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The impact of semantically congruent and incongruent visual information on auditory object recognition across development

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ABSTRACT

The ability to use different sensory signals in conjunction confers numerous advantages on perception. Multisensory perception in adults is influenced by factors beyond low-level stimulus properties such as semantic congruency. Sensitivity to semantic relations has been shown to emerge early in development; however, less is known about whether implementation of these associations changes with development or whether development in the representations themselves might modulate their influence. Here, we used a Stroop-like paradigm that requires participants to identify an auditory stimulus while ignoring a visual stimulus. Prior research shows that in adults visual distractors have more impact on processing of auditory objects than vice versa; however, this pattern appears to be inverted early in development. We found that children from 8 years of age (and adults) gain a speed advantage from semantically congruent visual information and are disadvantaged by semantically incongruent visual information. At 6 years of age, children gain a speed advantage for semantically congruent visual information but are not disadvantaged by semantically incongruent visual information (as compared with semantically unrelated visual information). Both children and adults were influenced by associations between auditory and visual stimuli, which they had been exposed to on only 12 occasions during the learning phase of the study. Adults showed a significant speed

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advantage over children for well-established associations but showed no such advantage for newly acquired pairings. This suggests that the influence of semantic associations on multisensory processing does not change with age but rather these associations become more robust and, in turn, more influential.

Introduction

Events in our world provide signals to multiple senses. The ability to use these different signals in conjunction confers numerous advantages on perception. First, senses can be complementary in providing unique kinds of information; for example, only vision can reliably tell us whether we are faced with a gray squirrel or a red one. Second, senses often provide redundant information about the same property; for example, both visual size and auditory amplitude could be cues to an animal's size. Using multiple redundant cues across senses allows adults to detect stimuli more readily (Lovelace, Stein, & Wallace, 2003; Stein, London, Wilkinson, & Price, 1996) and to respond more accurately (e.g., Alais & Burr, 2004; Ernst & Banks, 2002) and more rapidly (Hughes, Reuter-Lorenz, Nozawa, & Fendrich, 1994).

Studies investigating the development of multisensory perception have found mixed results. There is a body of evidence to suggest that some multisensory abilities are present during early infancy (e.g., Bremner, Slater, Johnson, Mason, & Spring, 2012; Neil, Chee-Ruiter, Scheier, Lewkowicz, & Shimojo, 2006; Scheier, Lewkowicz, & Shimojo, 2003). However, studies investigating the development of cross-modal cue combination suggest that in some tasks children do not combine information across senses as adults do until 8 years of age or later (e.g., Gori, Del Viva, Sandini, & Burr, 2008; Jaime, Longard, & Moore, 2014; Nardini, Bales, & Mareschal, 2016; Nardini, Bedford, & Mareschal, 2010; Nardini, Begus, & Mareschal, 2013; Nardini, Jones, Bedford, & Braddick, 2008; Petrini, Remark, Smith, & Nardini, 2014). Considering audio–visual stimuli specifically, children appear to integrate cues more frequently and less selectively than adults (Adams, 2016; Innes-Brown et al., 2011), and they also show a bias toward auditory stimuli (Nava & Pavani, 2013), which develops into an adult-like visual dominance across middle childhood. In addition, children show a diminished McGurk interference effect, which also suggests that they may be processing auditory information over visual information (e.g., Massaro, Thompson, Barron, & Laren, 1986). An early bias for auditory stimuli may partially be explained by the differential experience of the auditory and visual systems in the prenatal environment (e.g., Lecanuet & Schaal, 1996). This developmental shift in the way that audio–visual information is weighted suggests that the mechanisms underlying these processes are changing across this period.

Many studies now show that multisensory perception in adults is influenced by factors beyond simple low-level stimulus properties such as spatial and temporal coincidence. For example, adult multimodal perception is also influenced by how attention is allocated within a scene (Talsma, Senkowski, Soto-Faraco, & Woldorff, 2010) as well as by variation in the congruency (in terms of both perceptual and semantic features) between the different sensory inputs (e.g., Heron, Whitaker, & McGraw, 2004; Jackson, 1953; Slutsky & Recanzone, 2001). There is a growing body of evidence suggesting that adults are sensitive to the semantic congruency between multisensory signals and that this influences the way in which these signals are processed, enabling more accurate and efficient recognition (e.g., Chen & Spence, 2010; Laurienti, Kraft, Maldjian, Burdette, & Wallace, 2004; Lehmann & Murray, 2005; Senkowski, Saint-Amour, Kelly, & Foxe, 2007). This could be advantageous because it allows observers to use their previous experiences to improve their chances of making correct perceptual judgments. Semantic congruency is a particularly important factor when sensory reliability is reduced. For example, older adults (whose vision and hearing have become degraded over