Prediction of abstract representations from the rhythmic and the syntactic structures

Maria Teresa Guasti[*1]

[*]Corresponding Author: mariateresa.guasti@unimib.it
[1]Department of Psychology, Università degli Studi di Milano-Bicocca, Milan, Italy

Languages have a rhythmic structure, have (morpho)syntax and the two are somehow related. Why? In this paper, we attempt to provide an answer to this question based on experimental evidence from language impaired individuals and controls. In a nutshell, our answer is that rhythm and syntax allow humans to generate predictions concerning the incoming input. In turn, this ability reduces memory load through the pre-activation of the sensory system and allows one to anticipate abstract representations.

In Pagliarini et al. (2015), we showed that children with Developmental Dyslexia (DD) fail to comply with two rhythmic principles of the handwriting: (1) The principle of isochrony (Binet & Courtier, 1893; Stetson & McDill, 1923; Viviani & Terzuolo, 1982) which states "that the speed of movement execution is proportionally related to the length of its trajectory in order to keep the movement duration approximately constant" and (2) "The principle of homothety (Lashley, 1951; Viviani & Terzuolo, 1982), which guarantees the invariance of the relative duration of a movement's components under a number of possible variations in the duration of the very same movement. In handwriting, this principle predicts that the relative duration of the components of the whole movement (e.g., the individual letters of a word) will remain invariant across changes in duration." In our study, children had to write on a digital tablet connected to a computer the word "burle" in block script and cursive. They wrote it in a baseline condition, faster and bigger than in the baseline. Typically developing (TD) children maintained the same global and relative duration constant across conditions, as shown in Figure 1 from Pagliarini et al. (2015). In contrast, the duration of single letters (and also of the whole word) varied in children with DD varied, as shown by the fact the three curves in fig. 1 (left) are not superimposed.

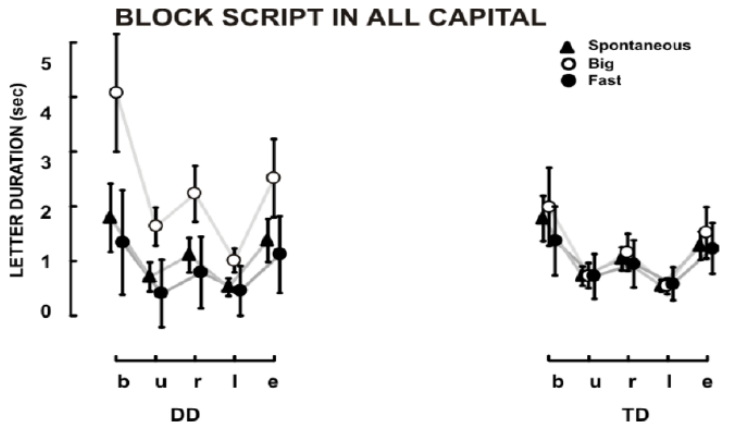

Figure 1

We also found that the ability to satisfy the two rhythmic principles of handwriting is correlated with reading measures, non-word repetition. In Pagliarini et al. (2017), we showed that TD children from grade 1 are able to comply with the two rhythmic principles of handwriting. This suggests that their acquisition does not require a lot of training. This fact also allow us to discard the hypothesis that the weakness of children with DD is not due to lack of practice, as younger children with little practice have no problem. The two studies together suggest that children with DD have problems with the temporal organization of events, with rhythm. Rhythm is useful to predict future events. Then, we expect that children and adults with DD have problems in anticipating future events. To test this hypothesis, we carried out an experiment with 18 adults with DD along with 20 controls. We engaged participants in a task requiring entrainment to a given rhythm using a warning and imperative paradigm. During habituation, participants heard a simple rhythm constituted by a sequence of 440 Hz pure tones with 8 ms rise and fall times and 200 ms steady-state duration. At test, couples of beats were singled out from the sequence by adding a harmonic to the basic sounds. The first beat, called the warning beat (WB), had the function of alerting the participant and getting him ready to tap in synchrony with the second beat, called the imperative (IB). Ten WB-IB couples were randomly distributed throughout the rhythmic sequence. A schematic representation of the experiment is given in Fig. 2.

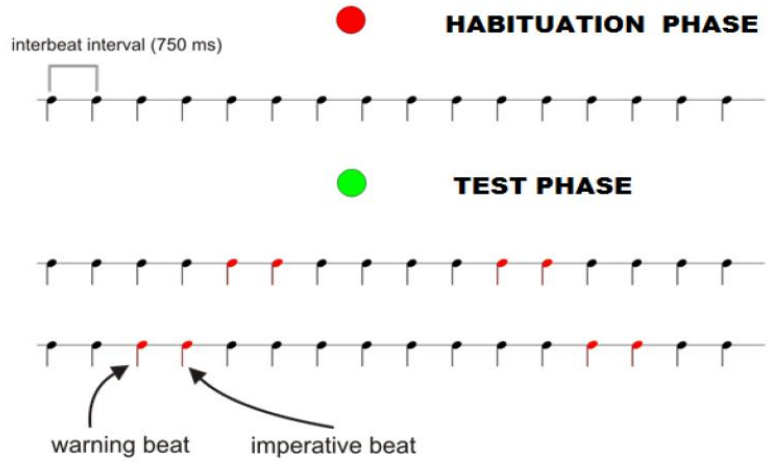

Figure 2. Schematic representation of the experiment.

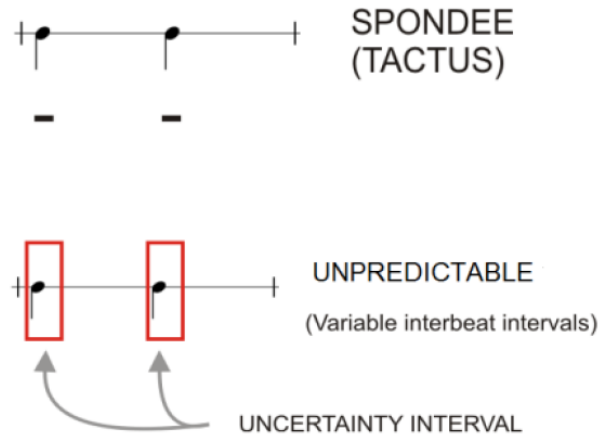

Figure 3. Graphic illustration of the Spondee and the Unpredictable condition.

Two conditions were included in the design: a Spondee (predictable) rhythm and an unpredictable pattern, which serves as control condition (Fig. 3). In the Spondee condition, beats were presented with onset-to-onset intervals of 750 m. In the control condition, beats were presented with a mean onset-to-onset intervals of 750 ms ± a random error of 30% of the reference duration of 750 ms. In the Spondee condition, participants are expected to extract the timing regularity during habituation and use it to predict when the IB is going to occur during test. In the control condition, the uncertain timing occurrence of the beat does not permit extraction of regularity and therefore participants are in a position where no timing prediction is possible.

Results. In order to establish whether the timing of participants tapping was synchronous with the occurrence of the IB, we calculate the synchronization error by subtracting from the timing of the IB the time of the subject's tapping response. A positive

error indicates a response after the IB; a negative error indicates a response before the IB. In the Spondee condition, significant group difference were found, $F(1, 36) = 9.33$, $p < .01$, $\eta 2p = .20$. Controls are synchronous or anticipate the IB within a maximum of 30 ms, whereas participants with DD display a tendency of tapping after the occurrence of the IB, with a delay between 20 and 90 ms. In the unpredictable condition, Group was not significant, as participants from both groups responded in response to the IB (i.e. reaction time). Interestingly, participants with good predictive skills were also faster in reading. We replicated the same result with children with DD.

Discussion. The result of the Spondee condition suggest that participants with DD are not able to use temporal regularity to anticipate the IB contrary to controls. Both groups showed a similar response pattern in the unpredictable condition, as no regularity can be exploited in order to predict the incidence of the IB. These results are in line with another finding from the literature provided by Huetting & Brouwer (2015). These authors engaged adults Dutch individuals with DD in an eye-tracking experiment in which they were shown a quadrant with four objects, one of which was the target object and the other three were distractors. At the same time, they were listening to the sentence "look at the displayed piano". Interestingly, the information as to target object was already available at the article (as the gender of the article was compatible only with the target object and no similar morphosyntactic information was available on the adjective). It was found that control participants shifted their eye gaze to the target objects substantially earlier than adults with DD. In another words, the adults with DD were unable to use the morphosyntactic information from the article to anticipate the target object.

Conclusion. Languages display a rhythmic structure that allows individuals to predict the incoming linguistic events; similar, morphosyntactic features are used to anticipate the incoming structure and generate an abstract representation used to accommodate the input. Individuals with DD are impaired in predicting or in extracting regularities and display subtle problems with language.