the ages of 3 and 7 months of age will categorize animals such as cats, dogs, horses (e.g., Mareschal & Quinn, 2001). The infants are presented with multiple instances from a common category during familiarization (e.g., cats) and then with a preference test pairing a novel instance from the familiar category (e.g., a new cat) with a novel instance from a novel category (e.g., a new dog). Categorization is inferred if infants generalize their familiarization to the novel instance from the familiar category and display a preference for the novel instance from the novel category.

Categorization versus Discrimination

It is worth emphasizing that the animal stimuli presented to the infants were realistic photographic images. In the case of cats, the stimuli depicted different breeds in a variety of colors and stances. In fact, the stimuli from within a category were highly discriminable, an observation which underscores that the novel category preferences cannot be attributed merely to processes of perceptual discrimination between categories. The infants can discriminate between the different instances of the cats just as readily as they can discriminate between a cat and a dog, yet they are also able to look through this variation so as to group together the various cat images into a common representation that excludes the dog images. As Kagan (2008) notes, “Young infants and many animal species can discriminate between pictures of an elm tree and an elephant and between parallel and non-parallel lines. But this evidence does not mean that they possess the semantic concepts of plant, animal, or parallel.” I agree completely with Kagan’s observation (is there anyone who would disagree?), but would also note that the categorization task presents infants with two novel stimuli in the preference test, thereby calling on the infant to generalize from the familiarized instances to a novel instance from the same category, and distinguishing the categorization task from a simple discrimination task.

Perceptually Based Category Representations versus Perceptual Schemata

Being careful not to over-interpret infant performance, I have adopted the stance Kagan (2008) recommends in describing the mental structure guiding infant looking behavior with a construct that differs from the term that might be used to describe adult performance. That is, infant performance has been described as being mediated by “perceptually based category representations” rather than “concepts”. This is to respect the fact that the infants at issue are just a few months of age and they are responding to visual images presented in the laboratory. They do not "know" about cats and dogs in the way that adults know about their more abstract genetic and reproductive attributes (e.g., cats have cat DNA and give birth to kittens). At the same time, I see no reason to minimize the accomplishments of the infants by relegating the status of their representations to "perceptual schemata", thereby creating a dissociation between the terminology used to describe the performance of infants and adults participating in category learning tasks. As described by Kagan, "schemata are used primarily to recognize events, places, and objects experienced in the past". By contrast, an important feature of category representations, even if based on perceptual information, is that they allow the infant to "go beyond the information given" in terms of being able to generalize to novel instances not previously experienced.

A Convergent Measure

As a complement to the behavioral looking-time studies demonstrating category formation for the various animal species by infants, Quinn, Westerlund, and Nelson (2006) asked whether neural correlates of category learning by infants might be measurable. They did so by developing an event-related potential (ERP) analogue of the behavioral looking-time procedure. The infants were presented with 36 cat images followed by 20 novel cat images interspersed with 20 novel dog images. The results (i.e., the neural activations observed in different parts of the scalp up to a second and a half after stimulus presentation) were partitioned into four different conditions: cats 1–18, cats 19–36, novel cats, and novel dogs. The rationale is that if there is a neural signal that corresponds with category learning, then the responses to cats 1–18 and the novel dogs (reflecting initial experience with exemplars of a category) should be equivalent. The responses to cats 19–36 and the novel cats (reflecting a learned category of cats) should also be equivalent, but different from the responses to cats 1–18 and the novel dogs.

Of interest was a late-slow wave component observed in the time window between 1000 and 1500 ms after stimulus presentation. In studies of recognition memory for individual stimuli in infants (Nelson, 1994; Reynolds & Richards, 2005), the amplitude of the slow wave has been associated with the differentiation of familiar and novel stimuli. In particular, a slow wave that returns to baseline has been associated with recognition of familiarity, whereas a slow wave that deflects away from baseline in the negative direction is associated with detection of novelty. The results from Quinn et al. (2006) were that a negative slow wave was observed over left occipital parietal scalp in the time window between 1000 and 1500 ms after stimulus onset in response to cats 1 through 18 and novel dogs, whereas a slow wave that returned to baseline was observed for cats 19–36 and novel cats. This analysis reveals that the infant's brain responded to novel cats with activity equivalent to that displayed for cats 19–36. More generally, it points to the neural instantiation of a key behavioral indicant of categorization: responding to the novel as if it is familiar. That there is distinct brain activity corresponding to the formation of a category representation for the exemplars presented during familiarization (e.g., the cats) provides convergent evidence with the looking-time studies and indicates a neural preparedness in the first half-year of life to represent category information on the basis of perceptual experience.

Quantitative versus Qualitative Change

The studies of infant learning of animal categories suggest that young infants divide the world of objects into perceptual clusters that later come to have conceptual significance for adults. As such, the conceptual representations found later in development may be viewed as informational enrichments of the category representations that infants form on the basis of perceptual experience (Quinn & Eimas, 1997). For example, infants who are presented with exemplars of cats and horses are not experiencing these exemplars as an undifferentiated mass, but rather as separate groups that fall into distinct representations. These representations might then serve as placeholders for the acquisition of the more abstract information that occurs beyond infancy, through language and more formal learning of the nonobvious attributes associated with semantic categories (Quinn & Eimas, 2000). Thus, over time, the perceptual placeholder representation for cats will come to include the information that cats eat tuna, hunt mice, have cat DNA, give birth to kittens, and are labeled as “cats”, whereas the representation for horses will come to include the information that horses eat hay, carry heavy loads, have horse DNA, give birth to foals, and are labeled as “horses”. The acquisition of this additional information serves to enrich the original perceptually-based category representations to the point that they attain the richness of the more mature conceptual representations of children and adults (Quinn, 2004). By this view, what changes as concepts mature is the content of the representations, rather than the processes underlying their development (Madole & Oakes, 1999; Rakison & Poulin-Dubois, 2001).

We have also been careful not to over-interpret our category learning studies as indicating that infants are forming concepts that they leave the lab with and then carry around in their heads for everyday usage. The claim is that infants are demonstrating perceptual grouping or clustering abilities in the laboratory that are presumably engaged when infants encounter cats and horses in the course of experience in the world outside the laboratory (or images of them as depicted in videos and picture books). The latter representations are those believed to be the ones that serve as the supports for the acquisition of the non-obvious attributes that occurs beyond the infancy period.

Against Dissociating the Perceptual from the Semantic

I agree with Kagan’s (2008) major claim that “perceptual competences” can be distinguished from “conceptual structures”, but I also disagree with the assertion that qualitative change need be the path to get from one to the other. More generally, I disagree with the idea that the “physical features” of events should be separated from their “meaning”. Even the most conservative theorists of cognitive development would grant that infants have operational perceptual input systems and a general learning mechanism to acquire a database of information about objects in the world. And that knowledge may be perceptual in nature. In the case of animals, stored data may include information about faces, coloring, skeletal appendages, a body shape bounded by curved contours, movement patterns, and species-specific sounds of communication. Kagan is strangely silent on the idea that powerful learning mechanisms provided with such perceptual input can acquire knowledge previously thought to be part of the infant’s conceptual endowment (Elman, Bates, Johnson, Karmiloff-Smith, Parisi, & Plunkett, 1996). Such mechanisms, instantiated in the form of connectionist learning systems that provide yet another source of convergent evidence for those interested in explicating the mental status of infants, have provided important in-principle demonstrations that a single network (and hence a single system of representation) can produce a broad-to-narrow trajectory for category learning that was once thought to provide a distinctive signature for learning concepts separately from percepts (Quinn, 2002; Quinn & Johnson, 1997; cf., Mandler, 2000). Notably, the ERP evidence described earlier in which infants were simply provided with perceptual experience with visual images of cats and dogs also produced neural evidence for learning the more global category (cat + dog) prior to separating cats and dogs into distinct groupings (Quinn et al., 2006).

These observations raise the question of whether perceptual information should be dissociated from semantic categorization as Kagan (2008) and others have contended (Carey, 2000; Mandler, 2000). An alternative view (one that I embrace) is that knowledge about the perceptible parts and properties of objects can be semantic knowledge (see also Murphy, 2002, in press). One could not have much of a concept of cats, for example, without knowing what they looked like and what parts they had. Concepts must include perceptual information, or else they would not be very helpful. It is hard to imagine how a child could even map the more abstract attributes onto their correct object referents without having category representations available from perceptual experience to serve as support structures. Even school children learning about biology must be able to recognize the Birman lying on the sofa, the long-haired gray Maine Coon sitting in the window across the street, and the short-haired orange tabby that just began patrolling in the yard next door as instances of "cats".

By this view, it becomes to difficult to envision that the concepts formed by infants from perceptual experience are simply cast aside when a later concept that is imbued with more abstract information becomes available. It is important to acknowledge that this view does not deny that in some instances, more abstract information can supplant perceptual information when the two sources of information are placed in competition as determinants of category identity (Keil, 1989; Plunkett, Hu, & Cohen, 2008). This type of evidence has been used to support an "essentialist" view of concept development (Gelman, 2003). However, while "essentialist" arguments have been forceful in the literature, Hampton, Estes, and Simmons (2007) have actually presented cases in which a majority of research participants weight characteristic perceptual features more heavily than defining essentialist features in decisions about category identity, thereby suggesting that at least in some instances information about perceptual properties is considered just as semantic as information about genetics. Moreover, if one accepts the argument that perceptual information may be meaningful, then the difference between perceptually- and conceptually-based concepts is less clearly a qualitative one. Indeed, in nature, perceptual (form) and conceptual (function) information are often correlated and experiments designed to tease apart whether perceptual or conceptual information is the more potent determinant of categorization behavior may serve only to perpetuate what is arguably a false dichotomy. Instead, the way forward may be to explain how perceptual and conceptual knowledge are integrated (not dissociated) to form mature concepts (Murphy, 2002, in press; Quinn, 2004).

A Role for Biases

The account of category development offered in the present commentary, like that offered in Kagan's (2008) target article, has attempted to avoid radical nativist solutions that rely on innate knowledge, but it does recognize that there are likely to be constraints or pre-existing biases of a general nature that help make the rapid development of categorization possible. Biases may assist infants in solving the nontrivial problem of determining which features should be selected for determining category membership. And while the evidence reviewed indicates that young infants can learn category representations on the basis of perceptual experience, it does not inform us as to the particular features the infants use to form the category representations. The answer to this question is not obvious, given that the exemplars from the various nonhuman animal categories possess a number of common attributes such as a head, torso, four legs, and a tail.

Quinn and Eimas (1996) examined infants' abilities to categorize cats versus dogs when provided with the whole stimuli, just the heads (with the bodies occluded), or just the bodies (with the heads occluded) during both the familiarization and preference test portions of the experiment. The results were that the infants categorized when presented with either the whole stimuli or just the heads, but not when presented with just the bodies. These findings indicate that the head provided a sufficient basis for the infants to categorize cats versus dogs. The conclusion of Quinn and Eimas (1996) was bolstered by an additional study in which infants were familiarized with whole cat or dog images and then preference tested with hybrid stimuli (i.e., cat head on dog body vs. dog head on cat body; Spencer, Quinn, Johnson, & Karmiloff-Smith, 1997). Infant preference during test followed the direction of the novel category head. Interestingly, adults also seem to emphasize the head when representing animal species (Reed, McGoldrick, Schackelford, & Fidopiastis, 2004).

Use of the head could arise from a biasing mechanism that directs infant attention to the head information that is present in a visual scene (Johnson & Morton, 1991). It is also possible that the infants simply learn during the course of experience with the exemplars that the head is the most diagnostic part of the stimulus. In other words, the head feature may be flexibly created as the basis for the category representation in an on-line fashion (Quinn, Schyns, & Goldstone, 2006). To determine whether infants used the head because of a bias or because of on-line learning, Quinn, Doran, Reiss, and Hoffman (in press) used an eye-tracking methodology to measure the eye fixations of infants as they scanned the visual images presented in the categorization task. On the assumption that stimulus regions used for categorization will be preferentially fixated over those not used, it was reasoned that if the head preference results from a biasing mechanism, then infants should fixate more on the heads than the bodies of the exemplars throughout the course of the familiarization portion of a category learning procedure. Alternatively, if the infants learn that the head is the most diagnostic region of the stimuli, then the head preference should emerge during the course of the familiarization trials. The major finding was that throughout the course of the familiarization trials, the infants were shown to have a marked preference for fixating the head that was present during the whole of familiarization.

The results are consistent with the idea that the reliance on the head for the categorical parsing of cats and dogs arises from a biasing mechanism. However, one could still argue that infants are simply orienting to the head because it contains high contrast internal features and infants are attracted to the most visible portion of the stimulus (Banks & Salapatek, 1981). To address this possibility, a control study was undertaken that repeated the eye-tracking version of the category familiarization procedure, but with stimulus images that were inverted (Quinn et al., in press). If the head preference resulted from infants' simply orienting to the most visible portion of the stimulus, then it should still be observed with inversion. However, if the infants orient to the head because of a bias that is in place to facilitate face recognition, then one would not expect it to be present with stimulus inversion, given that inversion changes the normal configuration of facial features, and faces are believed to be recognized on a configural basis. The major finding from the control study was that fixations to the head region of the stimuli were small when compared with fixations to the body.

The inverted control results provides evidence that infants use the head to categorize upright cat and dog images because of a biasing mechanism that responds to face information. This type of bias could facilitate conceptual development by allowing infants to differentiate categories that have faces (e.g., animals) and those that do not (e.g., furniture), as well as partition classes marked by distinctive facial make ups (e.g., cats vs. dogs). More generally, a bias of this nature may aid infants in selecting from among various features that are potentially available in the input (i.e., head or body), and in this way "set the system on the trajectory of learning" (Thelen & Smith, 1994, p. 315). Such biases may be especially important in determining the course of concept acquisition in a system that is otherwise characterized by flexibility.

Concluding Comments

This commentary has outlined an account of concept development that adheres to the guidelines set forth by Kagan (2008) in terms of being (1) cautious about the skills and knowledge attributed to infants, and (2) based on evidence that converges from multiple methodologies (i.e., looking time, ERPs, computational modeling, and eye tracking). However, in contrast with Kagan, the account maintains that the perceptually-based category representations of infants should not be dissociated from the knowledge-rich concepts of adults. Rather, the latter grow out of the former based on a continual process of enrichment in which category representations that are initially based on perceptual attributes come to incorporate non-obvious attributes acquired through informal and formal tuition, and language. From this perspective, infants may begin to form categories based on core competencies consisting of functioning perceptual systems (including that for language) and a general learning mechanism (that can represent within-category similarity and between-category dissimilarity) that is facilitated in its operation by biases to attend to some inputs more so than others. Such competencies equip infants with the ability to form functional category representations that, although not adult-like in their initial form, will become adultlike during continuous real-time development that occurs in day-to-day interactions with a structured environment. Infants are endowed with the tools to build a foundation for conceptual development, rather than with a pre-conceptual form that will be shed once metamorphosis provides mature concepts.

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