Complexity of Rhythmic Tapping Task and Stuttering

Anneke Slis, Christophe Savariaux, Silvain Gerber, Pascal Perrier, Maëva Garnier

Univ. Grenoble Alpes, CNRS, Grenoble INP, GIPSA-lab, 38000 Grenoble, France

Introduction: This study explores whether people who stutter (PWS) differ in rhythmic tapping behavior compared to people who do not stutter (PNS). Stuttering is a neuro-motor disorder, presenting itself as disfluent speech production[1]. Evidence suggests that stuttering is not limited to speech movements, but that upperlimb and non-speech orofacial movements are also affected[3,4,5]. One of the theories proposed is that deficiencies in temporal processing, originating at the neural level, play a role in the difficulty to execute movements[6]. When synchronizing with an auditory stimulus, PWS show larger asynchrony with a beat than PNS[7] and perform less accurate and consistently[2,8].

Most studies to date explore the differences in temporal processing between PWS and PNS with simple rhythmic tasks, such as the ability to synchronize with an external, predictable beat. Speech is characterized by a quasi-rhythmic structure that requires more complex temporal skills to estimate the less predictable timing of the consecutive events such as strong and weak syllables. It is speculated that the speaker employs an internal neural timekeeper which predicts how these syllables must be timed[10]. To the authors' knowledge, it has not been explored whether PWS have a deficit in estimating temporal dimensions between beats, for example when they are challenged to fill up the time between two predictable, external, beats with self-generated taps. The current study explores whether, compared to PNS, PWS differ in their ability to fill an empty time interval with a sequence of regular beats. In addition, to validate earlier studies, the study examines whether PWS differ in their ability to continue tapping a periodic rhythm without an external metronome when the external driving metronome stops and whether they differ in their tapping behavior when synchronizing with a metronome beat[2,7,8].

It was expected that, compared to PNS, PWS face more difficulties filling up the time gaps with self-generated beats. Based on findings in earlier studies[2,7,8], it was expected that PWS can synchronize and sustain a periodic beat but show more variability than PNS.

Methods: 16 French PWS (13 M, aged 19 to 65) and 16 French PNS (13 M, aged 19 to 70) were recruited. Speakers synchronized tapping with their dominant (left or right) index finger with an auditory beat played binaurally through earplugs. Three different rhythmic tasks were distinguished, all based on an eight-taps cycle:

T1) synchronization task (120 BPM).
T2) 4 taps on one metronome beat (30 BPM).
T3) continuation task (120 BPM)

For each rhythmic task, the participant listened to at least 2 cycles of the pattern before starting tapping, and then produced at least 3 tapping cycles of that pattern until the participant was instructed to stop. Such trains of tapping cycles were recorded 4 times for each rhythmic task so that at least 12 cycles (of 8 taps) of each rhythmic pattern were considered for analysis.

Tapping events were annotated semi-automatically with MATLAB scripts. The first step determined whether participants were able to produce taps with a sufficiently enough regular pattern and to estimate its actual period (Ta), knowing that, at a rate of 120 BPM, the theoretical period (Tt) should be 500 ms.. No participant demonstrated erratic tapping patterns, although some participants inserted an extra tap, or skipped a tap. In order to estimate the Ta of each 8-taps cycles, we considered the time differences (Δt) between a tap and the following one within a tapping cycle and removed Δt values which were larger than 1.5*Tt (750 ms.; considered as a missed tap) or smaller than 0.5*Tt (250 ms.; considered as a “double” tap). We then calculated Ta in seconds as the average value of the remaining Δt values, for each tapping cycle. The second step was to estimate, for each tapping cycle, the tapping variability (TV) around this actual periodicity (in percentage), as defined by the following equation:

$$1)\quad TV = mean\left(\frac{\Delta t - Ta}{Ta} \times 100\right)$$

In addition to these quantitative measures, all the missed and double taps were counted

Analysis: The data were analyzed with General Mixed Models in R[9], considering rhythmic task (T1, T2, T3), musical experience (no experience (0), medium (1), advanced (2)) and participant group (PWS, PNS) as fixed effects and the participants as a random effect. The level of significance was $\alpha = 0.05$.

Results: The results revealed no significant interaction effect between the fixed effects on tapping variability

(TV). PWS showed significant higher TV than PNS ($\chi^2(1)= 7.2168$, $p<0.01$; PNS<PWS: $p = 0.02$); TV varied significantly with rhythmic task (figure 1A; ($\chi^2(2)= 27.045$, $p<0.0001$) with a greater TV observed in T2 compared to the T1 ($p<0.01$) and T3 ($p < 0.001$). T1 resulted in smaller values than T3 ($p = 0.04$). TV was also significantly influenced by "Musical experience" (see figure 1B; $\chi^2(2)=7.95$, $p=0.02$). Speakers with advanced experience showed smaller tapping variability in all tasks.

No significant interaction effect between the fixed effects was observed on Ta. Only the Fixed effect "Rhythmic task" revealed significant differences ($\chi^2(2)= 11.47$, $p<0.01$; T1 < T2: $p < 0.001$; see figure 1C).

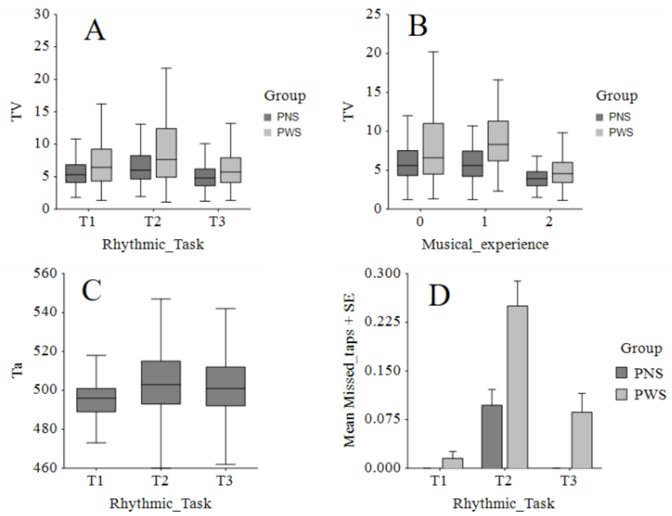

Figure 1 vertical axis A and B: TV (tapping variability normalized); C: mean tapping period in ms.; D: mean number of missed taps.

Finally, it can be observed from figure 1D that PWS missed more taps ($\Delta t > 750$ ms) than PNS in the T2 and T3 tasks. Very few taps were inserted, so these are not reported.

Discussion: PWS can synchronize with an external auditory reference and keep a regular beat once the auditory reference stops. Musical experience improved the tapping accuracy of both groups. PWS however present more tapping variability than PNS on all the tasks, confirming earlier studies[2,8]. The prediction that PWS show more difficulty with filling up a time frame with extra taps was not confirmed with the timing measures; however, PWS missed more taps than PNS, suggesting that this task is more difficult than the synchronization and continuation tasks. These results suggest a possible deficit in time processing by people who stutter that we are currently investigating by comparing finger tapping with speech productions and comparing simple regular rhythmic patterns with more complex ones.

1) Bloomstein, O., & Bernstein Ratner. N. (2008). A Handbook on Stuttering. Thomson Delmar Learning
2) Hulstijn, W., Summers, J.J., van Lieshout, P., & Peters, H.F.M. (1992). Timing in Finger Tapping and Speech: A Comparison between Stutterers and Fluent Speakers. Human Movement Science 11(1), 113–24.
3) Max, L., Caruso, A.J., & Gracco. V.L. (2003). Kinematic Analyses of Speech, Orofacial Nonspeech, and Finger Movements in Stuttering and Nonstuttering Adults. *Journal of Speech, Language, and Hearing Research, 46*(1), 215–232.
4) Daliri, A., Prokopenko, R.A., Flanagan J.R., & Max, L. (2014). Control and Prediction Components of Movement Planning in Stuttering Versus Nonstuttering Adults. *Journal of Speech, Language, and Hearing Research 57*(6), 2131–41.
5) De Felicio C.M., Rodrigues, R.L., Freitas, G., Vitti, M., Cecilio, S., & Regalo, H. (2007). Comparison of upper and lower lip muscle activity between stutterers and fluent speakers. International *Journal of Pediatric Otorhino-laryngology, 71*, 1187—1192.
6) Chang, S.-E., Chow, H. M., Wieland, E. A., & McAuley, J. D. (2016). Relation between functional connectivity and rhythm discrimination in children who do and do not stutter. *NeuroImage: Clinical*, *12*, 442–450.
7) Sares, A.G., Deroche, M.L.D., Shiller, D.M., & Gracco, V.L. (2019). Adults who stutter and metronome synchronization: evidence for a nonspeech timing deficit. *Annals of the New York Academy of Sciences*, 1-14.
8) Falk, S., Müller, T., & Dalla Bella, S. (2015). Non-verbal sensorimotor timing deficits in children and adolescents who stutter. *Frontiers in Psychology*, 6.
9) (R version 3.6.0 (2019-04-26) -- "Planting of a Tree" Copyright (C) 2019 The R Foundation for Statistical Computing Platform: x86_64-apple-darwin15.6.0 (64-bit)).
10) Grahn, J.A. (2012). Neural mechanisms of rhythm perception: current findings and future perspectives. *Topics in Cognitive Science 4*, 585-606.