Adults with Developmental Dyslexia fail to anticipate predictable upcoming input

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Background & Significance

Developmental Dyslexia (DD) is generally defined as a learning disorder characterized by specific difficulty in learning to read accurately and fluently (American Psychiatric Association, 2013). Despite recent developments in research and the proposal of several theories, its exact etiology is still a matter of debate. Classical theories of DD argue that the source of the disorder is phonological in nature (Ramus, 2003; Snowling, 2000), though it now seems that the phonological deficit hypothesis is by no means an exhaustive explanation of the range of difficulties experiences by individuals with DD. Notably, beyond reading difficulties, individuals with DD often suffer from subtle deficits in the processing of morphosyntatic features and of complex syntactic structures (Cantiani, Lorusso, Perego, Molteni, & Guasti, 2013, 2015; Robertson & Joanisse, 2010) and suffer from subtle fine and gross motor difficulties (Capellini, Coppede, & Valle, 2010; Fawcett, Nicolson, & Dean, 1996; Nicolson & Fawcett, 1990; Franck Ramus, Pidgeon, & Frith, 2003; Viholainen, Ahonen, Cantell, Lyytinen, & Lyytinen, 2002). What do reading, motor control and language processing have in common? Here we argue that prediction is a key characteristic of reading, language processing and motor control (Huettig & Brouwer, 2015; Lizarazu et al., 2015; Rayner & Duffy, 1986; Shadmehr, Smith, & Krakauer, 2010). Therefore, we hypothesize that the common source of difficulties in these different domains lies in an inability to efficiently anticipate upcoming input. In order to test this hypothesis, we engaged participants in a warning imperative task (Walter, Cooper, Aldridge, McCallum, & Winter, 1964). Participants are expected to predict the upcoming input on the basis of the given rhythmic structure which should enhance the extraction of regularities. However, if individuals with DD suffer from an impairment in predictive abilities, they are expected to over-anticipate or delay the estimation of the occurrence of the beat.

Methods

Participants

Sixteen participants diagnosed with DD (mean age=22.75; SD=2.83, 6 female) and 23 control participants (TD) (mean age 24.78, SD=5.93, 10 female) were tested. All participants were students at the University of Milano-Bicocca and were Italian monolingual speakers. Inclusion criteria for the TD participants were the absence of neurological, psychiatric and auditory deficits and learning disabilities. Participants with DD were recruited through the University Learning Disabilities Centre; they received a diagnosis of DD at primary schools by an authorized clinical institute, in accordance with the Italian standard criteria. On the basis of a preliminary interview, one DD participant has been excluded since he/she has been played an instrument for 11 years at a semi-professional level.

Materials[1]

In order to assess participants' ability to generate prediction according to a given rhythm, we used a Warning-Imperative Paradigm. The warning (henceforth WB) and imperative (henceforth IB) beats are pairs of adjacent tones, in which the WB is predictive about the timing of the IB. Participants were trained to tap the left mouse button in response to the IB. Crucially, the WB gives advance notice of the occurrence of the IB and therefore, if participants are able to generate temporal prediction on the basis of the presented rhythm, they are expected to tap exactly on time to the IB (or even to anticipate the IB). Three different conditions were presented, always in the same order: Rhythm 1. It was a plain metronome rhythm, which had a reference tempo of 80 bpm. Beats were presented with onset-to-onset intervals of 750 ms. Rhythm 2. It consisted of an alternation of strong beat and weak beat. The intensity of the weak tone was half of the

[1] We also administered a reading task (The Prova di velocità di lettura di brani per la Scuola Media Superiore Judica & De Luca, 2005) and a fine-motor abilities task (The Purdue Pegboard Battery, Tiffin, 1999).

strong one. Beats were presented with onset-to-onset intervals of 750 ms. Rhythm 3. It consisted of an unpredictable sequence of beats. Sounds were presented with a mean onset-to-onset intervals of 750 ms ± a random error of 30% of the reference duration of 750 ms. Given the unpredictable timing, this pattern serves as control condition. No difference between groups was expected. The WB and the IB were obtained by adding a harmonic to the sound used to present the rhythm.

Procedure

For each experimental condition, participants were presented a familiarization phase followed by a warning-imperative phase. During the familiarization phase, participants were asked to listen attentively to the rhythm (no actual task was required). During the warning-imperative phase, participants were presented the rhythmic pattern they were previously familiarized with and were asked to tap the left mouse button in response to the IB. For each condition, a train had a duration of 6000 ms and consisted of 6 basic tones and a WB-IB couple tones. In the familiarization phase, one train was presented 2 times per condition; in the warning-imperative phase, one train was presented 10 times per condition. In the analysis, the 10 WB-IB couples for each condition will be referred as Repetitions. The experiment was presented using MATLAB (MathWorks, R2013a) and Psych Toolbox (version 3.0.11; Brainard, 1997). All sounds were generated by MATLAB and played via loudspeakers.

Results

Participants with a mean error (computed on Rhythms 1 and 2) outside the interval delimited by ± 3SD of participants' mean were considered outliers. As a result, one TD participant was discarded.

For each condition, the dependent measures were: the synchronization error, the group consistency and the participant consistency. Here, I only present the results of the synchronization error, which is the difference between the observed time, namely the time of the key pressed on the IB and the expected time, namely the IB time. Results are shown in Fig. 1. GLM analyses on Synchronization error were carried out for each condition, with Group (DD, TD) and Gender (M, F) as between-subject factors, and Repetition as within-subject factor.

In Rhythm 1, a main effect of Group was found, $F(1, 36) = 5.89$, $p < .05$, $\eta^2_p = .14$. In Rhythm 2, Group was also significant, $F(1, 36) = 6.91$, $p < .05$, $\eta^2_p = .16$. as well as Repetitions, $F(9, 315) = 4.39$, $p < .001$, $\eta^2_p = .11$. Bonferroni post-hoc comparisons showed that the synchronization error of the 1st Repetition was bigger than the synchronization errors of the 3rd, 4th and 5th Repetition.

In Rhythm 3, no significant differences were found. Gender turned out to be not significant.

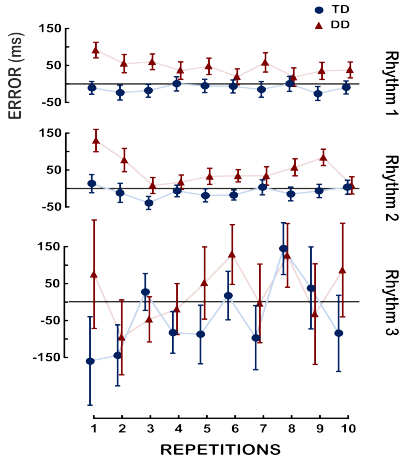

Fig. 1 Synchronization error of Rhythm 1, 2 and 3. (Unpredictable).

Discussion

The present study investigates whether adults with DD are able to predict - and thus to anticipate - the occurrence of an upcoming stimulus. Our results show that adults with DD were delayed with reference to the IB timing, differently from TD participants who were synchronous or slightly anticipated the IB (Aschersleben & Prinz, 1995). These results are novel and inconsistent with previous findings about rhythmic abilities in individuals with DD which displayed a tendency to over-anticipate the beat (Leong & Goswami, 2014; Wolff, 2002). However, it is worth stressing that a direct comparison among our results and previous findings cannot be drawn, due to different methodologies adopted (previous studies used tapping paradigm). Importantly, in our study no group difference was found in the control condition, in which the uncertain timing occurrence of the beat did not permit the extraction of regularities, thus showing that differences in reaction time cannot account for the difference found between the TD and the DD group in Rhythm 1 and 2.

Conclusions

The findings of our study suggest that well-compensated adults with DD are not able to exploit temporal regularities to anticipate the next sensory event, despite the high predictability of the stimuli. These results have been already replicated in children with DD and further investigation is in progress in children with Specific Language Impairment.

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