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Apples and oranges: developmental discontinuities in spoken-language processing?

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## APPLES AND ORANGES

### Abstract

Much research focuses on speech processing in infancy, sometimes generating the impression that speech-sound categories do not develop further. Yet other studies suggest substantial plasticity throughout mid-childhood. Differences between infant vs. child and adult experimental methods currently obscure how language processing changes across childhood, calling for approaches that span development.

*50 words*

*Keywords:* phonological development, speech perception, word learning, developmental methodologies

## APPLES AND ORANGES

While we know a great deal about the beginnings of spoken-language comprehension, a missing puzzle piece is the link from early perceptual sensitivities and word learning, to later perceptual memory, associative learning, and word-meaning mapping. Not uncommonly, language-development conferences and journals contain claims that young infants are speech “experts.” This emphasis on early abilities minimizes evidence of substantial plasticity in speech perception through primary school [1,2]. In the language-development literature, the fact that infants only discriminate sounds or learn words under a very narrow set of circumstances is often regarded as a mere methodological concern—yet it may reflect something about the learning infants still need to do to reach maturity.

Here we discuss a major barrier to seeing the continuous developmental picture of speech perception and word-meaning mapping: most experimental paradigms used with infants versus older learners differ substantially. Infant-appropriate tasks are exquisitely sensitive to subtle or incomplete knowledge—by necessity—while tasks used with older children and adults often require explicit indications of more complex knowledge or abilities. As a result, comparing learning or competence in infancy versus later childhood sometimes seems like comparing apples and oranges. This makes it difficult to characterize what changes across development. In an informal database search of speech-perception/word-recognition from birth to five years, only 15 of 512 total papers (3%) used the same method with both infants under 12-months-old and preschoolers or older learners. Below, we discuss two major causes of paradigm-based discrepancies across development, highlight some consequences of these discrepancies, and provide concrete suggestions for bridging the gap.

## APPLES AND ORANGES

### **Causes of paradigm-based discrepancies across development**

*Different tasks are used to test purportedly the same abilities.* Investigations of ostensibly the same ability in infants versus older learners—e.g., sound discrimination or word learning—often differ in both how sounds are presented to listeners, and what types of responses are prompted. Because young infants cannot indicate knowledge explicitly, infant tasks rely on implicit responses, such as looking times. Infants' sound discrimination is often tested by presenting one sound-category repeatedly (such as “*ba ba ba...*”, or a repeating set of voices [3]) until signs of boredom appear (often, ceasing to look at a picture on a computer screen). Then, the sound is switched (“*da*”) to see whether infants “perk up” and begin looking again, indicating *discrimination* (of “*ba*” vs. “*da*.”). Repeated exposure to the initial sound “*ba*” dramatically increases the memory strength for that sound. This “pumped-up” memory may be crucial to detecting when the sound changes. Supporting this are findings from a neural method called mismatch negativity (MMN). The MMN is an electrical brain response to a mismatching element (B) in a sequence such as A, A, A, ... B. The MMN response is thought to reflect sensory or perceptual memory. Critically, the more As that precede the oddball B element, the stronger the neural response [4].

While discrimination tasks are sometimes used with older learners, and are also argued to assess short-term sound discrimination, they are typically very different from discrimination tests with infants. They often present just two sounds (e.g., “*ba ba*” or “*ba da*”), and prompt a “Same” or “Different” judgment. Infant paradigms are likely more sensitive, both because they do not require an explicit response—reducing task demands—and because they build up a stronger representation of the first sound as it is repeated throughout the initial exposure.

## APPLES AND ORANGES

*Older learners are tested on more complex abilities.* Another way in which tasks for older learners are more demanding is that older learners are often required to not just differentiate sounds, but to *learn an association* between sounds and objects—for example, learning names for objects. Whereas infants are most often tested on sound discrimination, older learners are often asked to learn words or otherwise associate sounds to visual categories, which entails learning and differentiating several sound-meaning mappings. For example, the ability to tell apart different voices is typically assessed via simple discrimination in infancy [3], but older learners might be asked to associate voices to different characters [5]. There are some infant tasks that require associative learning [6]. However, infants typically complete just a few brief test items [6], while word-learning tasks (or other associative-learning tasks) with older learners typically require participants to maintain recently learned associations for dozens of test items. This is a significant difference considering that newly-formed word-meaning mappings in children may be quite fragile in memory, decaying in as little as 5 minutes [7].

### **Consequences of paradigm-based discrepancies: paradoxical developmental patterns**

The above differences in infant and child tasks and their memory requirements can create a puzzling picture of how perceptual abilities change between infancy and adulthood—in some cases leading to the appearance of greater sophistication in infancy than in later childhood. For example, infant learners discriminate a new voice amongst other voices [3], yet preschoolers have difficulty mapping two different voices to two different characters [5].

## APPLES AND ORANGES

In another well-known case, by 12 months, infants have tuned their discrimination of similar-sounding consonants like *b* versus *d* to their native language, only discriminating native contrasts [8]. However, children cannot reliably distinguish newly-learned *word-labels* differing only in these same sounds until 17-20 months [6]. Researchers debate whether this is due to infants' immature phonological knowledge [9], or because task difficulty masks good phonological knowledge [10]. In a third case, infants respond with different facial expressions to positive vs. negative adult speech [11]. Yet well into preschool, children struggle to associate emotional speech patterns with the concepts *happy* vs. *sad* [12].

Superficially, these three cases suggest that, paradoxically, infants are more mature listeners than older children, who recover abilities by adulthood—a U-shaped developmental pattern (Box 1). However, apparent U-shaped patterns may well be attributable to the increased complexity or memory demands of tasks used with older learners. The true developmental trajectory may be a slow, steady increase in perceptual knowledge. Unfortunately, because relatively little work bridges age and task divides, it is often difficult to discern what changes *between* infancy and later childhood.

### **Proposed solutions**

Task differences outlined above currently obscure the developmental picture of perceptual and memory abilities that support language. The following measures would help to better characterize the full course of perceptual development.

## APPLES AND ORANGES

First, more studies should focus on *a longer span of development*. One approach is to use different tasks with the same age group to obtain task equivalencies, facilitating cross-age comparisons across studies. Another approach is to relate each study's findings to existing literature on earlier and later ages, carefully considering differences in tasks, memory demands, and materials.

Second, *matched methodologies* across wide age ranges are possible with certain paradigms. While adults are unlikely to demonstrate sound-discrimination by sucking on a non-nutritive nipple (a common infant paradigm), nor are infants likely to spend an hour in the lab learning 40 new words, other paradigms can better connect disparate ages. These include neural methods like MMN to assess perceptual sensitivity; and eye-tracking, which can be used from infancy through adulthood to test learned associations between auditory words and their pictured images. When age differences emerge in matched methodologies, we can have more confidence that they reflect real developmental changes rather than methodological confounds. Then, we can begin trying to explain their causes and consequences.



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## APPLES AND ORANGES

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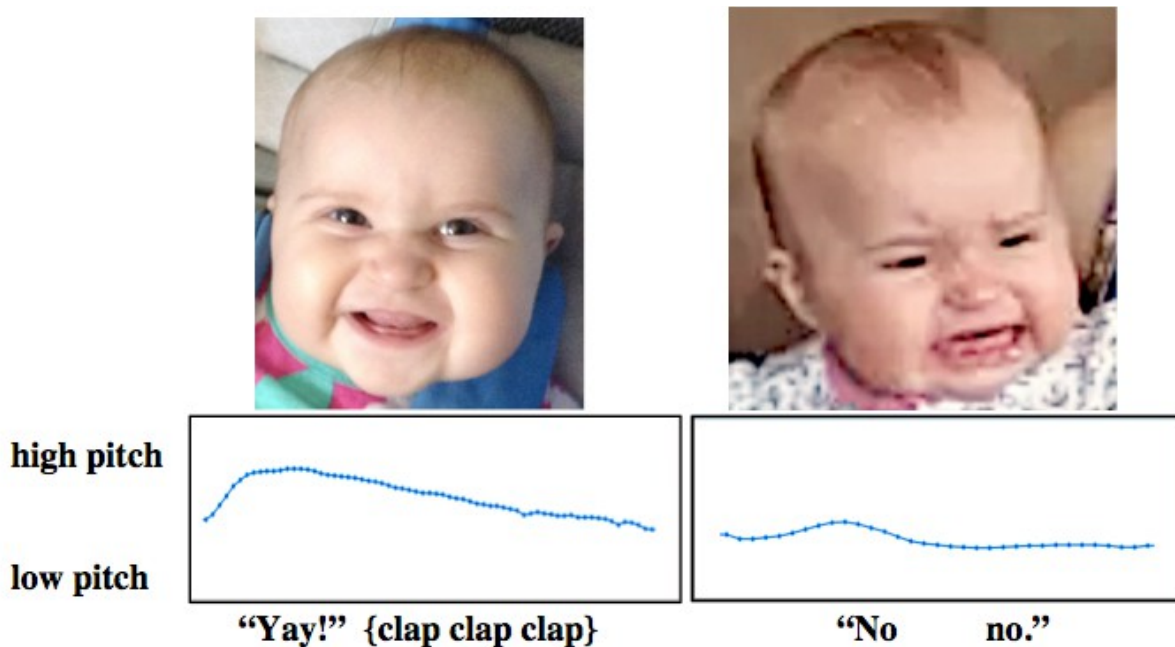
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## APPLES AND ORANGES

### Box 1.

Foundational work by Fernald [11] has demonstrated that infants respond to the emotional content and pragmatic functions (e.g., approval vs. disapproval) of adult speech. By as early as 5 months, infants smile more to parents' expressions of approval, which tend to be produced higher in the vocal range and with more sweeping contours (**Figure 1**, left; blue line indicates pitch contour) and are more likely to show negative affect in response to prohibitions (**Figure 1**, right) [11].

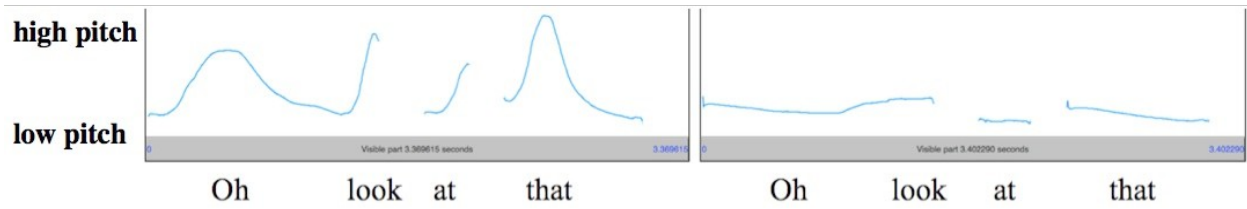


**Figure 1: Infants' facial expressions can demonstrate sensitivity to pragmatic functions of speech like approval (left) or disapproval (right).**

While infants are sensitive to emotions and pragmatic functions in speech, older children tested in more complex tasks show protracted development of interpretation of vocal emotion. For example, several studies have shown that preschool children weight the *words* that are spoken more heavily than the vocal emotion when these cues conflict. Even when words are

## APPLES AND ORANGES

intentionally neutral (**Figure 2**), children cannot map vocal expressions to the emotions “happy” or “sad” until about age 4 ½ [12].



**Figure 2: Happy (left) versus sad (right) vocal expressions used in a laboratory task to test preschoolers' ability to identify vocal emotions.**