MULTIMODAL INTERACTIONS IN ORTHOGRAPHIC LEARNING

Project No.: K 119365
Project Period: 2016.11.01. – 2022.09.30.
PI: Prof. Dr. Valéria Csépe

OBJECTIVES

The project was aimed to investigate the fine-grained structure of reading acquisition and skilled reading and to decompose the fast and automatic visual word recognition beyond orthographic representations.

- The first major part of the project plan was based on previous results of the research team (see Tóth & Csépe, 2008, 2017; Tóth, Czikora & Csépe, 2015; Varga, Tóth & Csépe, 2015) with the main assumption that connecting the written form of a newly encountered word to its spoken counterpart contribute to building up word-specific orthographic representations. According to the results mentioned, automatic visual word recognition was not present in adult readers with dyslexia and the development of its subprocesses took several years in young readers. This raised the question addressed in the project, namely how and how well the orthographic representations were acquired.
- The second main part of the project focused on the relationship between orthography and phonology, specifically on the role of prosody in reading. The study plan was based on the implicit prosody hypothesis assuming readers to impose prosodic patterns during silent reading, even without prosodic information encoded explicitly in orthography (Fodor, 1998). Our preliminary data (results published by Kóbor et al. in 2018) from experiments in a cross-modal word fragment paradigm showed that Hungarian listeners reliably used word stress information for triggering lexical access and facilitating the processing of words matching the prosodic structure of primes. These data provided evidence that during lexical access the word's full phonological form, including its stress pattern, was available to readers. We assumed that prosodic representations were an inherent part of word representations, but this was not associated with the very nature of word representations, but the co-occurrence of phonological and prosodic representations with orthographic word forms in hearing readers.
- The third significant part of the project was based on a novel approach with the aim to shed light the orthographic development with limited or no access to phonology, namely in deaf or hard of hearing subjects. Our assumption was that recoding is not restricted to the visual-auditory modalities and reading in sign language users relies on visual-visual interaction with limited access to a rather abstract phonology due to a not completely understood phonologization.

Two complex hypotheses about the visual- auditory recoding assumed as requirement for orthographic learning as well as the within- and across- modality factors with an impact on orthographic learning were investigated by using a rich set of cognitive and neurobiological methods. We introduced several novel aspects to the investigation to answer four main questions.

- Q1: Is recoding in self-teaching restricted to the visual-auditory modalities?
- Q2: Is there orthographic learning without mapping to language?
- Q3: Does visual attention relate to orthographic learning above recoding?
- Q4: Does prosody/word stress relate to orthographic learning above phonological recoding?

The GANTT table below (Figure 1.) summarizes the most important parameters of the research planned from the period of 2016-2020.

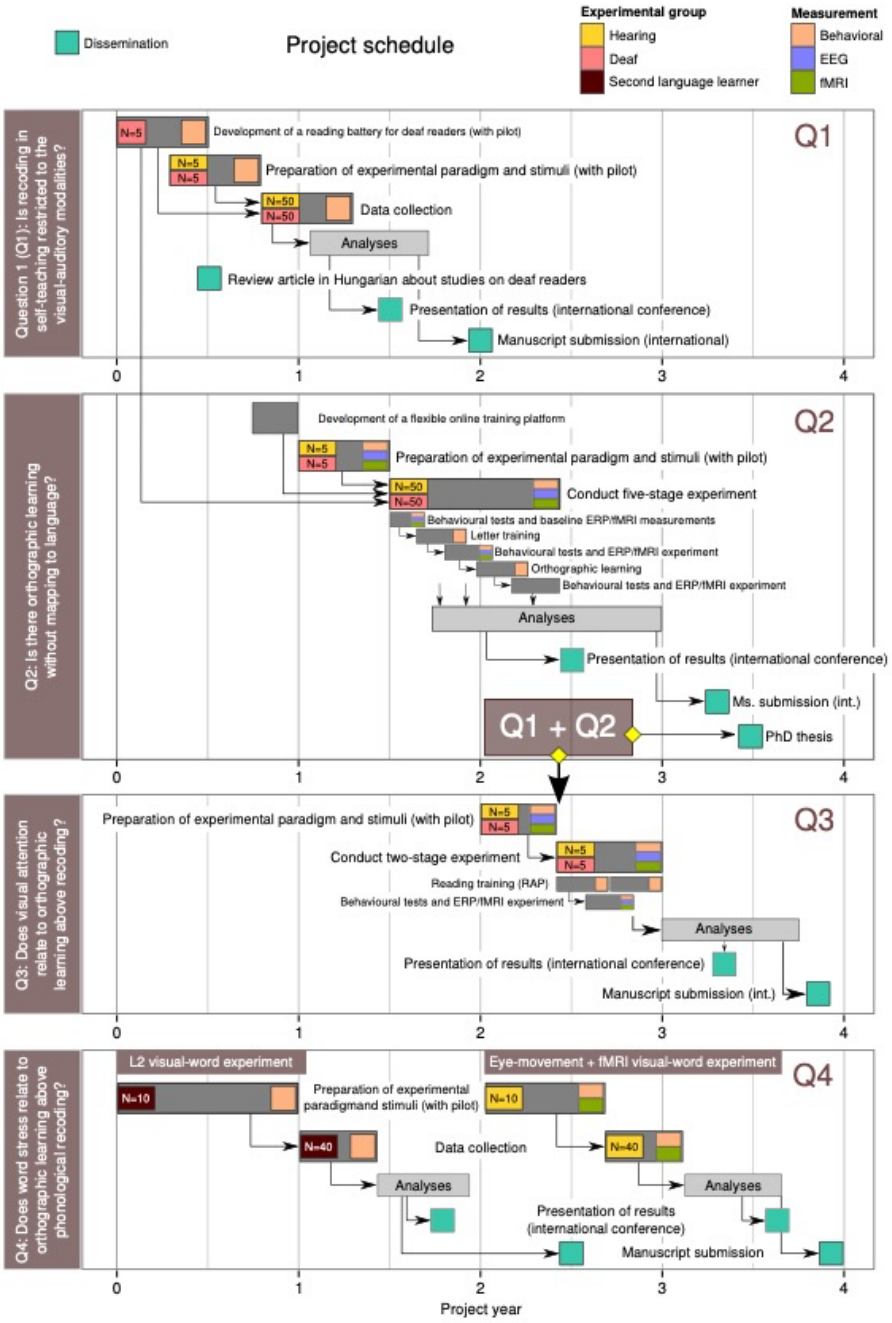

Figure 1. The Project' GANTT table provided in the year of application

PROJECT HISTORY

The first-year tasks of the project were performed according to the research plan. A delayed delivery of results as compared to the work plan occurred in second year and was related to different reasons. The original training planned in Q3 was cancelled because one of the main performing researchers switched to a different field, funded a startup and since then works further as data scientist though still in co-operation with the research group. Moreover, the pilots did not show a robust effect on orthographic development, so that the main target of Q3 has been changed to developing a spelling training with successful outcomes (see Results). The lack of human resources (participants retired, left for different job or abroad)) has influenced performing the Q2 tasks and Experiment 1 in Q4.
The 3rd year progress report of the project delivered in November 2019 reported delays in several tasks and gave information on the main circumstances (experiments with zero finding, further project participants leaving the institution, etc.) lead to problems to solve. Changes of the project's plan and extensions due to the COVID-19 pandemic were accepted by the Hungarian Research Fund in June 2020 then in 2022 (no access to schools for nearly two years), so that the project was finished 23 months after the planned end.
However, while the measurements were delayed due to the COVID-19 pandemic, the research team succeeded to submit and publish more publications than planned. Moreover, the pandemic-related fast switch to online conferences associated with no travel costs multiplied the number of conference presentations.

RESULTS

The project report follows the generally accepted rules of reporting published papers and submitted/in preparation manuscripts to provide an easy-to-read summary of the research team's performance and the results achieved. All experiments named in the original plan and performed accordingly or modified are reported and summarized for the original research papers. Reviews and theoretical papers are given in the publication list only.
While published papers are reported only in a few sentences followed by references of easy-to-access, somewhat more elaborated descriptions on the results available as manuscripts submitted or are in preparation (authors and titles) are given and illustrated with figures. The final project report does not refer to the background literature, as they were highlighted in the project proposal and are presented and discussed in detail in the papers published acknowledging the OTKA-NKFIH project No. K119365.

I. Beyond Orthography – Multimodal Interactions of Reading

The emergence of visual expertise for print with developing phonological recoding (novices)

In an event-related brain potential (ERP) study, a novel implicit same-different paradigm (ISDP) was applied to measure automatic orthographic coding. In this task, first (N = 32) and third-grade readers (N = 28) were presented with pairs of pseudowords and Armenian character strings. Children were required to indicate if a stimulus appeared in bold font. To test whether the emergence of visual expertise for print and its lateralization is driven by phonological recoding, stimuli were presented in visual-only and audiovisual conditions. The results demonstrated that tuning for print already emerges

in first grade. Moreover, the parallel presentation of auditory stimuli enhanced the N1 effect suggesting a pivotal role of orthographic-phonological mapping in the development of specialization for print. Results from were published in the journal of Child Development.

See Varga, Tóth & Csépe (2020) "Orthographic-Phonological Mapping and the Emergence of Visual Expertise for Print: A Developmental Event-Related Potential Study." Child Development 91 (1): e1–13. https://doi.org/10.1111/cdev.13159

Visual expertise for print with poor phonology (dyslexics)

As it was described in the project's plan, we aimed to investigate whether phonological deficits interfere with the emergence of visual expertise for print. To this end, we compared visual expertise for print in adult readers with and without dyslexia. The results indicated that pseudowords evoked larger N1 responses than Armenian symbol strings (see Figure 2). The interaction between Group and Stimulus class failed to reach significance which indicates that the N1 effect is similar for readers with and without dyslexia. Overall, readers without dyslexia showed more left-lateralized responses than readers with dyslexia. Thus, visual expertise for print might not relate to phonological processing per se but rather to the integration of orthographic and phonological information.

The manuscript Varga, Tóth & Csépe (in preparation) ERP correlates of orthographic processing in adult readers with developmental dyslexia will be submitted by the end of 2022.

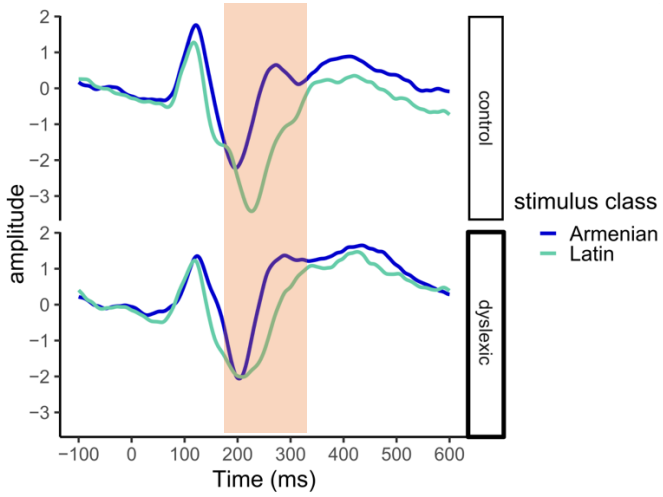

Figure 2. Grand averages to the reference stimuli for the Armenian (random string of Armenian characters) and Hungarian (legal string of Latin characters) pseudoword stimuli separately for the dyslexic and control group.

Visual expertise for print with poor orthographic-phonological mapping (dyslexic readers)

To examine whether automatic visual word recognition requires not only well-established phonological and orthographic representations but also efficient audio-visual integration of these representations, we used the implicit same-different paradigm (ISDP) for dyslexic readers. We assumed that the major deficits found in developmental dyslexia were characterized by inefficient orthographic processing and this might contribute to difficulties in poor to dysfunctional reading. Moreover, an alternative explanation might be in favor of inefficient phonological processing or inefficient integration of orthographic and phonological information. In the ERP study performed for

testing our hypotheses, participants with dyslexia ($N = 25$) and control readers ($N = 27$) were presented with pairs of words and pseudowords in an ISDP setup. The reference-target pairs could be identical, or different in the identity or the position of the letters. To test the orthographic-phonological processing, target stimuli were presented in visual-only and audiovisual conditions. Participants with and without dyslexia processed the reference stimuli similarly; however, group differences emerged in the processing of target stimuli, especially in the audiovisual condition where control readers showed greater N170 event-related potential (ERP) responses for words than for pseudowords, but readers with dyslexia did not show such difference. Moreover, the ERP changes around 300 ms after the stimulus onset, the expected lexicality effect, exhibited a more focused frontal topographic distribution in readers with dyslexia. Our results suggest that in developmental dyslexia, phonological processing and audiovisual integration deficits are more pronounced than the orthographic processing deficits. Results from the adult dyslexic sample was published in the open access Frontiers in Psychology.

See Varga, Tóth, Amora, Czikora & Csépe, (2021) ERP Correlates of altered orthographic-phonological processing in dyslexia. Frontiers in Psychology, 12, 723404 https://doi.org/10.3389/fpsyg.2021.723404

Visual expertise for print without phonology (deaf readers)

To further investigate the importance of phonology on the emergence visual expertise for print; we used the implicit same-different paradigm (ISDP) with deaf readers. According to our preliminary results, deaf readers, despite of limited access to phonology, showed an N170 effect (see Figure 3.) although, the topographic distribution of the effect is bilateral. This bilateral contribution to print recognition can be seen as a compensation. Further studies are needed to confirm our hypothesis based on our newest ERP data prepared for submission.

The manuscript Varga, Perlusz & Csépe (in preparation) Visual expertise without phonology: N170 effect in deaf and hearing readers will be submitted in 2023.

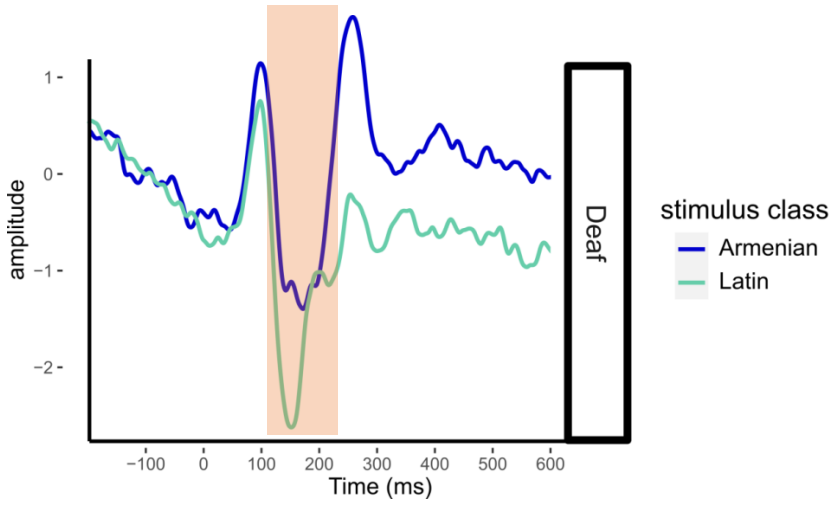

Figure 3. Grand averages for N170 to the reference stimuli for Armenian and Hungarian pseudowords in the deaf group

Orthographic representations without phonology (deaf readers)

Results of the masked lexical decision task investigating orthographic representation in the absence of phonology was published in the Journal of Deaf Studies and Deaf Education. In this study we investigated whether well-specified orthographic representations were available in the absence of well-specified phonological representations. We examined the prime lexicality effect (PLE), the index of lexical competition in deaf and hearing readers matched in age and education. Our results demonstrated that deaf readers with limited access to phonology showed no evidence for PLE. However, the hearing control participants did not show the expected effect. However, as our findings showed, the participants' reading skill differently modulated the effect for deaf and hearing readers. While better hearing readers showed PLE, better deaf readers did not.

See Varga, Tóth, & Csépe (2022, online 2021). Lexical competition without phonology: masked orthographic neighbor priming with deaf readers. Journal of Deaf Studies and Deaf Education https://doi.org/10.1093/deafed/enab040

To further explore whether well-specified orthographic representations in the absence of phonology might contribute to reading, we recorded the masked lexical decision task with EEG in a new sample of deaf and hearing participants (experiments performed in 2022 as included in the modified research plan). We used a more extended set of stimuli (216 items). Our preliminary results suggest that with this new stimulus list, deaf readers exhibit the PLE although to a lesser extent than the hearing control (see Figure 4.). The ERP data analysis confirmed that deaf readers showed lexical competition associated with greater N400 responses for words preceded by word primes as compared to words preceded by pseudoword primes (see Figure 5).

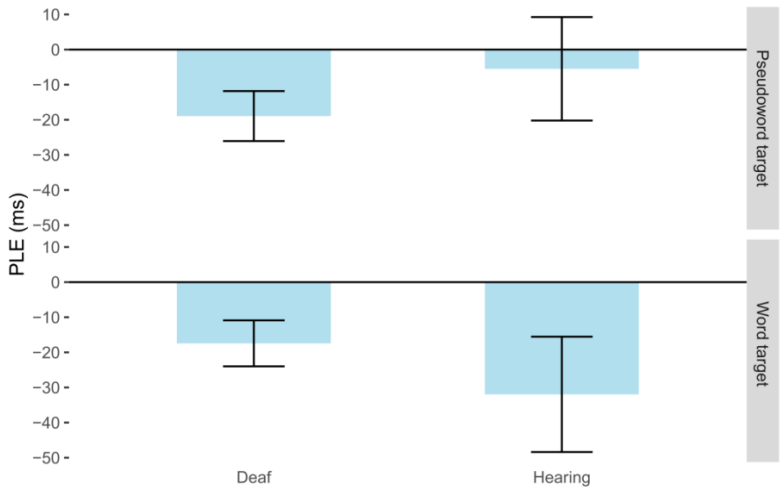

Figure 4. Prime lexicality effect (PLE) for the deaf and the hearing control group.
PLE was calculated as the difference of reaction times (RTs) for pseudoword (pw) and word (w) primes; thus, with negative values for word targets indicating lexical competition.
Error bars represent standard error.

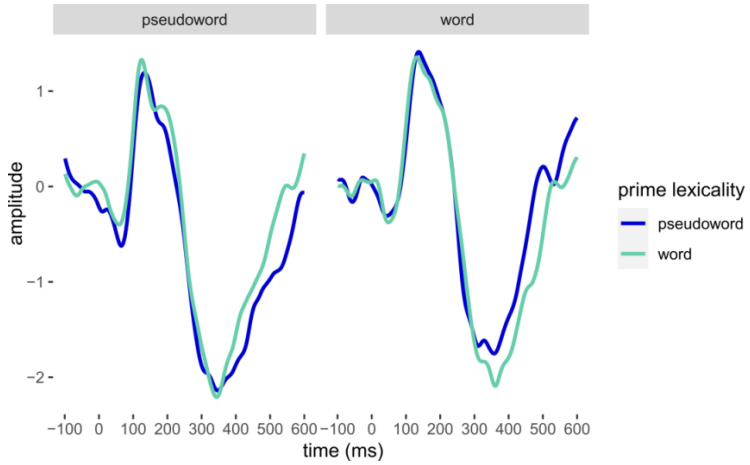

Figure 5. Grand average for the Prime lexicality effect (PLE) for deaf readers.

The results emerging from applying the newly developed paradigm are prepared for submission (Varga, Perlusz & Csépe /in preparation/ Lexical competition without phonology: An ERP study with deaf readers).

Novel word training to establish orthographic representations (deaf readers)

One of our original aims was to gain deeper understanding on how orthographic representations are established, the deaf and hearing participants were taught novel words in a picture-word matching task. These novel words served as pseudoword primes in the masked lexical decision task. A few days after the training, participants repeated the picture-word matching task and the masked lexical decision task. We expected that if these items become lexicalized, they would exhibit inhibition after the training. Although the results of online learning were rather similar for the deaf and hearing participants, deaf adults showed less retention after some days as measured in the picture-word matching task (see Figure 6).

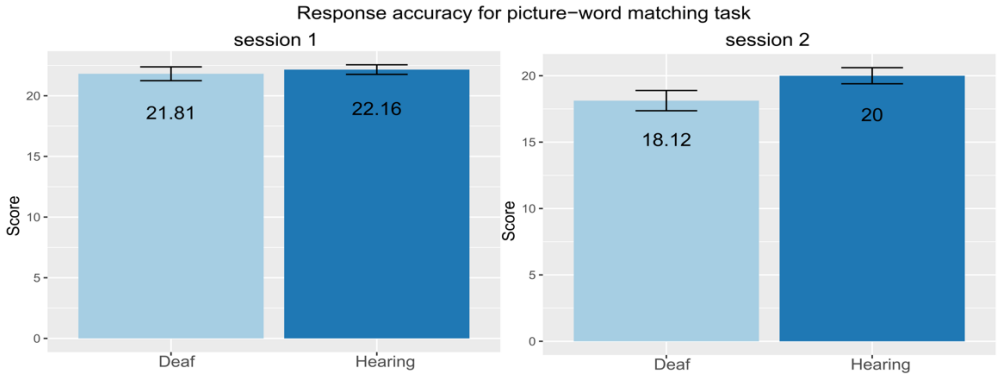

Figure 6. Response accuracy scores in the picture-word matching task during training (session 1) and after a few days during testing (session 2) separately for deaf and hearing participants. Error bars represent standard error.

In addition, while the deaf participants showed no training effect in the lexical decision task, in the hearing participants an expressed facilitation effect, instead of inhibition, was found (See Figure 4). This result suggested that while a single training session with 13 occurrences for deaf adults resulted

in less robust novel word learning, hearing adults showed a better storing of novel words in recognition memory but no lexicalization of the novel items.

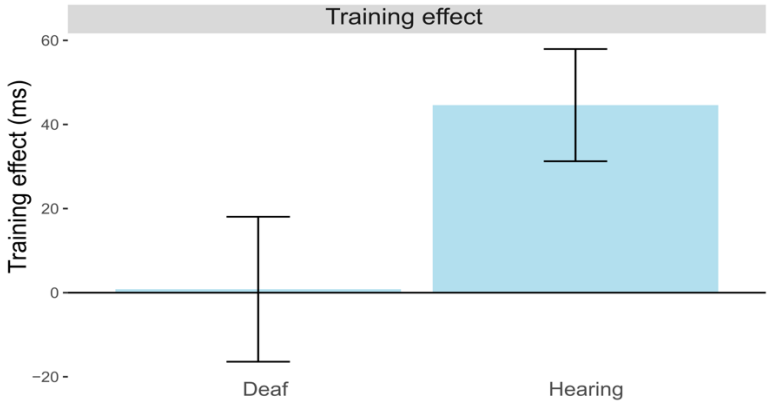

Figure 7. Training effect for word targets. Note that the training effect was calculated as the change in reaction time from session 1 to session 2 due to training (untrained – trained); thus, negative values indicate lexical competition for learned items in session 2, whereas positive values indicate facilitation for learned items in session 2. Error bars represent standard error.

The results will be submitted by the end of 2022 by Varga, Perlusz & Csépe (in preparation) as Orthographic learning and memory for novel words in deaf readers.

Orthographic representations with poor phonology (dyslexic readers)

To further explore the quality of orthographic representation and its relation to phonology, the prime lexicality effect was measured in the masked lexical decision task in children with dyslexia. In our study, we investigated whether well-specified orthographic representations are available despite severe phonological deficits. Thus, we examined the prime lexicality effect (PLE), the index of lexical competition in 3rd and 4th grade children with and without dyslexia. Our results demonstrated that children with dyslexia showed robust phonological deficits and no sign of PLE. Children without dyslexia showed a numerically larger PLE (see Figure 8); however, this difference was not statistically significant. Thus, neither children with nor without dyslexia showed evidence for lexical competition.

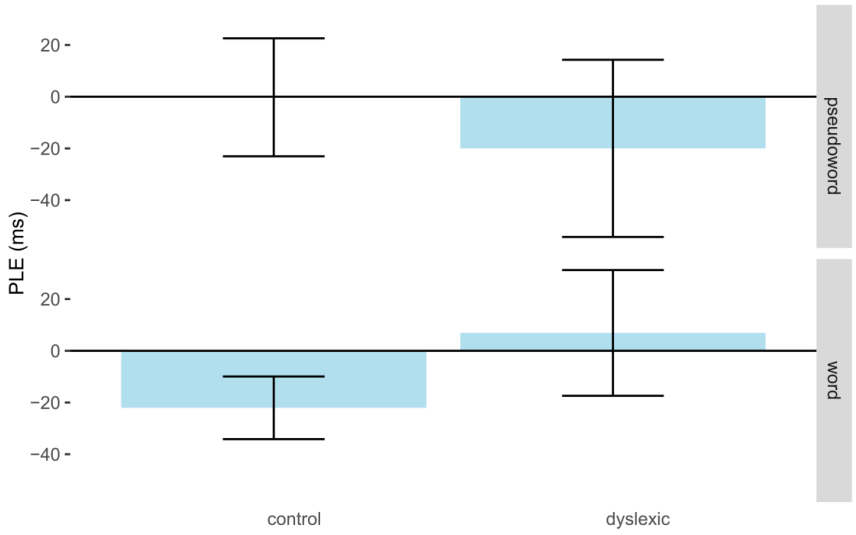

Figure 8. Prime lexicality effect (PLE) for the children with and without dyslexia. PLE was calculated as the difference of RTs for pseudoword (pw) and word (w) primes; thus, negative values for word targets indicate lexical competition. Error bars represent standard error.

See Varga, Nagy, Honbolygó & Csépe (2022, August 31). *Orthographic learning in children with dyslexia: Lexical competition effects after an online spelling intervention* [Poster presentation]. 22nd Conference of the European Society for Cognitive Psychology (ESCOP), Lille, France.)

Spelling training to establish orthographic representations (dyslexic readers)

A new training program (highlighted in the modified work plan) was developed to improve the spelling/orthographic skills of children with dyslexia. The training sessions were held online on the research group's website twice a week for 3 months.

A two-part training focusing on different aspects of spelling performance was developed.. The first gave emphasis to the role of short/long sounds, so that the participating children were presented with 60 words commonly misspelled and were required to either copy the word (copy condition) or spell the word from memory (visual dictation condition) in 10 sessions. Our results revealed that after training, children spelled the trained words significantly better. Nevertheless, there was no difference between the copy and the visual dictation conditions.

See Nagy, Varga, Honbolygó & Csépe V. (2022, August 31). Learning trajectory of spelling in children with dyslexia: Insights from an online training test [Poster presentation]. 22nd Conference of the European Society for Cognitive Psychology (ESCOP, Lille, France.)

The second part of the training focused on the spelling of high frequency words used previously as primes in the masked lexical decision task. Children were required to either copy the word (copy condition) or spell the word from memory (visual dictation condition) in 10 sessions. In addition to the spelling training group, a group of children participated in music training sessions to serve as a control group. Results revealed that children spelled the words used significantly better after training; however, there was no difference between the copy and the visual dictation conditions. In addition, PLE emerged after spelling training but not after the music training used as control training task. However, reaction times became faster for word targets preceded by word primes (see Figure 6) signifying facilitation instead of inhibition. This effect therefore does not reflect lexicalization. Thus, 10 spelling training sessions are not enough for establishing high-quality lexical representations in children with dyslexia. These results were presented on the 22nd ESCOP conference.

See Varga, Nagy, Honbolygó & Csépe (2022, August 31). *Orthographic learning in children with dyslexia: Lexical competition effects after an online spelling intervention* [Poster presentation]. 22nd Conference of the European Society for Cognitive Psychology (ESCOP), Lille, France.)

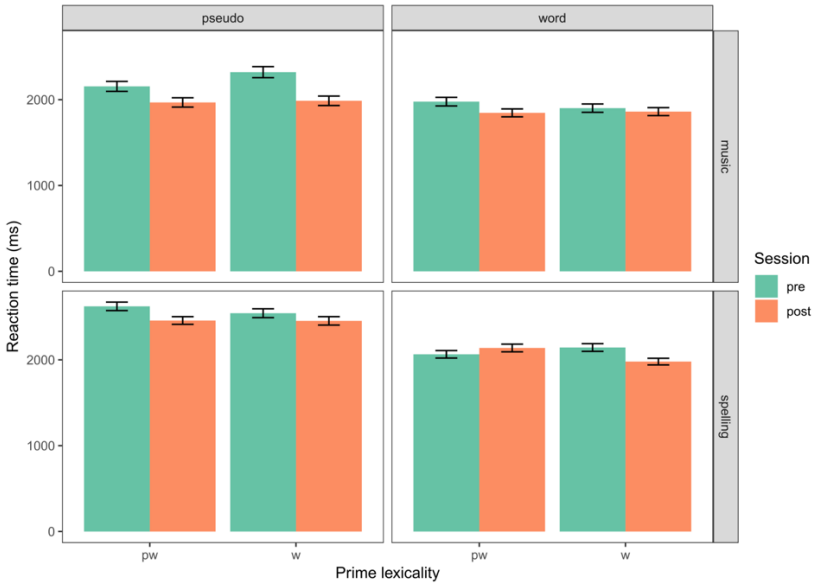

Figure 9. Prime lexicality effect (PLE) for the children with dyslexia before and after a spelling training or music training. Error bars represent standard error.

Publications statistics of the Q1-Q3 studies:
2 review papers in Hungarian, 1 comprehensive review paper in English, 5 original research papers in English (see publication list)
4 manuscripts in preparation
Presentations: 8 poster presentations, 10 oral presentations, 2 plenaries
PhD Theses: Results published first authored by Vera Varga are included in her PhD theses. She have submitted her thesis and successfully passed her in-house defense in August. The official defense is foreseen for January 2023 as Varga, V. *The Role of Phonology in the Tuning of Orthographic Representations in Typical and Atypical Readers* [PhD Thesis]. Budapest University of Technology and Economics.

II. Beyond Phonological Recoding - word level prosody and its impact on orthographic learning (Q4)

The effect of stress status on second language (German) processing (reading)
The pilot results of the first year of the project were analyzed in a short time and led to finalizing the prosodic visual-word paradigm in collaboration (University of Tübingen, Germany). Event-related brain potentials (ERPs) were used to investigate Hungarian listeners' implicit L2 processing. In a cross-modal word fragment priming experiment, spoken stressed and unstressed German word onsets (primes) were presented and followed by printed versions of initially stressed and initially unstressed German words (targets). ERPs reflected stress priming exerted by both prime types. This indicates that Hungarian listeners implicitly linked German words with the stress status of the primes. Thus, the formerly described explicit stress discrimination difficulty associated with a fixed-stress native language does not generalize to implicit aspects of L2 word stress processing.

See Kóbor, Honbolygó, Becker, Schild, Csépe, Friedrich (2018) ERP evidence for implicit L2 word stress knowledge in listeners of a fixed-stress language. International Journal of Psychophysiology, 128:100-110 https://doi.org/10.1016/j.ijpsycho.2018.04.006

The effect of word stress on second language (L2) processing (behavioral correlates)
A further study focused on the possible cognitive components of foreign word stress processing. The influence of cognitive factors and L2 proficiency on the processing of L2 stress was investigated and our study was the the first one to provide evidence about the cognitive background of the stress "deafness" effect, and to suggest the differential role of inhibitory control in phoneme and stress processing. Results showed that the stress task led to lower performance than the phoneme task, irrespective of L2 proficiency. Furthermore, the analysis showed different cognitive factors contributing to the performance in the tasks: in the phoneme task, it was working memory, phonological awareness, and inhibitory control, while in the stress task, it was only working memory and phonological awareness but not the inhibitory control.

See Honbolygó, Kóbor, & Csépe (2019) Cognitive components of foreign word stress processing difficulty in speakers of a native language with non-contrastive stress. International Journal of Bilingualism, 23(2), 366-380. https://doi.org/10.1177/1367006917728393

The effect of stress on second language (L2) processing (brain response correlates)
The behavioral data of the 2019 publication shed light on different factors including specific prosodic features of a given language. In this study, using the method of event-related brain potentials (ERPs) employing a cross-linguistic approach, Hungarian participants heard disyllabic pseudowords stressed either on the first (legal stress) or on the second (illegal stress) syllable, pronounced either by a Hungarian or a German speaker. Results obtained using a data-driven ERP analysis methodology showed that all pseudowords in the deviant position elicited an Early Differentiating Negativity and a Mismatch Negativity component, except for the Hungarian pseudowords stressed on the first syllable. This suggests that Hungarian listeners did not process the native legal stress pattern as deviant, but the same stress pattern with a nonnative accent was processed as deviant. This implies that the processing of word stress was based on language-specific long-term memory traces.

See Honbolygó, Kóbor,German & Csépe (2020) Word stress representations are language-specific: Evidence from event-related brain potentials Psychophysiology. 2020;57:e13541. https://doi.org/10.1111/psyp.13541

The contribution of working memory to word stress processing (Hungarian)
As it was shown by our 2019 study working memory (WM) might have a significant role in word stress processing. Although the role of working memory (WM) has been evidenced in language processing its contribution to the detection of significant linguistic deviances such as those prosodic ones, has remained unclear. In our study the Mismatch Negativity (MMN) event-related potentials (ERPs) were recorded during a passive oddball paradigm containing pseudowords with two different stress patterns, legal and illegal. Besides, complex WM tasks (Counting span task, Verbal fluency tasks) were administered. Results revealed that greater WM performance measured by the Counting span task was associated with smaller MMN response for the legally stressed stimuli but with larger MMN response for the illegally stressed ones.Our novel ERP results suggested a general role played by WM in processing the fixed word stress in Hungarian with sensitivity to unusual deviations.

See German, Honbolygó, Csépe & Kóbor (2021) Working memory contributes to word stress processing in a fixed-stress language. Journal of Cognitive Psychology, 33:4 https://doi.org/10.1080/20445911.2021.1898411

The impact of expected word stress on the speech-sensitive cortical networks (fMRI study)
The dual-stream models of language processing propose that the postero-dorsal stream performs predictive sequential processing of linguistic information via hierarchically organized internal models. However, it remains unexplored whether the prosodic segmentation of linguistic information involves predictive processes. Therefore, we addressed this question by investigating the processing of word

stress, a major component of speech segmentation, using probabilistic repetition suppression (RS) modulation as a marker of predictive processing. In an event-related acoustic fMRI RS paradigm, we presented pairs of pseudowords having the same (Rep) or different (Alt) stress patterns, in blocks with varying Rep and Alt trial probabilities. We found that the BOLD signal was significantly lower for Rep than for Alt trials, indicating RS in the posterior and middle superior temporal gyrus (STG) bilaterally, and in the anterior STG in the left hemisphere. Importantly, the magnitude of RS was modulated by repetition probability in the posterior and middle STG. These results reveal the predictive processing of word stress in the STG areas and raise the possibility that words stress processing is related to the dorsal "where" auditory stream. Furthermore, this result is one of the novelties of our study showing that word stress is processed predictively in the speech sensitive brain areas. The predictability of word stress assignments used by a given language explains the results of our studies performed by using different methods such as behavioral paradigms, ERP measures and eye-tracking.

The eye-tracking fMRI paradigm planned for investigating the role of stress in lexical access was cancelled due to the lack of human resources and to the COVID-19 pandemic (modification of the work plan was accepted by NKFIH) and resources were directed towards two studies (WM and time frequency correlates

See Honbolygó, Kóbor, Hermann, Kettinger, Vidnyánszky, Kovács & Csépe (2020) Expectations about word stress modulate neural activity in speech-sensitive cortical areas, Neuropsychologia 143, 107467, https://doi.org/10.1016/j.neuropsychologia.2020.107467

Prosodic competition (visual-word paradigm)

The experiments using the method of eye-tracking were designed to investigate the prosodic visual-word processing in mono- and bilingual Hungarian participants who were either L2 speakers of German, or native Hungarian speakers with no knowledge of German. In the paradigm, participants were presented with German words presented acoustically, and in written form on a screen. The words differed in their phonemic and stress structure. Each display showed four printed words, and the task of the participants was to press a button on a keyboard if they detected the word corresponding to the heard one. According to the results, German participants looked more to the prosodic competitor (relative to the control) than L2-Hungarians for both initially stressed and unstressed targets. However, native Hungarians seemed to differ in prosodic processing from the L2 speakers of German in a sense that they looked less to the prosodic competitor in the initially unstressed Go-trials and showed a different pattern in the stressed Go-trials (see Figure 10.).

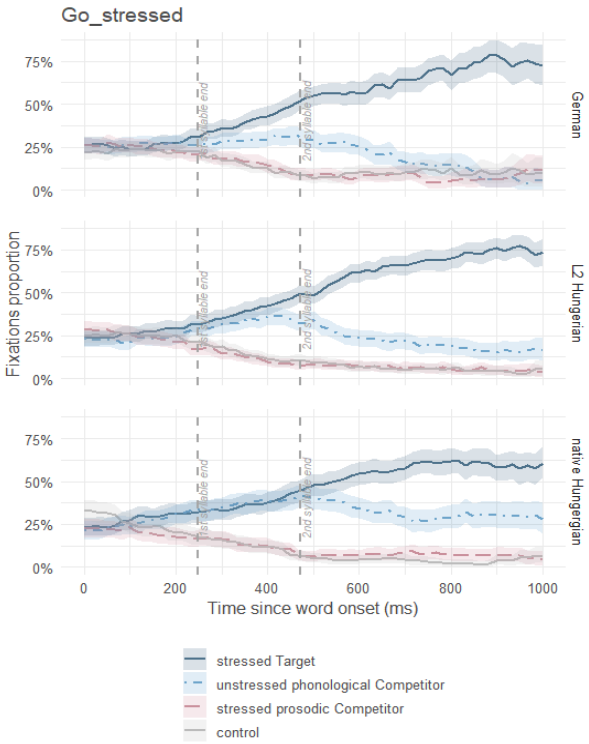

Figure 10. Eye movements produced by native Germans and mono- and bilingual Hungarians in the stressed Go-trials

The manuscript summarizing the results of the eye-tracking experiment conducted with Hungarian participants investigating the prosodic visual-world paradigm is in progress by the time of the final report.

Time frequency correlates of word stress processing

The last study aiming to shed light on the complex nature of word stress processing introduced an additional method not included in the original work plan. This study aimed at investigating the time-frequency aspects of word stress processing were investigated. The findings, novel in the literature, showed the processing of trochaic and iambic word stress being significantly different in the theta and alpha range, indicating the presence of entrainment processes in the lower frequency range, and stimulus expectancy and memory related processes in the higher frequency range. These effects found are of particular interest as the impact of music based on entrainment might have a a pivotal role in auditory processing probably present a concerted action with predictability mechanisms contributing to word stress processing, both musical and linguistic in nature.

See Noboa, & Honbolygó (2022) Alpha and theta band oscillatory activity in word stress processing. Under review in Psychophysiology.

The music-like nature of word stress

The investigations and the first results on time frequency correlates of word stress processing described above gave a particular impetus to further studies investigating the similarities and differences between the entrainment processes of music and word stress processing (Kertész & Honbolygó).

New studies not included in the original work has already started before aiming at investigating the effect of music on literacy skills and developing new musical training methods for intervention purposes. Participation in the Horizon 2020 Marie Curie ITN program (Csépe & Honbolygó) allowed to strengthen collaborations between different laboratories in the international research community,

and to find partners for national collaboration in a new project granted to Ferenc Honbolygó by the Hungarian Academy of Sciences' Research Programme for Public Education Development 2021.

See *Kertész & Honbolygó, (2021). Tapping to Music Predicts Literacy Skills of First-Grade Children. Frontiers in Psychology, 4412.*

Publications statistics of the Q1 studies

3 review papers in Hungarian, 5 original research papers in English (see publication list)

1 manuscript under review, 1 in press

Presentations: 7 poster presentations, 8 oral presentations, 2 plenaries

Other: Several MA dissertations on word stress processing were finished during the project period.

SUMMARY OF THE EXPERIMENTAL RESULTS

Our behavioral studies (newly developed paradigms, intervention trainings) and neurocognitive experiments (EEG, ERP, fMRI, eye-tracking) performed in the project period have focused on the multimodal interactions in orthographic learning.

Our results on the orthographic aspects and beyond demonstrated, that

(1) tuning for print already emerges in first grade (ERP, N170),

(2) parallel presentation of visual and auditory stimuli contributes to enhanced brain responses to print, so that orthographic-phonological mapping may have a pivotal role in the speech-write-read bonding mechanisms (ERP, N170),

(3) inefficient orthographic processing does not necessarily lead to major difficulties in reading (ERP, N170),

(4) deficient audio-visual integration contributes more to developmental dyslexia than known before (ERP, N170),

(5) different developmental trajectories of print expertise exist (behavioral),

(6) print expertise emerges in deaf readers, despite difficulties in access to phonology,

(7) deaf readers show limited prime lexicality effect (PLE) with no reading-skill-dependent modulation (behavioral), and

(8) deaf readers show expressed lexical competition (ERP, N400).

Our experiments on word level prosody and its impact on orthography revealed, that

(9) discrimination difficulties suggested for fixed native stress do not generalize to the implicit aspects of second language (L2) (ERP, MMN),

(10) impact of native word stress on L2 depends on cognitive factors such as working memory (WM) and phonological awareness (behavioral),

(11) legal stress patterns with native accent, in contrast to nonnative, are processed as deviant, and this suggests language-specific long-term memory traces in action (ERP, MMN).

The novel results of our studies getting increasing attention reveal, that

(12) WM plays a general role in processing the fixed word stress in Hungarian (ERP, MMN),

(13) word stress undergoes predictive coding in the speech sensitive brain areas (event-related fMRI),

(14) expressed prosodic competition is present in bilinguals (eye-tracking), and

(15) word stress processing undergoes different ways associated with entrainment-, expectancy-, and memory-related processes (EEG, frequency analysis).

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