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Global and local pitch perception in children with developmental dyslexia

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ABSTRACT

This study investigated global versus local pitch pattern perception in children with dyslexia aged between 8 and 11 years. Children listened to two consecutive 4-tone pitch sequences while performing a same/different task. On the different trials, sequences either preserved the contour (local condition) or they violated the contour (global condition). Compared to normally developing children, dyslexics showed robust pitch perception deficits in the local but not the global condition. This finding was replicated in a simple pitch direction task, which minimizes sequencing and short term memory. Results are consistent with a left-hemisphere deficit in dyslexia because local pitch changes are supposedly processed by the left hemisphere, whereas global pitch changes are processed by the right hemisphere. The present data suggest a link between impaired pitch processing and abnormal phonological development in children with dyslexia, which makes pitch pattern processing a potent tool for early diagnosis and remediation of dyslexia.

1. Introduction

Research on skilled reading suggests that global but not local pitch pattern perception is one of the strongest predictors of reading (Foxton et al., 2003). In their study, a strong correlation was found between global pitch perception and reading performance in skilled readers (i.e., university students). Thus, the primary goal of the present study was to investigate whether children with dyslexia would exhibit deficits in global but not local pitch perception.

On theoretical grounds, Foxton et al.'s (2003) finding is intriguing because contour (global pitch changes) and intervals (local pitch changes) are supposedly processed by asymmetrical and independent brain structures. The right hemisphere primarily represents melody in terms of its contour, and the left hemisphere in terms of its intervallic structure (Peretz, 1990; Peretz & Morais, 1987, but see Stewart, Overath, Warren, Foxton, & Griffiths, 2008). More generally, it has been suggested that local processing (i.e., sequential, analytic, relational) is preferentially located in the left hemisphere, whereas global processing (parallel, holistic, unitary) is preferentially located in the right hemisphere (Bever & Chiarello, 1974; Justus & List, 2005). Given that reading is a left-hemisphere task (Shaywitz et al., 1998), it is somewhat surprising that global and not local pitch pattern perception was shown to be correlated with skilled reading.

However, it is well known that global pitch pattern perception is important for speech prosody (Morton & Jassem, 1965) and speech prosody is crucial for word segmentation and phonological development in infants (Jusczyk, 1999). Thus, impaired processing of stress location in speech would affect speech segmentation, and this in turn would affect the development of phonological skills that are important for literacy acquisition (Goswami et al., 2002; Muneaux, Ziegler, Truc, Thomson, & Goswami, 2004; for review see Goswami, 2011). Thus, an account of dyslexia that emphasizes the importance of speech prosody for accurate phonological development should predict deficits in global pitch pattern perception, whereas an account that emphasizes the fact that dyslexia has been linked to a left-hemisphere deficit (Galaburda, Menard, & Rosen, 1994; Shaywitz, Mody, & Shaywitz, 2006; Shaywitz et al., 1998) should predict deficits in local pitch pattern perception.

Early evidence in favor of the claim that local pitches and global contour is processed in different hemispheres was provided in a study where subjects classified successive melodies as "same" or "different" (Peretz & Morais, 1987). The contour of the melodies was violated on half of the trials. A clear facilitative effect of contour was observed with contour-violated melodies being better discriminated than contour-preserved (but interval-violated) melodies. Moreover, a left-ear advantage was obtained in the first case and a right-ear advantage in the second. Thus, when the global cue was not available for discrimination, such as with

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contour-preserved melodies, participants had to rely only on local cues, and in this situation the left hemisphere appeared dominant.

Hemispheric specialization for local versus global pitch changes was also supported in neuropsychological studies, in which patients with unilateral brain lesions were presented with contour-violated and contour-preserved (interval-violated) melodies in a same-different classification task (Peretz, 1990). Patients with left-hemisphere damage showed deficits in processing intervallic structures (local violations), whereas patients with right-hemisphere damage showed deficits in processing contour (global violations). Similar findings in favor of hemispheric specialization for global and local processing has also been reported for visual stimuli (large letters made of small letters), where the right hemisphere contributes more to the processing of global aspects of visual stimuli, whereas the left hemisphere contributes more to the processing of the local components of visual stimuli (Fink et al., 1997; Robertson & Lamb, 1991).

Dissociations between global versus local pitch perception have been reported in a variety of developmental disorders. For example, high-functioning persons with autism perform better than controls in the detection of interval-violated but contour-preserved melodies, a finding that has been taken as evidence for a multi-modal abnormality in the integration of parts and whole in individuals with autism (Mottron, Peretz, & Menard, 2000). Local versus global processing abilities have also been assessed in children with Williams syndrome, a rare genetic disorder characterized by a weakness in visuospatial, motor, and arithmetic skills along with strengths in face perception, memory, sociability, and selected aspects of language. The advantage that is typically found for the perception of global configurations of visual stimuli was found to be absent in children with Williams syndrome (Bihrle, Bellugi, Delis, & Marks, 1989; Deruelle, Mancini, Livet, Casse-Perrot, & de Schonen, 1999). The same pattern was found in the auditory modality (Deruelle, Schon, Rondan, & Mancini, 2005).

In the present study, we investigated global versus local pitch pattern perception in children with developmental dyslexia and in normally developing children. This is interesting for a number of reasons. (1) Global pitch pattern perception is a potent predictor of skilled reading (Foxton et al., 2003). (2) Previous research on auditory processing deficits has neglected the role of pitch perception in favor of rapid temporal processing deficits (Ahissar, Protopapas, Reid, & Merzenich, 2000). (3) Global pitch pattern perception is important for processing speech prosody, which seems to be impaired in dyslexia (Goswami, 2011). (4) Dyslexia is associated with a left-hemisphere deficit, which would suggest a possible dissociation between deficits in local versus global pitch pattern perception. (5) The study of local versus global processing differences has yielded important dissociations in other developmental disorders (Deruelle et al., 2005; Mottron et al., 2000).

The present paradigm is modeled after Foxton et al. (2003). Subjects were presented with two consecutive 4-tone melodies and their task was to decide whether the melodies were the same or different (see Fig. 1). On the different trials, differences were created by randomly altering either the second or the third note such that on half of the trials the change maintained the overall pattern of rises and falls between the notes (i.e., contour-preserved), whereas on the other half of the trials it changed the overall contour (i.e., contour-violated trials). For the global sequences, this change always violated the contour. The predictions were straightforward. If children with dyslexia were impaired in global processing, no advantage for contour-violated over contour-preserved melodies should be seen in children with dyslexia in the "different" trials. If children with dyslexia were impaired in local processing, they should perform more poorly than normally-developing children in the local than the global condition. Finally, because making same-different judgments on two consecutive 4-tone melodies is a rather complex task that involves sequencing and short-term memory, we also added a simple pitch direction task in Experiment 2, which allowed us to further explore potential deficits in pitch pattern perception that cannot be attributed to memory, sequencing, or decision strategies.

2. Experiment 1

2.1. Methods

2.1.1. Participants

Fifteen dyslexic children (10.2 years old, range: 8.6–11.9) were recruited from the University Hospital La Timone Marseille, France. All dyslexics received a complete medical, psychological, neuropsychological, and cognitive assessment by an interdisciplinary team of psychologists, neurologists, and speech therapists. Dyslexics were included in the study if their reading age was at least 18 months below the age norm on a standardized reading test

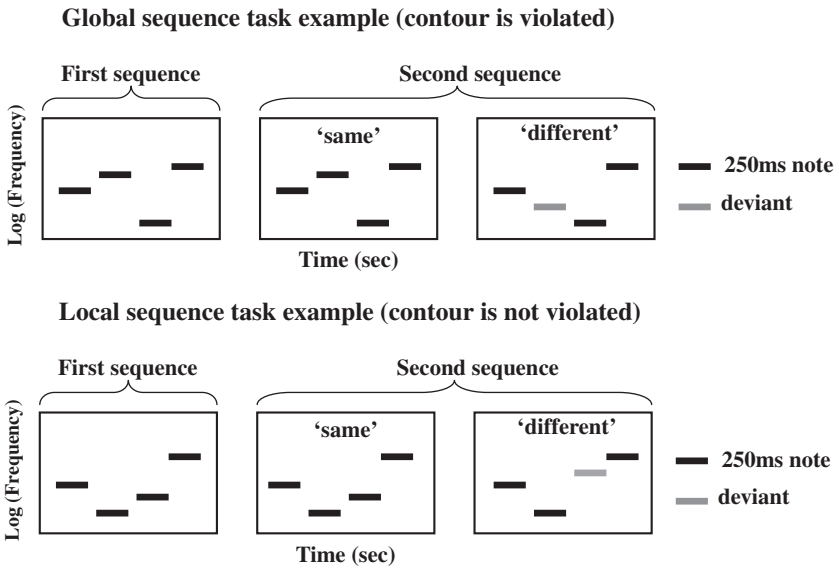

Fig. 1. Illustration of the global and local pitch change detection tasks.