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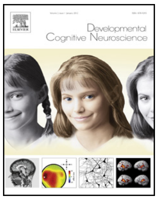

Audiovisual temporal fusion in 6-month-old infants

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ABSTRACT

The aim of this study was to investigate neural dynamics of audiovisual temporal fusion processes in 6-month-old infants using event-related brain potentials (ERPs). In a habituation-test paradigm, infants did not show any behavioral signs of discrimination of an audiovisual asynchrony of 200 ms, indicating perceptual fusion. In a subsequent EEG experiment, audiovisual synchronous stimuli and stimuli with a visual delay of 200 ms were presented in random order. In contrast to the behavioral data, brain activity differed significantly between the two conditions. Critically, N1 and P2 latency delays were not observed between synchronous and fused items, contrary to previously observed N1 and P2 latency delays between synchrony and perceived asynchrony. Hence, temporal interaction processes in the infant brain between the two sensory modalities varied as a function of perceptual fusion versus asynchrony perception. The visual recognition components Pb and Nc were modulated prior to sound onset, emphasizing the importance of anticipatory visual events for the prediction of auditory signals. Results suggest mechanisms by which young infants predictively adjust their ongoing neural activity to the temporal synchrony relations to be expected between vision and audition.

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1. Introduction

Temporal synchrony is one of the strongest binding cues in multisensory perception (King, 2005; Spence and Squire, 2003). Yet, in order to perceive simultaneity in a bimodal stimulus, perfect temporal synchrony of two sensory streams is not required. For audition and vision, the concept of a temporal window of integration was proposed in which auditory and visual input are pulled into temporal alignment to result in a fused, simultaneous percept (e.g., Fendrich and Corballis, 2001; Lewkowicz, 1996, 2000; Van Wassenhove et al., 2007; Vatakis et al., 2007). This temporal window was identified as being flexible and depending on a variety of parameters such as complexity of stimuli, familiarity and experience, or repeated asynchrony presentation (e.g., Dixon and Spitz, 1980; Fujisaki et al., 2004; Navarra et al., 2005, 2010; Petrini et al., 2009; Powers et al., 2009; Vatakis and Spence, 2006). The temporal range has a certain degree of variability across individuals (Stevenson et al., 2012) and appears to undergo changes across the lifespan (Hillock et al., 2011; Lewkowicz, 1996, 2010).

From early on, human infants are sensitive to intersensory temporal synchrony relations (e.g., Bahrick, 1983; Dodd, 1979; Hollich et al., 2005; Lewkowicz, 1986, 1992; Lewkowicz et al., 2008, 2010; Spelke, 1979). Multisensory capacities improve and responsiveness to complex multisensory temporal relations increases in the first months of life (e.g., Bahrick, 1987; Lewkowicz, 2000; Lewkowicz

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et al., 2008). For infants, Lewkowicz demonstrated that the window of perceptual fusion is larger than in adults, both for simple, abstract and for speech stimuli (cf. Dixon and Spitz, 1980; Lewkowicz, 1996, 2010; Vatakis and Spence, 2006). Hence, one may assume that temporal fusion processes undergo developmental changes from infancy to adulthood. This study is one of the first to document neural dynamics of audiovisual temporal fusion in infants, investigating an audiovisual temporal disparity within the temporal window of integration.

In adults, brain activity modulations related to audiovisual temporal synchrony perception were found in large-scale neural networks (e.g., Bushara et al., 2001; Dhamala et al., 2007; Macaluso et al., 2004; Stevenson et al., 2010). Evaluation of synchronous versus asynchronous presentation was shown to involve different networks (superior colliculus, anterior insula, anterior intraparietal sulcus) than successful perceptual fusion does (Heschl's gyrus, superior temporal sulcus, middle intraparietal sulcus, inferior frontal gyrus; Miller and D'Esposito, 2005; see also Stevenson et al., 2011), suggesting a functional dissociation between the mechanisms of physical synchrony and subjective simultaneity perception. Studies using event-related brain potentials (ERPs) have demonstrated that the auditory components N1 and P2 were sensitive to bimodal audiovisual versus unimodal auditory stimulation (e.g., Besle et al., 2009). Importantly, these modulations depended on the salience of the visual input and on anticipatory visual motion (Stekelenburg and Vroomen, 2007; Vroomen and Stekelenburg, 2009; Van Wassenhove et al., 2005) and were absent when the two sensory signals were not in synchrony (Pilling, 2009). Although the influence of temporal synchrony relations has been addressed in several studies (e.g., Talsma et al., 2009; Vroomen and Stekelenburg, 2009), electrophysiological dynamics of audiovisual perceptual fusion in adults merit further investigation.

Research on neural processes related to multisensory perception in infants is still developing. In a series of experiments on audiovisual perception, Hyde and colleagues found that, in contrast to adult ERP data, the auditory component P2 was not sensitive to multisensory versus unisensory presentation of circles and tones in 3-month-olds, but was modulated by manipulations of dynamic versus static faces and of audiovisual congruency in speech stimuli in 5-month-olds (Hyde et al., 2010, 2011). Visual recognition dynamics are reflected in the infant components Nc and Pb. Nc is a negative peak between 400 and 700 ms after stimulus onset, which has been related to mechanisms of attention and memory (e.g., Ackles and Cook, 2007; Kopp and Lindenberger, 2011, 2012; Reynolds and Richards, 2005). Pb is a smaller positive deflection peaking between 250 and 450 ms. It has been observed to be modulated by expectancy processes and the relevance of stimuli (e.g., Karrer and Monti, 1995; Kopp and Dietrich, 2013; Kopp and Lindenberger, 2011, 2012; Nikkel and Karrer, 1994).

A recent study at our lab (Kopp and Dietrich, 2013) investigated audiovisual synchrony and asynchrony perception in 6-month-old infants using ERP. Movies of a person clapping her hands were presented with visual and auditory input in synchrony in one condition and a visual delay of 400 ms in the other condition. Infants discriminated the 400-ms asynchrony behaviorally in a habituation-test task. ERPs revealed latency shifts of the auditory N1 and P2 between asynchronous and synchronous events, although the auditory input occurred at the same point in time in both experimental conditions. The magnitude of this shift indicated a temporal interaction between the two modalities. It was hypothesized that these latency delays in the infant auditory ERP components might be indicators for the emergence of an asynchronous percept on the behavioral level. Importantly, neural processing was already affected prior to the auditory onset, suggesting anticipatory mechanisms as to the timing of the two sensory modalities. Nc latency shifts implied an attentional shift in time between synchrony and asynchrony. Moreover, the polarity of Pb was reversed, being related to predictive processes as to audiovisual temporal synchrony relations prior to sound onset (for details see Kopp and Dietrich, 2013).

To date there is little insight into the emergence of multisensory percepts in infants and underlying neural activity. While behavioral performance indicates simultaneity perception both in physically synchronous and perceptually fused stimuli, differential neural processing is very likely (Miller and D'Esposito, 2005; Stevenson et al., 2011). The aim of the present study was to investigate neural dynamics within the temporal window of integration, that is, when the visual delay is smaller than the asynchrony tolerance. The paradigm used in Kopp and Dietrich (2013) was adapted for this purpose. First, a standardized infant-controlled habituation-test paradigm was applied. Children were tested for discrimination of a visual delay of 200 ms in audiovisual stimuli, an asynchrony known to correlate with simultaneity perception in infants (as proven by extensive piloting in our lab and by findings of Lewkowicz, 1996). Then, EEG activity was assessed in response to audiovisually synchronous stimuli and to stimuli in which the visual stream was delayed by 200 ms with respect to the auditory stream.[1]

It was predicted that infants would not be able to detect the 200-ms asynchrony behaviorally. However, following adult neuroimaging studies (e.g., Miller and D'Esposito, 2005; Stevenson et al., 2011), neural activity should differ between audiovisually synchronous and perceptually fused items. According to the discussion by Kopp and Dietrich (2013) that significant latency delays in the infant auditory components N1 and P2 might be an indicator for the emergence of an asynchronous percept on the behavioral level, one would predict these latency differences to disappear in the present paradigm, as the 200-ms

[1] As in the Kopp and Dietrich (2013) study, only the content of the visual input was delayed, while keeping both the video and audio onset times and durations identical between the two experimental conditions. This setup avoided differences due to attentional shifts as orienting responses to stimulus onsets and offsets during the presentation, and attentional competition between the two sensory modalities (e.g., Talsma et al., 2010).

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