Prosodic Writing shows L2 learners intonation by 3D letter shapes: state, results, and attempts to increase 3D perception

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Abstract

The IPA (International Phonetic Alphabet) has been widely used in dictionaries. However, IPA failed to replace standard writing systems in foreign language education, one of the goals of some of its founders. IPA didn't work out on sentence level. Yet, many language students struggle with the pronunciation of target languages, both, segmentally and suprasegmentally, since there are not sufficient pronunciation cues in standard texts. Thus the question for the optimal writing system for language learners still lacks an answer. It is the main thesis of this research that this optimum is NOT the standard writing system of any language of study. The main argument is that this standard has been optimized over many years by native speakers for native speakers, who share a huge mental storehouse of suprasegmentals – speech melodies – that do not need to be encoded. A second thesis is that this optimum system encodes also the prosody of a given language for beginners – rhythmical and intonational patterns invisible in standard written language. The paper will introduce a special writing system that encodes prosody (thus called: Prosodic Writing) and can be imagined as a text warping in a 3D space. It further summarizes some recent results, e. g. showing that an experimental group had a higher speaking speed compared to a control group given symbolically encoded prosodic cues. The paper finally suggests ways to improve generation and appearance of Prosodic Writing by computer, also by stereograms, and poses as future research question whether such stereograms could even be produced manually. All attempts – by computer or by hand – aim at a stronger 3D-impression of letters, words and text. Hopefully, students using Prosodic Writing – in conjunction with the indispensable audio sources of target language utterances – will acquire good pronunciation of foreign languages more efficiently.

1. Introduction:

Reading and writing have become such natural human activities that we seldom reflect on the complex mechanisms involved; e.g. for writing: spoken language – uttered or imagined – is mentally transformed into a set of symbols that are stored on some medium – a computer or a piece of paper. Or reading: The symbolic code is sequentially decoded and re–assembled to complete words and texts, and again either uttered or – more likely – just imagined and understood as a whole. This simplistic description takes into account that even silent reading evidentially involves prosody, this inherent component of any spoken language, its intonation and rhythm. For too long, western phonology concentrated mainly on the sound systems of languages, then understood as the basic set of phonemes, of spoken vowels and consonants; and graphemics concentrated on the sets of graphemes that code these audible units into visual entities, into the written consonants and vowels of alphabetic writing systems. Prosody has not been treated as systematically as segments – the individual sounds – which might be one reason why IPA failed to replace standard orthography at sentence level for language learners.

It is the basic assumption of this research that standard writing systems are suitable only for native speakers – or advanced learners – of a given language. Moreover, it is the main hypothesis that writing systems are not optimum for language learners at an early stage because of the absence of sufficient prosodic cues.

Prosody consists basically of temporal patterns of pitch, intensity and duration events, and these could be additionally encoded into the linear strings of graphemes. It is the second hypothesis that such a prosody-enriched writing style suits non-native language learners better than standard writing systems short of prosodic cues.

Several types of prosodic codes exist or can be imagined; they can roughly be divided into two groups: symbolic and iconic systems. It is the third hypothesis that iconic systems are better suited for language learners since they make use of idle mental faculties, whereas cognitive symbol processing is already tied up with decoding the ordinary graphemes of the language of study. The proposed writing system – Prosodic Writing – is a style in which the graphemes by themselves, through their 3D-position and distortion, visualize prosody, similar to a language teacher showing intonation or rhythm to language students by moving her hands through 3D space in distinct patterns.

The paper is organized as follows:

In the following section, the concept of Prosodic Writing is summarized (see also Rude 2013) and some results from the last two years are reported.

The third section reports the results from an experiment carried out in summer 2015, which compared two groups of language learners that differed only in the writing system used for visual materials – one receiving Prosodic Writing (PW) written by hand, the other group receiving identical text in which prosody was coded through symbols.

The fourth section describes several ways PW could also be generated by computers, e.g. by simple line drawings in “Excel”, or by a tool using the computer language “Processing”. The overall goal is to simplify the generation of PW and to make its 3D appearance more convincing, also through stereographic imaging.

The final section outlines a further research question, whether writing in 3D through stereographic writing could be possible without a computer, but with both hands simultaneously, and links this topic with the conclusion.

I would like to express my thanks to Katsufumi Narita for his support with the experiments performed in the last two years, to Nakane Takakazu, who developed the prototype tool by Processing and to his supervisor Motoyama Kiyofumi.[1]

2. Concept and former results of Prosodic Writing (PW)

In Prosodic Writing (PW), graphemes (e.g. those representing vowels) are not arranged in straight lines but positioned in a 3D space, giving them a distorted outlook; their spatial coordinates (x1-, x2-, x3-values) encode time, pitch and loudness of realized speech sounds in perceptual space. This section mainly explains the concept of PW in more detail and mentions some former results of using PW in university language classes.

2.1 The concept of Prosodic Writing (PW)

Prosody comprises many phenomena. One definition of prosody is the following:

> Prosody: A term used in SUPRASEGMENTAL PHONETICS and PHONOLOGY to refer collectively to variations in PITCH, LOUDNESS, TEMPO and RHYTHM. Sometimes it is used loosely as a synonym for ‘suprasegmental’, but in a narrower sense it refers only to the above variables, the remaining suprasegmental features being labeled PARALINGUISTIC. ...” (Crystal 2008, 393f)

Prosody in this research is understood as in the narrow sense of the quote, as the time-varying elements of pitch, loudness, tempo and rhythm. Western writing systems – e.g. English or German – use punctuation, which gives some indication of

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prosody: commas or full stops often – but not always – coincide with pausing, when the text is spoken out. Question marks can indicate rising intonation, but usually not for W-questions. This shows that punctuation is a defunct system of prosody representation; prosody includes accentuation, speech rhythm and lenghening of syllables, and these are seldom perceivable from a standard text and its graphical elements.

Interestingly, prosody in a narrow sense depends only on three variables: the perceptual height of the voice (pitch), the strength of the sounds (loudness) and the time when these two elements occur, or more concisely: prosody is given by pitch and loudness, both functions of time. All pitch values over time constitute the pitch contur or speech melody. Loudness patterns in time constitute stress patterns of words, and the rhythm in utterances. Actually, also pitch peaks and syllable lengthening can mark stress, even if loudness is held constant, but still the number of variables that contribute to stress is just three: *pitch*, *loudness* and *(perceptual) time*. The relationship of these three perceptual variables to their physical correlates fundamental frequency (F0, the basic frequency of the human voice resulting from the vibrating vocal chords), intensity (measurable in dB, in Dezibel) and (physical) time is not one-to-one, but rather complex, e.g. non-linear and interwoven. For the scope of this paper, however, it is enough to state that the number of variables on the physical side that match the prosody percept is also exactly three: *F0*, *intensity* and *(absolute) time*.

Prosody can be made visible by using a special writing system, a positional writing system: The graphemes are not ordered in a straight linear way as usual, but they are mapped into a 3D space with the coordinates x1, x2, x3 encoding the three prosodic variables time, pitch and loudness, respectively. The horizontal is x1, the vertical is x2 and the depth is x3 (see Fig. 1). The concept, developed by the author some years ago, is called Prosodic Writing (PW) (see for example Rude 2013).

2.2 Applying the theoretical concept in practice

Applying this basic concept needs some words of clarification:

- Depth can be shown through perspective – through augmented graphemes – even without a real 3rd dimension (comparable to depth illusions on photos or in movies).
- Pitch exists only for voiced sounds (vowels and voiced consonants). The x2-values for unvoiced sounds follow from interpolation.

Fig. 1: Prosodic Writing (PW): Graphs (the realization of graphemes) are not ordered on a straight line but according to the corresponding phonemes' appearance in time (x1), pitch (x2) and loudness (x3). ("Was möchtest du heute essen?", literally: What would-like you today eat? English: "What would you like to eat today?")

- Distortions should be large enough to indicate prosody clearly, but small enough to preserve the usual word forms.[2]

Keeping this in mind, Fig. 1 can be interpreted as showing

1) three stresses on "möchtest", "heute" and "essen", through a combination of grapheme augmentation and vertical peaks, which also render the rhythm of 3 beats in 8 syllabes visible,
2) among these three, the sentence stress on "essen", through the highest peak after a step in pitch and through maximum augmentation,
3) a fall to the bottom of the speaking range immediately after the sentence stress, and
4) syllabic reductions on "möchtest", "heute" and "essen", visible mainly through condensed "e"-graphs.

2.3 PW is a positional writing system

PW is similar to the decimal Hindu-Arabic numeral system, which is a positional writing system (Günther 1996, p. 1575). In that system, the ordinal position of the numbers in horizontal direction specifies their ordinal value: 1, 10, 100, 1000, etc. In

[2] It goes unspoken that each language learner likes to read standard texts at one point, and the more similar it is to the "learner writing system", the easier is the transition.

PW, in contrast, the position and extension of a given graph (e.g. “ö” in “möchtest”) in horizontal direction (x1) specify the placement of the corresponding sound ([œ]) in continuous time: the time of its appearance and its duration; additionally, the position of this graph in vertical and depth direction (x2, x3) specifies its pitch and loudness.

2.4 Section summary

Prosodic Writing is a mapping of 3D prosodic space into 3D geometrical space: down-up movements of graphs represent low-high pitch movements, back-front movements show increasing loudness, and wide or narrow vowel characters mean long or short vowel duration. The purpose is to make prosody transparent through the shapes of the graphs (materialized characters) without changing orthography. Students’ reactions to such “distorted” writing has been largely positive. In one class that had directly compared PW and a symbolic code in 2014, the students’ quantitative evaluations were in favor of PW (Rude 2015, p. 118, Tab. 3); this preference was also reflected in students’ comments (see App. 1 for some examples). Many experiments have shown trends in favor of PW, e.g. better reproduction rate of nuclear contours, or a higher rate of correct word stress on the false friend “zentral” vs. “central”, when using PW compared to other materials; but more experiments are needed.

3. New experimental results

An experiment was carried out in summer 2015; it was originally designed to show that PW can also help Japanese students with syllable reductions in the German language, a phenomenon the Japanese language does not possess. However, due to measurement problems (noisy environment in class), syllable duration could not be extracted; only the overall duration of target utterances was measurable and therefore analyzed. First, the experimental design will be described in detail. Then, the results from duration analysis and students’ feedback will be reported.

3.1 Design of the experiment

The primary hypothesis of the experiment had been:
“PW helps students to produce syllable reductions better than a symbolic writing style”. The experiment consisted of the following steps, all conducted in one 90-minute lesson in a beginner class for non-majors after 14 weeks of German lessons (after 2 x 14 x 90 minutes or 56 hours lesson time):

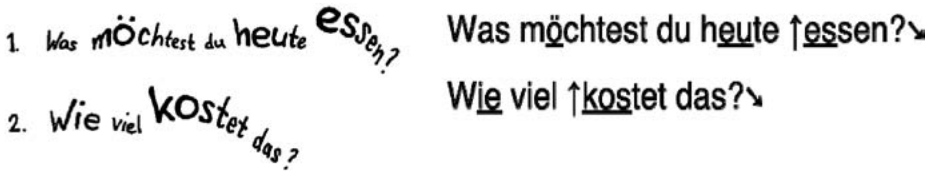

Fig. 2: Experiment with 2 questions, each in two forms: left in PW (prosody visible through curvature and size variations), right in a symbolic code (prosody visible through arrows and underlines) ("Wie viel kostet das?", literally: How much costs that? English: "How much does it cost?"). The left half of the class received PW, the right half of the class the symbolic code.

1) Prosody introduction: Short introduction to the writing system – PW or symbolic code of prosody – and practice to speak out some phrases in one breath.
2) Preparation: Group preparation of a mini dialog (1 minute). Two questions ought to be learned by heart (Fig. 2, also praticed to speak out fluently, in one breath).
3) Practice tests: Three practice tests with different partners, within groups of four students (1 minute each).
4) Experiment: Mini dialogs of every student with a random partner in front of the class (pairing of "PW students" with "symbol students"). All dialogs were recorded.
5) Questionnaire: After the experiment, all students filled out a short questionnaire about their attitude towards experiment and writing system used, PW or symbolic.

3.2 Observations during the experiment (held on 2015 July 29)

Most students successfully completed the dialog and thus produced question 1 and 2 (Q1 & Q2), both either learned from PW or from the symbolic code. Some students had to use the cunning paper placed on a chair behind them in order to produce one or even both questions. These utterances were excluded from the analysis (14 from 64 in total). In the following, one transcribed mini dialog is shown, including overall duration and durations of Q1 and Q2.

Original dialog: [1 min 11 s]	[my English translation]
(A: Symbolic code. B: PW)	
A: Was möchtet du heut' essen? [3.0 s]	A: What would you like to eat today?
B: Ich möchte einen Pudding essen – heut essen.	B: Ich want to eat a pudding – today.
A: Wie viel kostest das? [3.5 s]	A: How much does it cost?
B: Das – das kos – kostet 500 Yen. Was möchtest du heut' essen? [3.8 s]	B: That – that cos – costs 500 Yen. What would you like to eat today?
A: Ich möchte ein Brot essen.	A: I want to eat bread.
B: Wie viel kostet das? [2.2 s]	B: How much does it cost?
A: Das kostet 150 – hm – 150 Yen.	A: It costs 150 – hm – 150 Yen.
...	...

If time was sufficient, a third question could be asked (here not transcribed).

3.3 Analysis of the experiment

Altogether, 32 students participated in the experiment and had produced 64 questions. Half of them had material in PW, half in symbolic code. A small sample of recordings were checked by ear and did not show a notable difference between both groups with respect to syllabic reductions. More decisively, the recordings were too noisy for extracting syllabic duration reliably. However, the overall duration of the uttered questions could be measured. The complete duration of each uttered question was therefore determined.

3.4 Results of the experiment

These can be seen in Table 1. For uttering Q1, the native speaker (NS) took 1.4 s, the PW group on average 2.2 s, the symbol group 2.8 s, double the NS's duration. The effect size of the difference between the groups is middle to strong; however, the ranges of duration values for both groups reach 5.1 s (slow speakers or many repetitions) resulting in rather high standard deviations and worse, in skewed distributions. The T-test for significance of difference between groups – requiring symmetric distributions – could therefore not be done.

Therefore, speaking speed was calculated (inverse of duration) and normalized by the speaking speed of the NS (see lower half of Table 1); this procedure solved the skewness problem. For the speed values, the effect size of the group difference is even bigger than 1 (strong effect), and there is statistical significance in favor of

Table 1: Duration measurements of all questions (upper half) in seconds, and the same values transformed into speed of speaking (lower half). Relative speed of speaking was calculated by dividing the duration of the native speaker's utterance (e.g. 1.4 s for Q1) through the duration of the utterance by each student (e.g. 1.8 s for the PW median of Q1), yielding the speed of each student relative to the native speaker (e.g. 77.6%; all values are rounded.).

Duration	Native Speaker NS [s]	PW students avg. [s]	Symbol students avg. [s]	PW students stdv. [s]	Symbol students stdv. [s]	PW students median [range]	Symbol students median [range]	Effect size	Effect is
Question 1 (Q1)	1.4 s	2.2 s (13 students)	2.8 s (11 students)	1.1 s	0.9 s	1.8 s [1.5 – 5.1]s	2.6 s [1.8 – 5.1]s	-0.64	middle to strong
Question 2 (Q2)	1.2 s	2.1 s (14 students)	2.4 s (12 students)	1.0 s	1.1 s	1.7 s [1.1 – 4.6]s	2.0 s [1.1 – 4.7]s	-0.27	small to middle
		27 questions	23 questions						
Relative speed	Native Speaker NS	PW students avg.	Symbol students avg.	PW students stdv.	Symbol students stdv.	PW students median [range]	Symbol students median [range]	Effect size	Effect is
Question 1 (Q1)	100%	71%	52%	20%	14%	77.6% [27 – 91]%	52.4% [27 – 75]%	1.06	strong
Question 2 (Q2)	100%	71%	64%	26,5%	28,2%	72.9% [27– 117]%	61.3% [26 – 115]%	0.25	small to middle

the PW group: it reached 71% of the speaking speed of the native speaker for Q1, compared to just 52 % for the symbol group.

The difference for Q2 shows the same trend (71% vs. 64%); however, it is not significant and the effect size is rather small.

3.5 Discussion of the results

The speaking speed calculated here should not be confused with speech rate (syllables per minute), since here the overall duration including repetitions was measured. Still, this measure is important since it reflects the speed of a speaker to complete a question and thus how easily he can engage in a conversation. It is remarkable that the median of the duration for Q1 in the PW group (1.8 s) coincides with the lower range limit of the symbol group (1.8 s). In other words, 50% of the students of the PW group spoke quicker than, or at least as quickly as the fastest symbol student.

3.6 Section summary

In the reported experiment, a test group (PW) was compared with a control group (standard text with symbolic coding of prosody) after two target questions had been learned by heart and used in a 1-minute conversation. Measuring the complete duration for each uttered question (2 target questions Q1 & Q2, each for 32 students) revealed for the longer question Q1 that relative speaking speed – the normalized inverse of the durations – was significantly higher in the PW group than in the symbol group. The shorter question Q2 showed the same trend; however, the difference was not significant. In the questionnaire, the PW group evaluated PW slightly higher than the symbol group did the symbolic code, which is also reflected in the comments (see App. 2 for some examples). However, the experiment should be replicated since the class had been exposed in one lesson to PW – but not to the symbol code – about 3 months before the experiment, which might explain a part of the PW group's advantage.

4. Improvement of PW

PW lacks feedback from other teachers who could use it in their classes and confirm or reject the reported findings. Therefore, software applications are needed for producing materials in PW easily and with good quality. This section will introduce two prototype tools for that purpose. Finally, it will be argued that a 3D version (stereographic version) would also be a potential application.

4.1 An Excel tool to produce PW

A simple version of PW can already be produced by a spreadsheet program like Excel (Fig. 3, Rude 2014) by Microsoft. The mathematics used in this prototype tool are standard vector calculations, the interface of the system being as follows: users have to (1) input a line of text, (2) specify the characters where *pitch accents* occur, including the respective height (or elevation) for each, (3) specify the characters where *stresses* occur, including their respective strength (or augmentation), (4) specify the characters where *lengthening* occurs, plus their respective degree (or elongation). (Rude 2014)

The tool is still in a rather early stage and has not yet been used to produce class materials.

4.2 A typographical tool to produce PW

In a more sophisticated way, PW can be produced by a tool developed in "Processing", an open source programming language and development environment for the visual arts. (See Fig. 4, Nakane 2015)

The human interface functions in a similar way as the one for the Excel tool; however, start- and end points of curves have to be specified as well. On one hand, this gives more flexibility (e.g. variable start and end of up- or downcurving pitch contours); on the other hand, it increases the number of data that the user needs to specify.

4.3 Further development and stereographical solutions

The presented prototypes – though in an early stage – show that the technology is given to produce PW semi-automatically: in addition to the text, all prosodic elements have to be input; the computer then generates curving strings of characters from these data. Complete automation of PW generation from voice input to PW output would likely require a project of several man-years.

Moreover – since PW is based on percepts – a "simple" automized system – based on

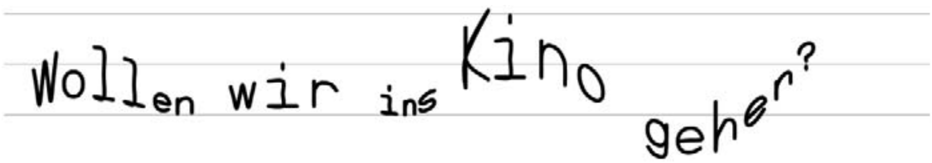

Fig. 3: PW produced by Excel (Microsoft): text is realized through a line chart. The basic form of each character is composed by up to 20 points. The final shapes that constitute the text are produced by taking the manual input from the user (text and parameters) and calculating hereof (1) horizonal deformation (for length, time), (2) vertical displacement (for pitch accents), (3) vertical deformation (for stress) and (4) appropriate shearing (slanted base- and cap line to yield a continuous outline).

Fig. 4: Sample of PW created by a tool programmed with "Processing", an open source programming language for the visual arts. The basis of the characters is a well-defined typeface. The advantage to the Excel tool is better readability of individual characters; its disadvantage is the rugged outline of words, since shearing of characters is not yet realized.

physical variables – would not yet yield optimal PW for human learners: adjustment of basic 3D-forms to ensure general readability, but also adjustment to individual learners (e.g. different visualizations for different language backgrounds of learners) would need considerable effort in such a project.

Computer realizations of PW also offer another direction of research: true 3D perception. As already described in Rude (2013), there is a huge potential to use 3D imaging in pedagogy and training in various fields (sciences, medicine, etc.), and PW could serve as a paradigm for 3D imaging in the domain of foreign language learning (see Fig. 5).

4.4 Section summary:

As shown in this section, technical tools are already available for computerized versions of PW. However, the prototypes do not yet meet typographical standards: The Excel version (Fig. 3) lacks variation of weight (thickness of characters) and is incomplete, the Processing version (Fig. 4) lacks a continuous contour on word level, and the stereogram (Fig. 5) contains just capital letters which are also too simplistic. However, the shortcomings of all three versions are rather due to limited manpower than to limited technology.

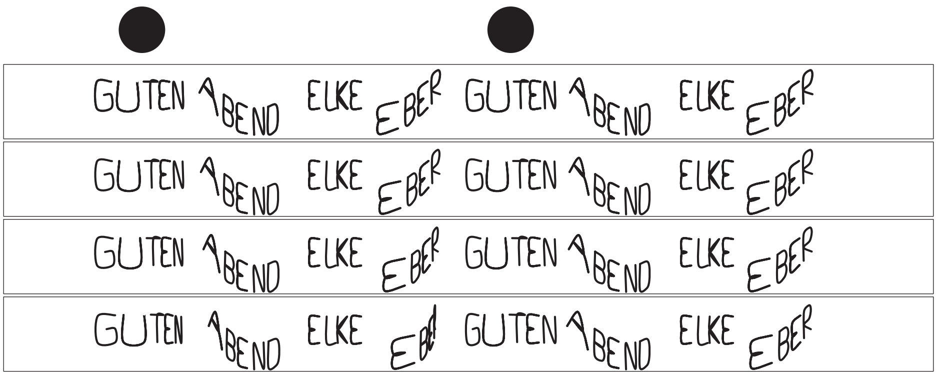

Fig. 5: Stereogram (for parallel view) of the German utterance “Guten Abend Elke Eber” (English: “Good evening, Elke Eber”). Pitch is made visible through the vertical (as in Fig. 1); however, loudness is shown through perceived depth in stereographic view rather than through augmentation: the underlined characters in “GUTEN ABEND ELKE EBER” seem to stick out of the plane and so denote stress of the containing syllables (from Rude 2013, Fig. 4.2. Depth impression increases from top to bottom through increasing parallax. For viewing technique: see [ibid.]).

5. Perspectives and conclusion

This section poses an interesting further research question and concludes the paper. The question is whether stereographic versions of PW could even be done by hand. Finally it is argued in favor of a parallel development of PW, by hand and by computer.

5.1 Can humans write 3D-text by hand?

Recent developments of stereographic imaging make use of computers and technology and it seems as if further advances are solely depending on technical advances, e.g. the possibility of 3D perception without special glasses (e.g. Nintendo 3DS shows 3D effects without the need of 3D glasses, as do more and more mobile phones).
In the examples in this paper unfortunately, we still need the stereoscopic viewing technique for perceiving 3D, e.g. in Fig. 6 (parallel view). It shows a basic prosodic component, word stress, through elevation in z-direction (depth). The homographs "digital" in German and English share meaning and orthography, but they differ in pronunciation, both in sound quality (segments) and quantity (stress). The different stress pattern becomes visible in stereographic view in the normal writing style.
The generation of this simple stereogram is realized through a tiny lateral shift of the stressed syllables relative to the unstressed word parts. The question could be raised whether such writing in 3D, stereographic writing, could be possible also by hand. Several facts linked by system theory suggest this possibility:
Most human beings

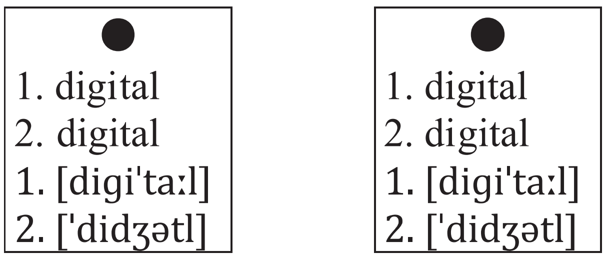

Fig. 6: Stereographic image of (1.) the German word "digital" and (2.) the English word "digital". If viewed in an ordinary way, only the lower two IPA-versions reveal the pronunciation difference – both in stress pattern and sounds. However, when viewed stereoscopically in parallel view, stressed syllables also become visible in standard orthography, through their elevation in depth: in the German version the 3rd syllable "digital", in the English version the 1st syllable "digital".

- are capable of stereo-viewing of natural scenes and even of artificial stereograms,
- possess two hands with which they could principally write in parallel (as they can steer a car by coordinated motion of right and left hand/arm),
- are capable of sub-millimeter control of the hand-finger-pen system, and
- possess the cognitive plasticity to learn how to maneuver in complex real environments or in virtual worlds.

Now, putting these facts together we could ask, whether humans could write both-handed and thus produce the two half-images of a stereogram simultaneously, while looking at the emerging patterns in stereographic view, controlling and manipulating them in realtime.

- Parallel motion in x1- and x2-directions (the horizontal and the vertical on the paper) would lead to corresponding x1- and x2-motions of the emerging line in the virtual world, while
- differential motion[3] in x1-direction would result in stereoscopic parallax and thus be interpreted as x3-motion of the emerging line in the virtual world (perpendicular to the paper, see Fig. 7),
- however, differential motion in x2-direction ought to be avoided, since a vertical parallax above some threshold leads to non-matching half-images, which are usually neglected by visual perception (e.g. like non-matching reflections on objects in the real world).

Is it possible that a human can operate – write or draw – in this virtual 3D-world just as she can move her finger tip in all 3 directions in the real world? A virtual 3D-world that is created by the control loops closed by simultaneous parallel and differential motion components of her two hands (or two pen tips) as movable parts, and the 3D stereoscopic view by her eyes as sensors? Does this scenario not remind us of what a pilot does when she becomes a unison with the machine she is controlling? Steering through a 3D-environment, forgetting the complex steering motions she is carrying out in order to keep the machine in balance and to go where she wants to go, whether she is a helicopter in a mountainous area or a shuttle landing on the moon? An equally important question is whether humans could acquire such stereographic writing capability – if at all possible – in a reasonable amount of time, thus being able to produce arbitrary lines in 3D directly, without the detour via a computer.

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[3] differential motion = symmetrical movements relative to the sagittal plane; one hand moving in +x1-direction, the other in –x1-direction.

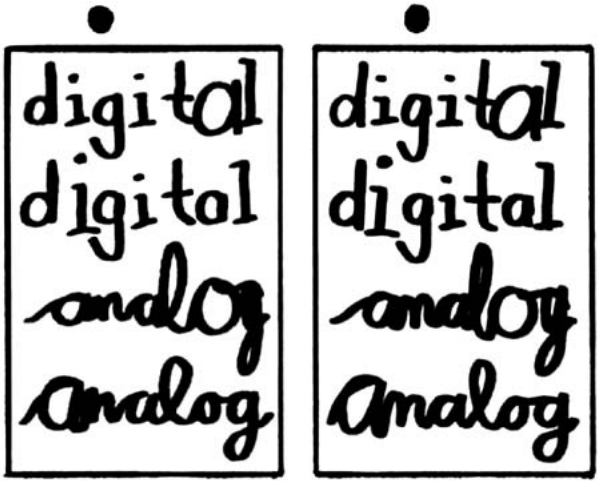

Fig. 7: German and English words “digital” in block letters and “analog” in cursive style, written both-handed synchronously in parallel view. Stereoscopic view reveals the different stress patterns by augmentation and z-elevation of different vowels: the upper version of each style showing stress on the last syllable (German stress pattern: digital, analog), the lower version stress of the first syllable (English stress pattern: digital, analog).[4]

Of course, a human cannot reach the precision of a computer, hence such writing might be useful for creating prototypical samples of PW (either by teachers, or by language learners). Still, there might be many other useful applications beyond the creation of Prosodic Writing samples, e.g. drafts of drawings of buildings in architecture, sketching of 3D-objects like faces and so on).

5.2 Conclusion

This paper has started from the observation that IPA failed to replace standard writing for language learning purposes on sentence level (section 1). However, also standard writing has failed for many language learners as a tool to teach spoken language with reasonable prosody. The negligence of prosodic cues in standard writing – a tool mainly developed for native speakers – is assumed to be the culprit. Prosodic

[4] The main point in this drawing is one of feasibility, not of aesthetics: Stereographic writing needs four control modes in eye-hands coordination that have to be carried out simultaneously, (1) parallel x1- and (2) parallel x2-motion, (3) defined differential x1-motion, and (4) suppression of differential x2-motion. Learning of modes (3) and (4) for an adult might be comparable in complexity to a young child's learning of modes (1) and (2) (one-handed), e.g. drawing circles with crayons.

Writing (PW) is an attempt to fill this gap and to make prosody visible through a 3D-distortion of the otherwise unchanged string of graphemes (section 2). Students like it and seem to have a learning advantage compared to students with a symbolic code of prosody, but more experiments are needed (section 3). Before long, we might have computer versions of PW, such that every language teacher or student could try PW and judge its impact. Prototypes that approach 3D shapes of text through perspective or stereoscopic view already exist (section 4).

However, the question for the optimum writing system for language learners is still unanswered, and thus the hypotheses from the introduction stay as they were – neither proven nor rejected.

The double failure - of standard writing systems and of the IPA - for supporting language students in how to learn to speak might not be a coincidence. Peter Eisenberg, a German linguist, wrote:

"Bis heute ist nicht entschieden, in welchem Umfang eine schriftunabhängige Phonologie etwa andere funktionale Kriterien als Distinktivität zu berücksichtigen hätte und in welchem Umfang sie segmental zu konzipieren wäre."

(Eisenbach 1996, 1377)

[Until today it has not been decided to what extent a writing-independent phonology would have to follow other functional criteria than distinctiveness, and to what extent it should be segmentally based. (my translation)]

Eisenbach is obviously questioning the IPA which – from its outset – was developed rather to reconstruct the Roman alphabet and its characters than to completely understand the audible, here understood in general terms and not necessarily segmentally (Eisenbach ibid.). However, as long as we do not know the distintive items in the suprasegmental domain reliably, as long as our explicit analysis of this domain is incomplete, we could – tentatively – just visualize the sound material as well as we can, and trust the implicit analysis of the human brain to make best use of the structural cues contained. Humans are quite successful to learn the meaning of prosodic cues when learning spoken language directly; they might learn it in a similar way if being visualized as with PW.

And – as we start to understand the distinctive suprasegmental units – PW could be restricted to show certain dimensions no longer in a continuous but in a categorical way, like in a variation of PW used in 2013 which visualized only the nuclear contour of utterances.

In this developmental process, handwritten and computer-generated writing samples should be developed in parallel: they could benefit from each other to find the best way to visualize language for language learners.

It is not by coincidence that some typographers, e.g. Hermann Zapf (1918 – 2015, creator of the typefaces Palatino, Aldus and Optima), were also successful calligraphers. This shows in a very illustrative way that the computer is but a tool to support human activities, and both types of writing - by hand or by computer - have their place. Hermann Zapf (1982) wrote "Computers have not done away with any methods as yet, they have only changed them", and this is still valid today.

Literature

Crystal, David: *A Dictionary of Linguistics and Phonetics* (6th ed.). Malden (USA): Blackwell Publishing, 2008.

Eisenberg, Peter: "Sprachliche Aspekte von Schrift und Schriftlichkeit. Linguistic Aspects of Writing and Its Use" In: *Schrift und Schriftlichkeit (Writing and Its Use). Handbuch (Handbook)*. Ed: Hartmut Günther, Otto Ludwig. Berlin: Walter de Gruyter, 1996.

Günther, Hartmut: "Schrift als Zahlen- und Ordnungssystem – alphabetisches Sortieren" [Scripture as number and ordering system – alphabetic sorting]. In: *Schrift und Schriftlichkeit (Writing and Its Use). Handbuch (Handbook)*. Ed: Hartmut Günther, Otto Ludwig. Berlin: Walter de Gruyter, 1996.

Rude, Markus, Takakazu Nakane, Kiyofumi Motoyama & Katsufumi Narita: "Prosodic Writing for visualizing spoken language for learners: how to improve its flexibility and usability." in: Motoyama Kiyofumi (Ed.) Designing Objects Connects Literacy. International Symposium on Visual Literacy "Designing Objects Connects Literacy". Post Proceedings, 2014 (p. 27).

Rude, Markus: "Prosodic Writing with 2D- and 3D-fonts: An approach to integrate pronunciation in writing systems". In: *Studies in Language and Culture* 言語文化論集. Nagoya University, 2013 (p. 233-252).

Rude, Markus: "Reshaping Sentences with Excel for Showing Prosody". Presentation at: *JALT 2014 International Conference*. Tsukuba-City (2014 Nov 23).

Rude, Markus: "Können Visualisierungen den Prosodieerwerb unterstützen? Der Einfluss von Verschriftungen auf Produktionen in spontanen Partnergesprächen Deutschlernender" (In German). In: *Mündliche Kommunikation im DaF-Unterricht: Phonetik, Gespräch und Rhetorik*. Japanische Gesellschaft für Germanistik. München: iudicium, 2015 (p. 108-127).

Zapf, Hermann: "BOOK DESIGN IN THE FUTURE". Announcement of a course on typographic computer programs at Rochester Institute of Technology, 1982. In: *Alphabetge-*

schichten. Eine Chronik technischer Entwicklungen von Hermann Zapf. Bad Homburg: Mengenthaler Edition – Linotype, 2007 (p. 133).

App. 1: Experiment 2014 summer: direct comparison of PW and symbolic code

Four students' comments on PW (Prosodic Writing) and ...	... – by the same students – on the symbolic code (underlines & arrows)
• Thanks to PW, I can stress word parts easily.	• It is very clear.
• I like PW.	• I prefer PW to the symbol system.
• The movement of the wave was easy to understand.	• When there were two arrows, it became complicated.
• It is easy to understand Prosodic Writing.	• Also here it is easy to understand the prosody, but we have to memorize the meaning of the symbols.

App. 2: Experiment 2015 summer: six students' comments on PW or symbolic code

Three (PW group) students' comments on PW and ...	three (symbol group) students' comments on symbolic code:
• It make[s] me understand easily. • I like it because I can imagine the way to pronounce. • It was clear to understand.	• It is easy to understand. • It was very useful to understand. • There were too many symbols, so I was confused a little.