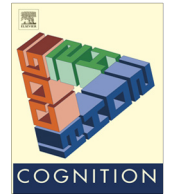




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Timing matters: The impact of label synchrony on infant categorisation

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ABSTRACT

The impact of labelling on infant visual categorisation has yielded contradictory outcomes. Some findings indicate a beneficial role while others point to interference effects in the presence of labels. The locus of these divergent outcomes is largely unclear. We explore the hypothesis that the timing of the label is of crucial importance, proposing that synchronous presentation of words and objects induces a higher processing load than asynchronous presentation (image onset before labelling). A novelty preference experiment with 12-month-olds reveals that synchronous presentation leads to a diminished preference for a novel object on test in comparison to asynchronous labelling, suggesting a detrimental impact on category learning. However, analyses of infants' gaze patterns to object parts reveal that even synchronous labels do not hinder learning completely. We conclude that synchronous labels interfere with the familiarisation process, but this process involves shifts in familiarity vs. novelty preference rather than overshadowing of visual learning. Besides offering detailed insight into the effects of labelling on infants' visual attention, these findings offer the potential to reconcile previous contradictory results.

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1. Introduction

Investigations of linguistic influences on cognitive processes have drifted in and out of fashion over the past half century or so. Strong assertions in favour of linguistic determinism (Whorf, 1956) and relativity (Brown & Lenneberg, 1954) have gradually yielded ground to less radical points of view (e.g., Boroditsky, 2001; Hunt & Agnoli, 1991). From a developmental perspective, the investigation of the impact of language on thought is of fundamental importance: do infants use language, and words in particular, as cues to learn about the complex structure of the world? Brown and Lenneberg (1954) were well aware of the developmental implications of Whorf's thesis:

The world can be structured in many ways, and the language we learn as children directs the formation of our particular structure. Language is not a cloak following the contours of thought. Languages are molds into which infant minds are poured. (Brown & Lenneberg, 1954, p. 454)

The ubiquity of labels in an infant's environment, both in speech directed at the infant and in conversation between adults overheard by the infant, renders the possibility of linguistic influence highly plausible (Akhtar & Tomasello, 1996). Shared labels can indicate that dissimilar looking things may share attributes or function (e.g., a bonnet and a boater may both simply be called a "hat"). Thus, several studies over the past 20 years have found facilitative effects of labelling on categorisation in pre-linguistic infants between three and twelve months (e.g., Balaban & Waxman, 1997; Ferry, Hespos, & Waxman, 2010; Fulkerson & Waxman, 2007; Waxman & Braun, 2005; Waxman & Markow, 1995).

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One focus in this line of research was placed on the question of whether these effects are specific to linguistic labels or can be achieved by any consistent auditory stimulus. In both 6- and 9-month-old infants the facilitation of category formation seems to be restricted to novel labels (Balaban & Waxman, 1997; Ferry et al., 2010; Fulkerson & Waxman, 2007). Three-month-olds appear to benefit equally from non-human primate vocalizations, but not other tone stimuli (Ferry, Hespos, & Waxman, 2013), indicating that infants gradually learn to treat speech as a specific signal.

In addition to the studies demonstrating the facilitation of single-category formation, Plunkett, Hu, and Cohen (2008) have demonstrated that labels serve to guide the formation of category boundaries when the structure of visual space is ambiguous. This work suggests that even infants who are just at the beginning of language development can make use of labels when learning about objects and similarities between them. However, contradictory results which report “auditory overshadowing” effects in the presence of labels, as well as other auditory stimuli (Robinson & Sloutsky, 2004, 2007a, 2007b; Sloutsky & Robinson, 2008), question whether labelling has uniformly beneficial effects for infant visual categorisation. In these studies, labels are considered to have an interfering effect, blocking the formation of object categories. This constellation of findings raises the question as to the conditions under which labels facilitate learning, and what factors may contribute to labels attenuating learning.

From an information-processing perspective, labels undoubtedly provide information that may help learning, e.g., by increasing perceived similarity between objects that share labels (Sloutsky, Lo, & Fisher, 2001), or by highlighting commonalities (Waxman & Markow, 1995). However, processing this additional signal comes at a cost: attention and processing resources have to be allocated to two modalities rather than one. The exact circumstances in which labels are encountered may play a vital role in determining whether they will interfere with, or facilitate, processing. We explore the possibility that the timing of the label is critical: If image and label are presented in exact synchrony, this may impose high perceptual load (Lavie, Lin, Zokaei, & Thoma, 2009; Robinson & Sloutsky, 2007b), and processing in one or both modalities may be attenuated. By contrast, if there is a delay between visual and auditory onset, this may allow infants to process both stimuli equally well because some visual object recognition processes will already have been completed by the time the label occurs (Grossmann, Gliga, Johnson, & Mareschal, 2009; Quinn, Westerlund, & Nelson, 2006).

The question of modality-specific attenuation is particularly interesting in the light of results indicating a transition from auditory dominance in infancy (Lewkowicz, 1988a, 1988b; Robinson & Sloutsky, 2004; Sloutsky & Napolitano, 2003) to visual dominance in adulthood (Colavita, 1974; Posner, Nissen, & Klein, 1976; Sinnett, Spence, & Soto-Faraco, 2007). Studies investigating the developmental trajectory have found visual dominance to emerge between 9 and 10 years of age (Nava & Pavani, 2013), with 4-year-olds exhibiting mixed results (Robinson & Sloutsky, 2004). Robinson and Sloutsky (2004) state two plausible reasons for advantages in

auditory processing early in development. The first is that audition develops earlier and is available to the fetus from the third trimester of gestation (Birnholtz & Benacerraf, 1983), whereas the visual system only receives external input from birth. This may cause audition to outweigh visually perceived signals early in life. An alternative hypothesis is that audition is initially dominant due to the transient nature of auditory stimuli. According to this argument auditory dominance is directly related to the limited attentional resources available in infancy, which cause attention to be predominantly directed toward the stimulus that needs to be processed immediately. Posner et al. (1976) suggested that visual dominance may emerge in adult sensory processing in order to compensate for the fact that visual signals are less alerting than signals in other modalities. In summary, a hypothesised developmental trajectory is that an increase in attentional resources over development allows the early auditory dominance to disappear, and a visual dominance develops once it becomes advantageous to compensate for the less alerting nature of visual stimuli.

Regarding the processing of object and label pairings we therefore hypothesise that if interference occurs due to the presence of multiple stimuli in the synchronous (but not the asynchronous) condition, visual learning should be attenuated rather than auditory learning.

In addition to the impact of processing capacity there is another argument to be made regarding ecological validity of synchronous vs. asynchronous labelling. Whereas synchronous label onsets have been used in experimental studies reporting interference effects (e.g., Robinson & Sloutsky, 2004, 2007a, 2007b; Sloutsky & Robinson, 2008), asynchronous labelling scenarios are more likely to occur in a young child’s everyday experience, e.g., a caregiver asking “Do you like the ball?” when the child is already attending to the object (Baldwin, 1991). In fact, Tomasello and Farrar (1986) reported that the caregiver’s tendency to name objects already in the infant’s attention (as opposed to re-directing their attention to an object by labelling it) correlated with vocabulary size at 21 months. Similarly, they found an advantage for labelling following the child’s attention in a word learning experiment. Even though some researchers have claimed that synchrony is beneficial to the formation of word-object associations (Gogate, Bahrick, & Watson, 2003), and cross-modal synchrony has been demonstrated to facilitate discrimination of amodal signals such as tempo or rhythm (Bahrick & Lickliter, 2000), it is likely that synchronous picture-word pairings are unusual and surprising to infants at one year of age. These infants, after all, are at a stage in development where they have learned that words often occur together with their referents, but not generally in synchrony like “causal” sounds, such as a hammer hitting a wall. By contrast, recent work using a head-mounted camera demonstrates that word learning is successful in situations where the referent object is brought close to the infant’s face several seconds before the label occurs (Pereira, Smith, & Yu, 2013).

Another potential source of the differential impact of labels is the type of objects used in the respective studies. Investigations reporting a facilitative effect on

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