Cortical oscillations and auditory processing in developmental dyslexia

Franck Ramus
Cognitive development and pathology
Laboratoire de sciences cognitives et psycholinguistique
Ecole Normale Supérieure

The general aim of this project is twofold: a fundamental aim is to understand the role of auditory cortical oscillations at different frequency-bands in the processing of sounds and in particular in the processing of speech. A more clinical aim is to understand in what respect auditory cortical oscillations deviate in individuals with developmental dyslexia, and how these deviations impact speech processing and phonological skills relevant to reading acquistion. This project therefore has the potential to illuminate the neurophysiology of auditory and speech perception, and the neural and cognitive basis of developmental dyslexia.

Developmental dyslexia is a specific and significant impairment in the development of reading skills that is not solely accounted for by mental age, visual acuity problems, or inadequate schooling (World Health Organization, 2011). It is now well-established that at least a majority of dyslexic children have a so-called phonological deficit, manifested by difficulties paying attention to and manipulating speech sounds, poor verbal short-term memory, and slow sequential naming (Ramus & Ahissar, 2012; Wagner & Torgesen, 1987). Yet the underlying cause for such a deficit remains mysterious and controversial. Earlier hypotheses about a primary temporal auditory processing deficit (Farmer & Klein, 1995; Tallal, 1980) have not been well supported (Ramus, 2003; Ramus et al., 2003; Rosen, 2003). More recently, a growing interest in stimulus-driven cortical oscillations in auditory cortex (ASSR: auditory steady-state responses) has led to the hypothesis of a disruption of such oscillations in dyslexia, at certain frequency bands crucial to speech processing (Giraud et al., 2007; Giraud & Poeppel, 2012; Goswami, 2011). However there are diverging hypotheses concerning the specific bands that would be disrupted in dyslexia, and the evidence so far seems contradictory (Hamalainen, Rupp, Soltesz, Szucs, & Goswami, 2012; Lehongre, Morillon, Giraud, & Ramus, 2013; Lehongre, Ramus, Villiermet, Schwartz, & Giraud, 2011; Lizarazu et al., 2015; Poelmans et al., 2012). Furthermore, the link between auditory cortical oscillations and speech processing remains hypothetical, as until now participants of ASSR studies have never been subjected to a comprehensive battery of auditory and speech perception tests.
It is therefore important to clarify exactly which cortical oscillations matter for phonological processing, and which are disrupted in dyslexia.

In the course of a previous project, we have carried out a new MEG study on 23 dyslexic and 22 control adult participants, with the aim of addressing previously unanswered questions. All the MEG recordings described below have already been collected and partly pre-processed, but remain unanalysed. The MEG recordings were made as participants listened to amplitude-modulated noise at various modulation frequencies, as well as to speech and backward speech (sentences and stories). Furthermore, the same participants have been tested with a complete battery of auditory psychophysical and speech perception tests.

The project will consist in performing various analyses of the ASSRs to these increasingly complex stimuli. This will involve:

1) Quantifying the responses to amplitude modulations at the frequencies of interest in the most reliable manner;
2) Estimating the same responses in a more complex, naturalistic and relevant stimulus: speech, at two different time-scales: sentence and whole discourse. This will involve more sophisticated analyses, such as the coupling between phase and envelope across different frequency bands (e.g., Gross et al., 2013).
3) Trying and understanding why backward speech, although essentially the same signal, seems to be processed differently from forward speech by the human brain

4) Assessing to what extent individual differences in ASSRs to amplitude-modulated noise are related to individual differences in ASSRs to natural speech.
5) Testing exactly in what respect the ASSRs of dyslexic individuals differ from those of controls, in what frequency band, in what aspect of coupling across frequency bands, for what kind of stimulus, and with what consequences on sound and speech processing.

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