Neuroscience Letters 455 (2009) 124–128

Contents lists available at ScienceDirect

Neuroscience Letters

journal homepage: www.elsevier.com/locate/neulet

The pseudohomophone effect: Evidence for an orthography–phonology-conflict

Benny B. Briesemeister*, Markus J. Hofmann, Sascha Tamm, Lars Kuchinke, Mario Braun, Arthur M. Jacobs

Department of Psychology, Freie Universität Berlin, Habelschwerdter Allee 45, D-14195 Berlin, Germany

A R T I C L E I N F O

Article history:
Received 14 November 2008
Received in revised form 20 February 2009
Accepted 3 March 2009

Keywords:
Pseudohomophones
Conflict
Lexical decision task
MROM-p
Pupillary responses
N400

A B S T R A C T

The standard pseudohomophone effect in the lexical decision task, i.e. longer response times and higher error rates for pseudohomophones compared with spelling controls, is commonly explained by an orthography–phonology-conflict. This study tested this conflict account, using a multi-method approach including participant's behavioral responses, confidence ratings, pupillary responses and event-related potentials (ERPs). The classic pseudohomophone effect was replicated using relatively long, multi-syllabic stimuli. Pseudohomophones were rated less confidently as being nonwords than spelling controls, and they affected the pupillary response by increasing the peak pupil diameter. Both findings are interpreted in terms of increased conflict and higher cognitive demands leading to uncertainty while solving the task. The ERP revealed an N400 component for spelling controls, showing a graded effect: word < pseudohomophone < spelling control. This can be seen as evidence for (partial) semantic activation through pseudohomophones. Taken together, the results provide strong multi-method evidence for the conflict account of the pseudohomophone effect.

Neuroscientific research on cognitive control recently focuses on the question of how cognitive conflict is detected and how the need for cognitive control is signalled [5,6,14]. Different paradigms and effects are used for investigation (for an overview, see Refs. [5,6]), e.g. the lexical decision task (LDT) [14]. However, the pseudohomophone effect, which is proposed to be caused by a conflict between phonological and orthographic processing [9,35], has not yet been used in this context. Pseudohomophones (PsHs, e.g. "BRANE", see Refs. [7,15,24,27,33]) are pseudowords that differ from real words in orthography, but not in phonology. When participants in a LDT are asked whether or not a presented letter string is a word, correct rejections of PsHs take longer than correct rejections of letter strings without correct phonology, so-called spelling controls (SCs, e.g. "BRINE", see Refs. [9,30,35]). Additionally, PsHs are more often falsely classified as words, presumably because of the correct phonological representation signalling the existence of a word. Although widely accepted, this orthography–phonology-conflict explanation was never tested directly using a multi-method approach.

A computational model of visual word recognition that accounts for orthographic and phonological processing is the multiple read-out model including phonology (MROM-p, Ref. [16]), which was the first model that implemented the PsH effect. In the model, word stimuli are identified whenever single word node activation reaches a certain threshold, the so-called M-criterion. Alternatively, a "yes" (word) response is given whenever the summed activity of all word nodes, the so-called global lexical activity (GLA), reaches the sigma-criterion. A stimulus is rejected as nonword when neither does happen within a certain time interval. The temporal threshold T is flexible, however, and it is readjusted when the GLA comes close to its criterion within the first seven cycles. Jacobs et al. [16] used this mechanism to explain the PsH effect: PsHs and SCs are orthographically similar but not equal to real words, both activate the corresponding orthographic word nodes and increase the GLA. Additionally, PsHs are phonologically correct and the resulting phonological word node activation is forwarded to the orthographic word node. This forces the GLA for PsHs to come close to the sigma-criterion, which then leads to a temporal threshold readjustment, resulting in longer response times (RTs). Accordingly, the orthography–phonology-conflict should be mirrored in the GLA.

In a somewhat different explanation proposed by Ziegler et al. [35] a mismatch between the orthographic and the corresponding phonological single node representation accounts for the PsH effect. For words and SCs, no mismatch is expected, since phonological and orthographic processing are congruent. PsHs in contrast produce a mismatch, because phonological activation is high while orthographic activation remains low. This mismatch causes the inhibitory psdeudohomophone effect. It is important to note that the proposed mismatch mechanism operates at the single node level and is independent of the GLA. Moreover, the MROM-p predicts that the single node activation in the phonological lexicon is supposed to be greatest for words, intermediate for PsHs and smallest for

* Corresponding author. Tel.: +49 30 838 556 21; fax: +49 30 838 556 20.
E-mail address: fsyron@web.de (B.B. Briesemeister).

0304-3940/$ – see front matter © 2009 Elsevier Ireland Ltd. All rights reserved.
doi:10.1016/j.neulet.2009.03.010

SCs (see p. 171, Figure 5.9 in Ref. [16]). The present study aimed at testing between these alternative explanations using event-related potentials (ERPs).

The GLA-based explanation predicts that words produce the highest GLA, followed by PsHs and the lowest GLA should be observed for SCs. The relation between GLA and ERP components in the LDT was previously examined by Braun et al. [8], who found that a larger GLA is accompanied by a larger N400. Most importantly, nonwords generally produced a greater N400 than words do [8]. Thus one would expect PsHs to elicit the highest N400, followed by SCs and finally by words.

In contrast, the single node activation explanation [35] predicts a different pattern, where words elicit the highest activations, and SCs the lowest. PsHs are supposed to elicit intermediate phononological word node activations. Words' phonology is known to affect ERP components around 400 ms post-stimulus onset [20] with smaller negativity related to higher activation of a particular phonological representation [24]. Words and PsHs produced smaller N400 amplitudes compared with nonwords [24]. This was interpreted in terms of a more fluent semantic integration for words associated with higher phonological activation. Thus, following the single node phonological activation hypothesis, one would expect that words elicit the smallest N400, followed by PsHs, while SCs elicit the highest N400.

In addition to ERPs, task-evoked pupillary responses were recorded. Pupil dilations have reliably been shown to be associated with the cognitive processing demands of a task [2,3,21,25,32] and have previously been interpreted as an indicator for uncertainty [11,29]. Resolving the orthography–phonology-conflict during lexical decisions is expected to increase cognitive processing demands: the subject's decision should be uncertain. Contrasting the task-evoked pupillary responses of PsHs with SCs and words is expected to elicit greater pupil dilations to PsHs. Moreover, trial-wise confidence ratings as a measure of uncertainty are expected to correlate with the pupillary response. The less confident the ratings the larger the pupillary response should be [11,29].

Thirty healthy participants (14 male, 16 female, mean age = 23.9, S.D. = 5.2, ranging from 18 to 45, one left handed), recruited at the Freie Universität Berlin took part in this study. Some of them received course credits, others were paid 15 Euros for participation. All reported normal or corrected-to-normal vision and German as their native language.

A total of 432 four to eight lettered stimuli were used, half of them words, half of them nonwords. Fifty-four PsHs were constructed by changing (i.e. replacing, adding or removing) one or two letters from low frequency basewords (less than 30 per million, mean CELEX frequency = 5.8 [1]; mean Leipzig frequency = 1934.2, Leipzig frequency class 11 or higher [4]), leaving their phonology intact. Spelling controls were constructed by changing the letters again, vowels being replaced by vowels and consonants by consonants. This way, PsHs and SCs were equally long (mean = 6.3 letters). They did not differ significantly in mean bigram frequency (type and token counts), mean letter frequency (type and token counts, taken from Ref. [13]) and number of orthographic neighbors (N), and their basewords were controlled to have neutral valence according to the Berlin Affective Word List in its revised form [31] (all $Fs < 1$). The remaining 108 nonwords ranged from pronounceable pseudowords (e.g. "MANHEL") to unpronounceable consonant strings (e.g. "XRDT") and served as fillers.

To compare the ERPs of PsHs and SCs with that of words, a subset of 54 low frequency words with neutral valence were selected. The remaining 162 words served as fillers.

Participants sat in a dimmed room in 70 cm distance to a 19 in. computer screen, receiving verbal and written instructions. Experimental stimuli were presented in two blocks of 216 stimuli, each block starting with 10 practice trials. The button-to-response assignment was reversed after the first block and counterbalanced across participants.

Stimuli were presented by Presentation 9.9 software (Neurobehavioral Systems Inc., Canada) in pseudorandomized order, using black uppercase letters (font type "Times New Roman", size 22) on a blank white screen. No more than three words, nonwords or PsHs were allowed to appear consecutively. Each trial began with a fixation cross (+) presented for 500 ms, followed by the stimulus for 60 ms and a mask of pound signs (#####) for 1940 ms. Participants were instructed to respond as fast and accurate as possible within these 2000 ms by pressing one of two response buttons with the right or left index finger. After a blank screen of 500 ms, participants indicated the degree of confidence of this decision [17] by clicking with the mouse on one of seven response fields ranging from 1 (confident nonword) to 7 (confident word). Confidence values below 4 indicate a confident nonword, values above 4 indicate a confident word decision. The rating remained until button press during which participants were allowed to blink. The next trial began after 500 ms of blank screen. If participants did not respond in time, the confidence rating was replaced by an acoustic signal, reminding to speed up the decision.

EEG data were recorded by a 32 channel amplifier (Brainamp, Brain Products, Germany, sampling rate 250 Hz) using 27 Ag/AgCl electrodes attached to an elastic cap (EASYCAP, Germany) according to the international 10–20 system ([18]; positions: FP1, FP2, F3, F4, F7, F8, FC5, FC6, Fz, FC1, FC2, CP5, CP6, P3, P4, P7, P8, O1, O2, C3, C4, T7, T8, CP1, CZ, CP2, PZ and M1). They were referenced to the right mastoid. The electrooculogram (EOG) was recorded above and below the right eye and on the outer canthus of each eye. Impedances were kept below 10 kΩ for EOG, and below 5 kΩ for all other electrodes. Pupil data were recorded with a video-based IView X Hi-Speed eye tracker (SensoMotoric Instruments, Teltow, Germany). An infrared sensitive camera recorded pupil diameters at a sampling rate of 240 Hz. Before the experimental session, participants' right eyes were calibrated using a 5-point-calibration.

Error-free mean RTs and mean confidence ratings were calculated for each condition and each participant. Behavioral errors were summed up per participant and condition for error analyses. Nonresponders (1.3%) and outliers (1%), defined as responses outside of a 300–2000 ms window, were excluded for all analyses. Pupil raw data were sampled down to 60 Hz and smoothed by a 7-point weighted filter. Major blinks were excluded (4.5%), smaller artifacts were interpolated within a time window of 200 ms before and 2500 ms after stimulus onset, using a MATLAB (version 6.5, The MathsWorks, MA, USA) algorithm [21]. One participant was excluded because of too many artifacts. Stimulus-locked peak dilations were computed as percent signal change relative to a 200 ms pre-stimulus baseline. Mean pupil diameter was calculated as average per condition and per participant after exclusion of errors, non-responders and outliers. Mean peak amplitudes were correlated with subjects' confidence ratings. ANOVAs comparing RTs, errors, confidence ratings and peak pupil dilations were computed for the experimental conditions (PsHs vs. SCs vs. words) at an a-priori significance level of 0.05.

EEG raw data were filtered (0.1–20 Hz) and visually corrected for artifacts, drifts and amplifier blocking, using BrainVision Analyzer software (BrainProducts GmbH, Germany). Blinks and eye movements were corrected using an independent component analysis (ICA; [26]). ERPs were corrected relative to a 200 ms pre-stimulus baseline and averaged per participant and per condition. Errors, non-responders and outliers were excluded from analyses. Five participants had to be excluded from all subsequent ERP analyses due to less than 25 remaining segments in one condition after artifact rejection.

A three factorial ANOVA was performed, comprising the within participant factors laterality (left, central, right), anteriocity (anterior, posterior) and experimental condition (low frequency words, PsH, SC), followed by planned pairwise comparisons. Where necessary, Greenhouse-Geisser correction was applied. To analyze the N400 component, electrodes were averaged across the time frame of 380–600 ms: anterior right (Fp2, F4, F8, FC6), anterior central (Fz, FC1, FC2), anterior left (Fp1, F3, F7, FC5), posterior right (CP6, P4, P8, O2, C4, T8), posterior central (CP1, Cz, CP2, Pz) and posterior left (CP5, P3, P7, O1, C3, T7). Statistical analyses were computed using SPSS (version 13.0, SPSS Inc., USA), significance level set at 0.05. One participant was excluded from all analyses, reporting that most of his decisions had been guessed.

Analyses revealed a significant PsH effect (see Fig. 1) in RTs [$F(1.4,27) = 118.9$, $p < 0.001$], error rates [$F(1.3,2) = 63.4$, $p < 0.001$], and confidence ratings [$F(1.2,27) = 127.1$, $p < 0.001$]. Planned pairwise comparisons for mean RTs of PsHs (978.0 ms, S.D. = 153.6), SCs (943.1 ms, S.D. = 147.9) and words (695.0 ms, S.D. = 124.3) revealed significantly longer RTs for PsHs than for SCs [$t(28) = 2.6$, $p = 0.014$], and longer RTs for SCs than for words [$t(28) = -12.2$, $p < 0.001$]. Likewise for mean error rates (PsHs: 24.0, S.D. = 8.0; SCs: 18.0, S.D. = 7.3; words: 7.1, S.D. = 5.9): PsHs revealed significantly more errors than SCs [$t(28) = 6.9$, $p < 0.001$]. SCs elicited more errors than words [$t(28) = -6.7$, $p < 0.001$]. Mean confidence ratings were lower for PsHs (3.7, S.D. = 0.7) than for SCs (mean confidence rating = 3.4, S.D. = 0.6) [$t(28) = 5.5$, $p < 0.001$], and lower for PsHs than for words (5.9, S.D. = 0.7) [$t(28) = -10.8$, $p < 0.001$].

A significant effect of experimental condition was found in mean peak pupil dilation [$F(2,27) = 3.7$, $p = 0.032$]. Planned pairwise comparisons on mean peak pupil diameter revealed larger dilations for PsHs (0.094, S.D. = 0.048) than for SCs (0.088, S.D. = 0.046) [$t(27) = 2.3$, $p = 0.029$]. Moreover, PsHs revealed larger pupil dilations than words (0.087, S.D. = 0.045 [$t(27) = 2.4$, $p = 0.022$], see Fig. 2). Confidence ratings significantly correlated with mean pupil dilation (Pearson correlation coefficient $r = -0.180$, $t(161) = -2.32$, $p = 0.022$).

ERP data (see Fig. 3) revealed a significant main effect of experimental condition [$F(1.0, 22) = 32.0$, $p < 0.001$] and a two-way interaction between anteriocity and experimental condition [$F(1.1, 22) = 17.4$, $p < 0.001$] as well as a three-way interaction between anteriocity, laterality and experimental condition ($F(1.6, 20) = 4.3$, $p = 0.030$). Planned pairwise comparisons between the conditions PsH and SC revealed significantly greater negativity for SCs on the whole scalp (all $p < 0.002$). The same was true for a low frequency words vs. PsHs comparison, PsHs being more negative than words (all $p < 0.004$).

The present study was designed to directly examine the assumptions following the orthography–phonology-conflict explanation for the classical PsH effect in the LDT. Behavioral measures, in particular RTs, error rates and confidence ratings, pupillary measures and ERPs were recorded, resulting in four important findings:

(i) Comparing RTs and error rates between PsHs and SCs revealed a disadvantage for PsHs in both measures. Participants took longer to correctly reject PsHs and committed more errors. Thus, for the first time, a PsH effect was observed using stimuli with more than two syllables and more than 6 letters on average. This confirms Ziegler et al. [35] conclusion that the PsH effect is independent of stimulus length which was demonstrated using 3–5 letter stimuli. Word stimuli were accepted faster and more accurately than both nonword conditions.

(ii) Confidence ratings revealed that lexical decisions to PsHs were less confident than decisions to SCs, which were judged less confidently than words. This effect supports an orthography–phonology-conflict explanation: the conflict forces participants to further evaluate their decision, reducing their confidence. As a consequence, participants respond slower and commit more errors. The confidence ratings also show a strong tendency to misjudge PsHs as words. This finding might be attributed to the activated phonological representation of a PsH, referencing it to the debate on phonology's role in retrieving semantics [24].

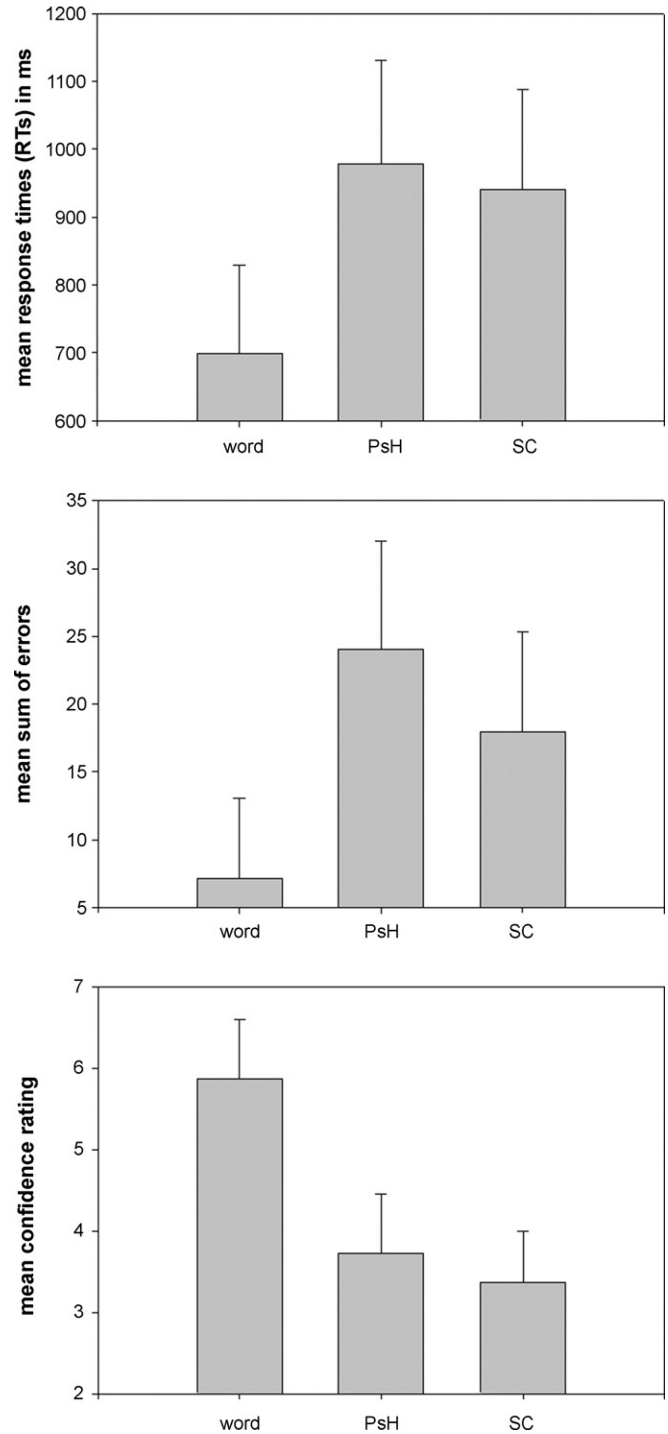

Fig. 1. Response times (RTs), error rates and mean confidence ratings for words, pseudohomophones (PsHs) and spelling controls (SCs). Error bars represent one standard deviation.

(iii) Mean pupil diameter was calculated in order to investigate the conflict's impact on pupillary responses. PsHs led to a significantly greater pupil diameter than SCs and words, revealing the expected pupil's PsH effect. Past studies reported a relation between cognitive task demands [2,3,21,25,32] or uncertainty [11,29] to greater pupil dilations. The solution

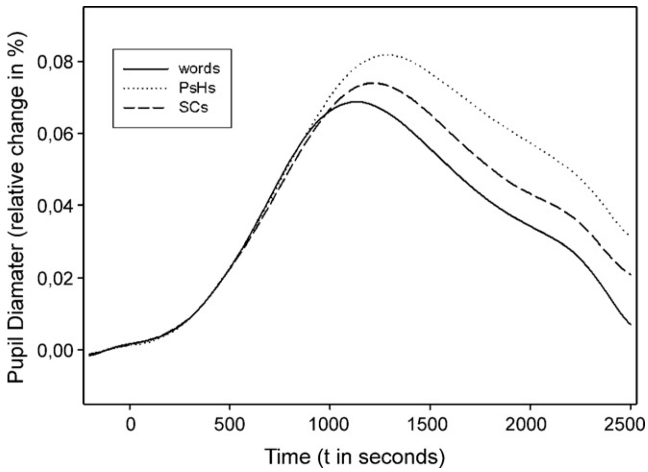

Fig. 2. Stimulus locked mean pupil diameter change during a lexical decision task for words, pseudohomophones (PsHs) and spelling controls (SCs).

of the orthography–phonology-conflict, which is assumed to underly the classical PsH effect, is cognitively demanding, the following lexical decision being uncertain, as indicated by the confidence rating. The correlations between pupillary measures and confidence ratings support the interpretation, that both – confidence ratings and pupillary responses – reflect conflict monitoring. The current study thus provides additional evidence for the PsH conflict explanation by indicating that conflict processing and monitoring are not only indicated by the obtained activity in the anterior cingulate cortex (ACC) [5,6] and the related N2 component in the ERP [34], but can be addressed through pupillary measures as well. We thereby introduce another measure into the line of those that allow for testing the conflict monitoring theory [5,6].

(iv) SCs elicited a greater negativity in the ERP component about 400 ms after stimulus onset than PsHs, which were more negative than word stimuli. This word-PsH-SC relation is in line with the MROM-p prediction of single node activation in the phonological lexicon [16]. The N400 component has a long tradition in research concerning lexical stimuli, commonly being interpreted as a measure for semantic processing/integration [22,28]. Words and word-like stimuli consistently evoke reduced N400 negativity, while nonword stimuli increase the N400 amplitude. This is exactly what was found in the current study. The word stimuli produced a decreased N400 and a quick identification. SCs, in contrast, for which semantic processing is impossible produced a high N400 and relatively quick rejection responses. PsHs, finally whose phonological representation might trigger at least some semantic activation produced an N400 negativity intermediate between words and SCs. We suggest that the evidence for conflict processing in the behavioral and pupillometric data at least in part results from this phonological activation in the N400 time frame. For models of word recognition this suggests that a PsH conflict is best modelled at the single word node level and thus puts further constraints on GLA-based modelling accounts [35]. The summed lexical activity account [16] seems inappropriate, because an increased GLA should lead to an increased N400 for PsHs-relative to SCs [9].

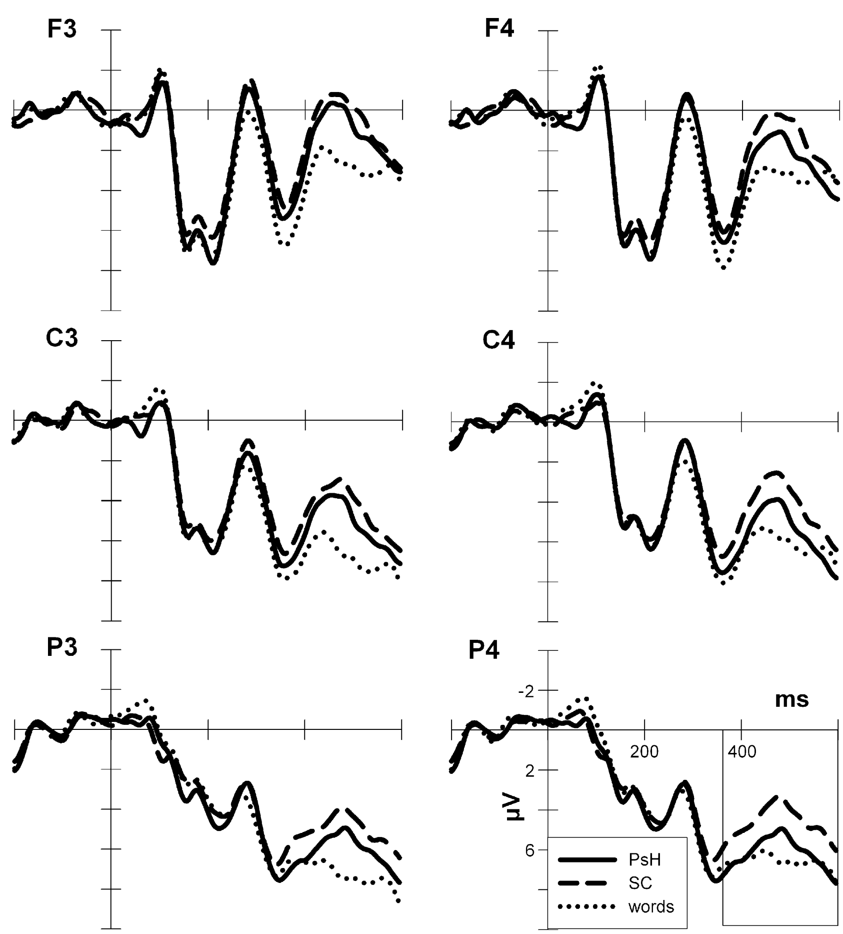

Fig. 3. Event-related potentials (ERPs) for words, pseudohomophones (PsHs) and spelling controls (SCs).

On a more general level, these data are in line with studies indicating little or no evidence for a close relation between medio-frontal ERP components (such as the N2, the N400 or the error-related negativity, ERN [14,34]) and a conflict monitoring interpretation [12], in particular when participants process lexical stimuli [19,23]. The current study also failed to find an N2 component related to the orthography–phonology-conflict elicited by PsHs, although PsHs have been shown to elicit ACC activation [10]. Hence, the lexical conflict during processing of PsHs seems to differ from conflicts associated with the N2 [5,6,34].

Taken together, our multi-method results support the conflict explanation for the classical PsH effect. It can account for all behavioral findings of the current study, for RTs, error rates and confidence ratings. Pupillary measures were shown for the first time to be systematically influenced by the processing of PsH, correlating with the confidence ratings and thereby introducing another measure that allows to test the conflict monitoring theory. Most importantly, this is the first time that an N400 component in the ERP is used to indicate that the orthography–phonology-conflict is indeed a conflict between the orthographic and the phonological representations activated by the presented PsH. The present PsH effects, thus, offer new ways to investigate cognitive conflict and cognitive control.

Acknowledgements

This work was supported by a grant by the Deutsche Forschungsgemeinschaft (JA 823/41: Cognitive and affective conflict control in implicit and explicit language memory) to Arthur Jacobs as part of the DFG-Forschergruppe “Between interference and optimization: Conflicts as signals in cognitive systems”.

References

[1] R.H. Baayen, R. Piepenbrock, L. Gulikers, The CELEX Lexical Database (CD ROM), Linguistic Data Consortium, University of Pennsylvania, Philadelphia, PA, 1995.
[2] J. Beatty, Task-evoked pupillary responses, processing load, and the structure of processing resources, Psychological Bulletin 91 (1982) 276–292.
[3] J. Beatty, D. Kahnemann, Pupillary changes in two memory tasks, Psychonomic Science 5 (1966) 371–372.
[4] C. Biemann, S. Bordag, G. Heyer, U. Quasthoff, C. Wolff, Language-independent methods for compiling monolingual lexical data, in: Proceedings of CicLING, LNCS 2945, Springer–Verlag, Berlin, Heidelberg, 2004, pp. 215–228.
[5] M.M. Botvinick, T.S. Braver, D.M. Barch, C.S. Carter, J.D. Cohen, Conflict monitoring and cognitive control, Psychological Review 108 (3) (2001) 624–652.
[6] M.M. Botvinick, J.D. Cohen, C.S. Carter, Conflict monitoring and the anterior cingulate cortex: an update, Trends in Cognitive Sciences 8 (12) (2004) 539–546.
[7] R. Borowsky, W.J. Owen, M.E.J. Masson, Diagnostics of phonological lexical processing: pseudohomophone naming advantages, disadvantages, and base-word frequency effects, Memory and Cognition 30 (6) (2002) 969–987.
[8] M. Braun, A.M. Jacobs, A. Hahne, B. Ricker, M. Hofmann, F. Hutzler, Model-generated lexical activity predicts graded ERP amplitudes in lexical decision, Brain Research 1073–1074 (2006) 431–439.
[9] M. Braun, F. Hutzler, J. Ziegler, M. Dambacher, A.M. Jacobs, Pseudohomophone effects provide evidence of early lexico-phonological processing in visual word recognition, Human Brain Mapping, 2008 Aug 22. [Epub ahead of print].
[10] J.D. Edwards, P.M. Pexman, B.G. Goodyear, C.G. Chambers, An fMRI investigation of strategies for word recognition, Cognitive Brain Research 24 (2005) 648–662.
[11] D. Friedman, G. Hakerem, S. Sutton, J.L. Fleiss, Effect of stimulus uncertainty on the pupillary dilation response and the vertex evoked potential, Electroencephalography and Clinical Neurophysiology 34 (1973) 475–484.
[12] M. Heldmann, U. Markgraf, A. Rodríguez-Fornells, T.F. Münte, Brain potentials reveal the role of conflict in human errorful and errorless learning, Neuroscience Letters 444 (2008) 64–68.
[13] M.J. Hofmann, P. Stenneken, C. Conrad, A.M. Jacobs, Sublexical frequency measures for orthographic and phonological units in German, Behavioral Research Methods 39 (2007) 620–629.
[14] M.J. Hofmann, S. Tamm, M.M. Braun, M. Dambacher, A. Hahne, A.M. Jacobs, Conflict monitoring engages the mediofrontal cortex during nonword processing, NeuroReport 19 (1) (2008) 25–29.
[15] L.A. Huntsman, Looks aren’t everything: pseudohomophones prime words but nonwords do not, Journal of Psycholinguistical Research 36 (2007) 47–63.
[16] A.M. Jacobs, A. Rey, J.C. Ziegler, J. Grainger, MROM-P: an interactive activation, multiple read-out model of orthographic and phonological processes in visual word recognition, in: J. Grainger, A.M. Jacobs (Eds.), Local Connectionists Approaches to Human Cognition, Lawrence Erlbaum Associates, New York, 1998, pp. 147–187.
[17] A.M. Jacobs, R. Graf, A. Kinder, Receiver operating characteristics in the lexical decision task: evidence for a simple signal-detection process simulated by the multiple read-out model, Journal of Experimental Psychology: Learning, Memory, and Cognition 29 (3) (2003) 481–488.
[18] H.H. Jasper, The ten-twenty electrode system of the International Federation, Journal of Electroencephalography and Clinical Neurophysiology 20 (1958) 371–375.
[19] F. Klonek, S. Tamm, M. Hofmann, A.M. Jacobs, Does familiarity or conflict account for performance in the word-stem completion task? Evidence from behavioural and ERP data, Psychological Research, in press, published online as preprint 27 Nov 2008.
[20] A.F. Kramer, E. Donchin, Brain potentials as indices of orthographic and phonological interaction during word matching, Journal of Experimental Psychology: Learning, Memory, and Cognition 13 (1) (1987) 76–86.
[21] L. Kuchinke, M.L.-H. Võ, M. Hofmann, A.M. Jacobs, Pupillary responses during lexical decisions vary with word frequency but not emotional valence, International Journal of Psychophysiology 65 (2007) 132–140.
[22] M. Kutas, K.D. Federmeier, Electrophysiology reveals semantic memory use in language comprehension, Trends in Cognitive Sciences 4 (12) (2000) 463–470.
[23] H. Masaki, M. Falkenstein, B. Stürmer, T. Pinkpank, W. Sommer, Does the error negativity reflect response conflict strength? Evidence from a Simon task, Psychophysiology 44 (2007) 579–585.
[24] R.L. Newman, J.F. Connolly, Determining the role of phonology in silent reading using event-related brain potentials, Cognitive Brain Research 21 (2004) 94–105.
[25] A. Nuthmann, E. van der Meer, Time’s arrow and pupillary response, Psychophysiology 42 (2005) 306–317.
[26] J. Onton, M. Westerfield, J. Townsend, S. Makeig, Imaging human EEG dynamics using independent component analysis, Neuroscience and Biobehavioral Reviews 30 (6) (2006) 808–822.
[27] M. Reynolds, D. Besner, Basic processes in reading: a critical review of pseudohomophone effects in reading aloud and a new computational account, Psychonomic Bulletin and Review 12 (4) (2005) 622–646.
[28] F. Rösler, A. Hahne, Hirnelektrische Korrelate des Sprachverstehens: Zur psycholinguistischen Bedeutung der N400-Komponente im EEG, Sprache and Kognition 11 (3) (1992) 149–161.
[29] S. Steinhauer, J. Zubin, Vulnerability to schizophrenia: information processing in the pupil and event-related potential, in: E. Usdin, I. Hanin (Eds.), Biological Markers in Psychiatry and Neurology, Pergamon Press, Oxford, 1982, pp. 371–386.
[30] C. Transler, P. Reitsma, Phonological coding in reading of deaf children: pseudohomophone effects in lexical decision, British Journal of Developmental Psychology 23 (2005) 525–542.
[31] M.L.-H. Võ, M. Conrad, L. Kuchinke, K. Hartfeld, M. Hofmann, A.M. Jacobs, The berlin affective word list reloaded (BAWL-R), Behavior Research Methods, in press.
[32] M.L.-H. Võ, A.M. Jacobs, L. Kuchinke, M. Hofmann, M. Conrad, A. Schacht, F. Hutzler, The coupling of emotion and cognition in the eye: introducing the pupil old/new effect, Psychophysiology 45 (1) (2007) 130–140.
[33] M. Yates, L. Locker JR., G.B. Simpson, Semantic and phonological influences on the processing of words and pseudohomophones, Memory and Cognition 31 (6) (2003) 856–866.
[34] N. Yeung, M.M. Botvinick, J.D. Cohen, The neural basis of error detection: conflict monitoring and the error-related negativity, Psychological Review 111 (4) (2004) 931–959.
[35] J.C. Ziegler, A.M. Jacobs, D. Klüppel, Pseudohomophone effects in lexical decision: still a challenge for current word recognition models, Journal of Experimental Psychology: Human Perception and Performance 27 (3) (2001) 547–599.