

# Understanding Fairy Tales Spoken in Dialect: An fMRI Study

Julia M. Schmitt<sup>1,2</sup>, Peter Auer<sup>1</sup> & Evelyn C. Ferstl<sup>2</sup>

1) Department of German Linguistics

2) Institute for Psychology, Centre of Cognitive Science

University of Freiburg, Germany

Address for correspondence:

Prof. Evelyn C. Ferstl  
Institute for Psychology  
Cognitive Science  
Freiburg University  
Hebelstr. 10  
79104 Freiburg  
Germany

e-mail:

[evelyn.ferstl@cognition.uni-freiburg.de](mailto:evelyn.ferstl@cognition.uni-freiburg.de)

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## Abstract

Dialect comprehension has rarely been studied on the text level. Using functional magnetic resonance imaging (fMRI), the neuronal processing of auditory story comprehension was compared in 17 bilingual listeners who spoke Standard German and High Alemannic dialect, and in 19 monolingual listeners who did not speak dialect but only Standard German. 24 fairy tales were translated and recorded by speakers of both varieties. A text-related Extended Language Network (ELN) was more active for intelligible conditions compared to an unintelligible baseline. When High Alemannic fairy tales were presented, bilingual listeners activated the left aTL significantly more than monolinguals. This activation was stronger for listeners who rated the dialect more pleasant. It increased over the duration of the stories, but more so for the familiar varieties. These results confirm the importance of the left aTL for text comprehension and add to our understanding of the functional neuroanatomy of dialect comprehension.

## Understanding Fairy Tales Spoken in Dialect: An fMRI Study

Bilectalism, the simultaneous proficiency in two varieties of one single language, is a phenomenon rarely investigated in psycho- and neurolinguistic research. This is all the more astonishing as the past decades have seen a rising interest in the related, but different question of the neurological representation of bilingualism (i.e. the simultaneous proficiency in two different languages; for a review see Abutalebi & Chang-Smith, 2012; Coderre, 2015). An open research question is whether the neuronal processing of varieties of one single language (in our case the standard variety and a regional dialect) differs between mono- and bilectal comprehenders. In analogy to the distinction between monolingual and bilingual speakers, we use the term *monolectal* here and in the following to refer to people who speak the standard variety of their native language, and who were not exposed to a regional dialect during childhood. Bilectal comprehenders are defined here as people who, in addition to the standard variety of a language, speak a dialect themselves or were exposed to a dialect from early childhood (for a more detailed discussion and slightly different uses of these and related terms see Grohmann, Kambanaros, Leivada and Rowe, 2016).

The few available studies on dialect comprehension (see below) use word or sentence level stimuli, rather than connected language, such as stories. Studying dialect comprehension on the text level provides a much better window into natural language use, however. Beside the fact that oral realization, as often found in narration, is an inherent characteristic of dialects (Sowinski, 1974), texts include the entire range of features distinguishing the dialect from the standard variety. This includes pronunciation, lexico-semantic, but also grammatical and pragmatic aspects. Additionally, temporally extended narration allows non-dialect speakers to accustom themselves to a less familiar variety and to improve comprehension.

In the present fMRI experiment, we aurally presented fairy tales to study dialect processing in monolectal and bilectal listeners. Before explaining the details of the study, we first describe the sociolinguistic status of dialects (with a focus on Germany), and further specify the concepts of bilectalism and bilingualism. Given the lack of neuroimaging studies on bilectal text comprehension, we then review two lines of previous neuroscientific research: The first line of research targets the perception of single feature variation within a language, in particular, that of accent features. These studies confirm that phonetic features are readily distinguished by listeners and immediately influence lexico-semantic

interpretation. The second line of research investigates text comprehension in mono- and bilingual speakers. The results of these studies are useful for deriving predictions about the candidate brain regions in which processing differences might be observable.

### ***Dialect and Bilectalism***

The term ‘dialect’ is used here in the sense of continental European research on dialectology as referring to a geographically bound way of speaking that has not undergone standardization. The traditional dialects of Europe are self-contained linguistic systems that predate the standard languages which have emerged on their basis. They differ in this respect from the regional varieties of the Americas (which have sometimes been called secondary dialects) (Coseriu, 1980). The structural differences between the dialects are substantial, and can endanger understanding in inter-dialect communication. The difference between the standard variety and the dialects (and hence their mutual intelligibility) varies according to the degree to which these dialects contributed to the emergence of the standard variety (Auer, 2005).

Until the end of the 19<sup>th</sup> century (and often much longer) most of the European population acquired dialect as their first language (L1) and used it as the language of everyday life. The use of the standard variety was restricted to writing. In the course of the 20<sup>th</sup> century, however, acquisition of the standard variety has become more and more the rule. Today, almost all dialect speakers in Europe are also fluent speakers of the standard variety. In Germany, acquisition of the standard usually starts very early in childhood, due to the media and to schooling/kindergarden. Young children growing up in dialectal environments are therefore hardly ever monolectal dialect speakers, but bilectal from a very early stage onward. Thus, both the dialect (if it is spoken in the family) and the standard variety have the status of an L1 (Katerbow, 2013).

It can be argued that bilectalism strongly resembles (or is a form of) bilingualism. This equation suggests itself particularly in cases such as Switzerland where standard and dialect are clearly separate and speakers are always aware of the variety they are currently using (diglossia) (Ferguson, 1959). However, several arguments can be raised against this equation of bilingualism and bilectalism. One is that the structural difference between the languages of a bilingual can be huge, while the structural difference between standard and dialect is usually much less pronounced. To be sure, there are exceptions to this; it is easy to find varieties whose status as a dialect or a language is highly disputed and cannot be settled on structural linguistic grounds alone (cf. the shifting status of Ukrainian, or Catalan; Coseriu, 1980).

However, at least in the context of neurolinguistic research on bilingualism, the languages investigated are usually structurally quite distinct and mutually unintelligible. More important is the specific sociolinguistic constellation that characterizes dialect/standard bilingualism. In many cases, only the standard is used for (official) writing, and it is the only variety acceptable in formal situations. The standard usually has an official prestige which the dialects do not have. In many European countries, among them Germany (while German-speaking Switzerland is an exception), this has led either to the gradual disappearance of the dialects, or to the advergence of the dialects to the standard variety, and the emergence of intermediate ways of speaking ‘halfway’ between the traditional dialect and the standard (diaglossia, cf. Auer, 2005). This type of advergence is not found between (standard) languages investigated in neurolinguistics studies on the bilingual brain. Hence, the question of whether bilingualism is only a variant of bilingualism is at least open.

The German dialect chosen for this study is the most traditional form of High Alemannic dialect spoken in the very southwest of Germany. (High Alemannic dialects are also spoken in large parts of Switzerland, see the map in Figure 1, but under different sociolinguistic conditions.) This traditional dialect is characterised by salient features on all linguistic levels, so-called primary features (Spiekermann, 2008), which often get lost in standard-dialect advergence (Auer, 2005; Spiekermann, 2008). Even though many younger speakers nowadays would not use this traditional dialect themselves (but rather a more standard-near, levelled out version of the dialect), its characteristics are still well known. The traditional dialects are therefore still comprehensible for speakers who have grown up in the area and in a family in which the dialect is still alive.

----- insert Figure 1 and Table 1 here -----

### ***Neurolinguistic Studies on Language-Internal Variation***

Most neuroscientific research on the processing of geographically or socially defined language variation targets single phonetic, phonological or morphological features, focusing on perceptual processes. These studies confirm that variations in pronunciation are perceived by listeners, and that they in turn influence lexical access, semantic interpretation, and syntactic processes. Even though they investigate more basic linguistic levels, these results provide a basis for a neuroimaging study on higher level dialect comprehension.

In a magnetoencephalographic (MEG) experiment, Scharinger, Monahan, and Idsardi (2011) used a passive oddball paradigm with different instances of the simple word *hello*

spoken in African American English or in Standard American English (SAE). In speakers of SAE, within-variety deviants (i.e. infrequent stimuli, “oddballs”) revealed a smaller mismatch negativity (MMN) than deviants from the other variety. Thus, listeners perceive not only the acoustic variation but use their familiarity with the variety to rapidly categorize speech stimuli. Conrey, Potts, and Niedzielski (2005) used event-related potentials (ERP) to show that the discrimination of minimal word pairs (e.g., *pin/pen*) embedded in sentence contexts (e.g., “Blue ink leaked out of the \_\_\_\_”) depended on whether the participants made the vowel distinction in production. Similarly, Brunellière, Dufour, and Nguyen (2011) found that a phonological contrast in French (e.g., *épée* and *épais*) led to different cortical topographies of the EEG signal for speakers of Standard French. In an oddball paradigm, in which the word *épi* was repeated, an infrequent *épais* elicited a mismatch negativity (MMN) with a fronto-central maximum, but not the phonologically closer *épée*. In contrast, the MMN topographies for the two words were very similar for listeners from Southern France, where the two vowels are merged. Thus, for this group of participants, the pronunciations are linked to the same semantic representation.

Using German varieties, Lanwermyer et al. (2016) aurally presented sentences to Central Bavarian speakers in an ERP experiment. The sentences were spoken in a variety used in the geographical transition zone between Bavarian and Alemannic and included phonological vowel contrasts. Lexemes heard by Bavarian speakers in the unfamiliar dialect led not only to an N200 suggesting early perception of the difference, but also to late components (N400 or LPC, depending on the condition). These effects confirm a direct influence of the phonological characteristics of dialect speech on lexico-semantic interpretation. Varying speaker accent, Hanulíková, van Alphen, van Goch, and Weber (2012) reported similar effects on morphosyntactic processes. Dutch sentences with grammatical gender agreement errors spoken by a native Dutch speaker elicited a P600 effect in native Dutch listeners. When the speaker had a Turkish accent, however, this effect diminished over the course of the experiment, indicating that the Dutch listeners adjusted to speaker characteristics based on the accent. -.

Using functional magnetic resonance imaging (fMRI), Adank, Noordzij, and Hagoort (2012) attempted to disentangle speaker identity from accent effects. They created a novel, artificial Dutch accent and asked participants to passively listen to pairs of sentences. The first presentation was spoken in Standard Dutch. The second presentation varied speaker identity, accent or both. A switch of speaker elicited mostly right-sided activation, whereas a switch to the novel accent engaged a large, bilateral network of regions involved during language

comprehension in context (see below). These included posterior and anterior temporal regions, as well as the inferior frontal gyrus. To control for intelligibility, Adank, Davis, and Hagoort (2012) contrasted the same novel accent with speech presented against background noise. During a semantic judgment task, the only region which was more active in the accent condition compared to the standard speech condition was the left anterior temporal lobe (aTL).

To summarize, ERP and MEG studies provide neuroscientific evidence for perceptual differentiation of variable features within a language and immediate consequences for lexico-semantic and morphosyntactic processing. These effects depend on familiarity with the respective varieties. Interestingly, two fMRI experiments on the sentence level, using an artificial, novel accent (Adank, Noordzij & Hagoort, 2012; Adank, Davis & Hagoort, 2012) yielded activation differences in regions resembling those usually reported during higher level language interpretation, and, in particular, during the comprehension of coherent texts. Whether similar results would be obtained using a natural, familiar accent (for example, a regional dialect), is an open question (see also Goslin, Duffy, and Floccia, 2012, for a distinction between foreign and dialect accents).

To our knowledge, dialect processing on the text level has not yet been studied using neuroscientific methods. In the next section, we briefly summarize neuroimaging studies on text comprehension, both in monolingual and bilingual speakers.

### ***Neuroimaging of Text Comprehension in Mono- and Bilingual Speakers***

The functional neuroanatomy of text comprehension has been described in a number of review articles (e.g., Bornkessel-Schlesewsky & Friederici, 2007; Ferstl, 2007; Ferstl, 2010; Mar, 2004; Mason & Just, 2006; Zacks & Ferstl, 2016). Not surprisingly, language comprehension in context engages brain regions including, but also extending beyond the perisylvian language areas in the left hemisphere. Ferstl, Neumann, Bogler and von Cramon (2008) have described this extended language network (ELN) based on a meta-analysis. In the left hemisphere, many studies show activation along the entire extent of the superior temporal sulcus (STS), reaching into the anterior temporal lobe (aTL) and temporal pole, and posteriorly into the temporo-parietal junction and inferior parietal lobe (angular gyrus, AG; supramarginal gyrus, SMG). The right-sided homologues of these temporal regions are also often activated. In addition, medial brain regions (dorso-medial prefrontal cortex, dmPFC; posterior cingulate cortex, PCC/precuneus) are important for inference processes, for establishing coherence across sentence boundaries, and the updating of situation model

representations based on general world knowledge (e.g., Friesse, Rutschmann, Raabe, & Schmalhofer, 2008; Speer, Reynold, & Zacks, 2007). Activations in dorso-lateral prefrontal cortex seem to be dependent on task demands and are more likely to be observed during reading than during listening (Schmitt, 2017; Ferstl, 2007).

The current view on bilingual language processing is that the languages are active in parallel, and that similar areas are used to process both (or all) languages (i.e., L1 and L2) (see Abutalebi & Chang-Smith, 2012; Gómez-Ruiz, 2010; Perani & Abutalebi, 2005). Thus, activation differences are gradual, rather than qualitative, and often vary with age of acquisition (AoA) or with proficiency level (Kroll, Dussias, Bice & Perrotti, 2015).

Text comprehension in bilingual speakers, however, has surprisingly rarely been investigated. Using PET (positron emission tomography), Perani et al. (1996, 1998) studied story comprehension in bilingual participants in order to disentangle the influence of proficiency and AoA. In contrast to the hypothesis that L2 would activate regions related to task difficulty (cf. Abutalebi & Chang-Smith, 2012), Perani et al. (1996) were first to show stronger activation for L1 in the ELN, indicating better comprehension. Specifically, for late bilinguals with moderate proficiency, they reported higher activations for L1 in the aTL bilaterally, the left inferior frontal gyrus (IFG), and the inferior parietal cortex (IPC) bilaterally. Perani et al. (1998) pointed out the role of proficiency: an additional sample of late acquisition participants with higher L2 proficiency, as evidenced in better word translation performance, did not show any activation differences between L1 and L2. Using fMRI, Dehaene et al. (1997) analysed the interindividual variability. Activations in L1 were more homogenous than in L2, and, once more, left temporal regions showed stronger activations in L1 compared to L2.

More recently, Hesling, Dilharreguy, Bordessoules, and Allard (2012) studied story comprehension in late French bilinguals who learned their second language English after the age of eleven. Participants with moderate proficiency showed higher activation levels for French (L1), compared to the second language English (L2), in the anterior temporal lobes (middle temporal and inferior temporal gyri, MTG/ITG) bilaterally.

These few studies on bilingual text comprehension converge on the importance of anterior temporal regions during skilled language processing. Activation levels are higher in L1 than in L2. Age of acquisition plays less of a role in explaining interindividual differences than proficiency level (Hesling et al., 2012; Perani et al., 1998). Finally, the consistent sensitivity of the aTLs to these factors suggests that the linguistic subprocess distinguishing comprehension of L1 and L2 is the integration of single words into phrases (i.e.,



propositionalization or linguistic composition, cf. Bemis & Pylkkänen, 2013; Brennan & Pylkkänen, 2017; Ferstl et al., 2008; Wong & Gallate, 2012), a process which is based on semantic as well as syntactic information. Note, however, that other functions have also been proposed for the aTL, in particular Theory-of-Mind (e.g. Frith & Frith, 2003) and emotional processes (e.g. Wong & Gallate, 2012). We will return to this issue in the discussion.

### *The Current Study*

The current study was designed to describe the functional neuroanatomy of dialect comprehension. Two groups of participants were recruited based on the results of a questionnaire. The first group, called *bilectal* speakers here, grew up in a dialect speaking family where they simultaneously acquired the Upper German dialect High Alemannic and Standard German. Most of them reported to have no knowledge of other German dialects than Alemannic. The second group of speakers, called *monolectal* here, grew up in a different region in Germany and reported to speak Standard German but not High Alemannic. Beyond that, most of them reported to have no knowledge of any other German dialect. Besides their linguistic background the two groups did not differ (e.g. in level of education, number of foreign languages learned in school, or English proficiency level).

Using functional magnetic resonance imaging (fMRI), we examined the functional neuroanatomy of narrative dialect comprehension. Fairy tales by the Brothers Grimm were used as stimuli. This genre is likely to be associated with a familial setting in which dialects are often spoken. To reduce effects of speaker identity (e.g., age, sympathy, voice characteristics), the stories were read by a number of different speakers with slightly varying dialect features. In contrast to previous studies (e.g. Perani et al., 1998), the same stories were translated in all language conditions to minimize potential confounds due to the content of the stories (such as Theory-of-Mind or inferencing demands). The two varieties of interest, Standard German and High Alemannic, were compared to an unintelligible language baseline (Vietnamese).

For the comparisons between the intelligible (i.e., Standard German or dialect) stories and the control condition (Vietnamese, unintelligible to all participants), activations were expected in the ELN, in particular, in the temporal lobes bilaterally, and, to a lesser extent, in lateral and medial frontal areas (cf. Ferstl et al., 2008; Xu, Kemeny, Park, Frattali, & Braun, 2005). For the comparisons between Standard German and High Alemannic, the hypotheses were rather exploratory. If, as the neuroscientific literature on single variable feature perception suggests, non-familiar linguistic features increase demands on processing (cf.

Goslin et al., 2012), activation increases are to be expected in inferior frontal and posterior superior temporal regions, including the auditory cortex. However, if bilectal story comprehension processing is similar to bilingual story comprehension, the crucial contribution of the anterior temporal lobes to text comprehension processes (cf. Perani et al., 1996) should be replicated. Specifically, this region is expected to show lower activation levels for monolectal participants when listening to High Alemannic than for Standard German (their L1), but equal activation levels for bilectal participants who are familiar with both varieties.

## Methods

The study was approved by the Ethics Commission of the University Hospital Freiburg and followed the principles of the Declaration of Helsinki.

### *Participants*

102 students and employees from the University of Freiburg (Germany) completed an extensive dialect questionnaire, developed to assess the dialect background and proficiency of potential participants. The Dialect Experience and Proficiency Questionnaire (DEAP-Q; Schmitt, 2017) is based upon the Language Experience and Proficiency Questionnaire by Marian, Blumenfeld and Kaushanskaya (2007) and the Language History Questionnaire (LEAP-Q; Li, Sepanski, & Zhao, 2006). Fifty questions were used to assess self-estimated dialect competence, dialect use of parents, proficiency in other acquired varieties or foreign languages, code-mixing and percentages of language/variety use. The test was implemented using q-set (Goldecker, 2017; [www.q-set.de](http://www.q-set.de)) and made available online via an access link. Additionally, participants' English proficiency level was tested via a web-based English test (Telc Company, [www.sprachtest.de/einstufungstest-englisch](http://www.sprachtest.de/einstufungstest-englisch)).

Based on the results of these assessments, participants were selected for inclusion in the fMRI study. Non-native speakers of German or bilinguals, as well as respondents who spoke an Upper German dialect other than High Alemannic, were excluded. Criteria for inclusion in the bilectal group were that the participant 1) was born and raised in the High Alemannic area, 2) had acquired High Alemannic and Standard German before the age of six, and 3) had at least passive, and preferably active knowledge of the dialect, 4) High Alemannic was regularly spoken in the family. Monolectals had to meet the following conditions: 1) born and raised in a Middle or Low German area, 2) no or only passive knowledge (i.e.,

comprehension) of a Middle or Low German dialect, 3) no passive or active knowledge of any High Alemannic or any other Upper German dialect, 4) dialects were not or only rarely spoken in the family.

Both groups showed an intermediate English level of B1 (range A2-B2) which was tested after all the other criteria were guaranteed.

The final sample of participants consisted of 40 people (20 women, 20 men;  $M = 23$  years,  $sd=3.7$ ). 20 of them were monolectals and 20 bilectals. Most of them were university students. All had finished schooling with or were close to the German ‘Abitur’, which is equal to the British A levels. They were all right-handed and showed no hearing or cognitive impairment, nor did any other reason prevent them from taking part in an fMRI study. Two bilectal participants had to be excluded from the analyses due to recording failures. Two further participants (one bilectal, one monolectal) were excluded due to head movement artefacts during the scans (see section on data preprocessing for more detail). Therefore the analyses were based on the data of 36 participants (17 bilectals, 19 monolectals). For their participation in the fMRI study, participants received course credits or they were paid 30 Euros.

### *Stimuli*

For the auditive stimuli 36 fairy tales from the Grimm Brothers’ collection (Grimm & Grimm, 2017) were selected and shortened to 200 words each. Based on the results of a pretest with 21 participants (10 women, 11 men;  $M = 27.12$  years;  $sd=3.12$ ) 24 fairy tales were selected so that they were unfamiliar, were rated as neutrally connotated, and only moderately exciting. All 24 fairy tales were then translated into High Alemannic by a native speaker of the traditional dialect. To ensure that the dialect texts were sufficiently comprehensible even for Standard German speakers, 51 participants (28 women, 23 men;  $M = 29.3$  years;  $sd=8.2$ ) coming from middle or northern German areas rated two further fairy tales translated and spoken in High Alemannic on a 5-point Likert scale (1=very easily comprehensible; 5=not comprehensible at all). The results showed that the comprehensibility of the stories was at an intermediate level ( $M=3.24$ ;  $sd=1.19$ ). Six short text passages of a Vietnamese fable were chosen for the baseline condition.

For each variety six different female native speakers were recruited. The speakers came from different geographical regions within the dialectal area. Their age ranged from 20 to 78 years. Every speaker read eight different stories which took them 60-80 seconds each, so that each story was spoken by two different speakers in each condition. For the dialect recordings

speakers were instructed to read ‘as if they would tell a story to a family member with whom they speak dialect’. For the Standard German recordings speakers were instructed to read ‘as if they would tell a story to an unknown person’ in order to induce clear standard articulation. Before recording, the speakers took some time to familiarize themselves with the stories. For the baseline condition we chose one female native speaker who read short text passages from a Vietnamese fable, assuming that voice recognition would not be relevant for a totally unknown and incomprehensible language. The readings were recorded in a quiet room, using the recording device H2 of the brand ‚Zoom‘. The sampling frequency was 44100 Hertz with a 24 bit resolution. Using this method, 96 recordings for the experimental conditions plus six Vietnamese recordings for the control condition were created. On average, recordings in the High Alemannic condition were 74 s long ( $sd=4.6$ ; range 64-79) and recordings in Standard German 71.8 s ( $sd=6.7$ ; range 61-79). Length differences can be ascribed to specific grammatical features of the dialect (e.g. analytic instead of the synthetic past tense). Two other control conditions (Bavarian and English) were also translated and recorded, but are beyond the scope of this paper (see Schmitt, 2017, for more detail).

A short yes-no-comprehension question was selected for each fairy tale, and recorded by one male speaker in Standard German. To ensure that the questions were appropriate, 36 independent participants (20 women, 16 men;  $M=22.17$  years,  $sd=3.36$ ) listened to all stories in Standard German and answered the question. The overall performance on the selected questions was 78% correct.

Counterbalancing lists were created in which each story was read by a different speaker, and each language/variety was used six times. Across lists, each story appeared in all languages/varieties, and was spoken by a younger and an older speaker. An excerpt is presented in Table 2. The experiment was programmed in Presentation ("Neurobehavioral Systems," [www.neurobs.com](http://www.neurobs.com), version 16.5).

--- insert Table 2 about here ---

To assess the participants’ attitudes towards the dialects, a short paper-pencil questionnaire was prepared. It contained 7-point Likert scales on which participants first rated the comprehensibility of the conditions (1=almost impossible to comprehend, 7=easily comprehensible), and the pleasantness of the variety (1=I do not like this dialect/language at all, 7=I like this dialect/language very much).

### ***Procedure***

The experiment was conducted at the Freiburg Brain Imaging Center (FBI) at the University Clinic Freiburg. Following written and oral instructions, participants gave their informed consent for the fMRI procedure. After being positioned in the scanner, a response pad was placed into their left hand. For the auditory presentation MR-compatible headphones of the brand *MR confon* were used. At the beginning of the experiment, a practice trial was presented, which was later excluded from the analysis, followed by the 24 story trials and six control trials of one of the counterbalancing lists. The order of the trials was pseudo-randomized. A trial sequence is shown in Figure 2. Each trial started with a beep to alert the participant to the presentation of the next story. After each text (except the Vietnamese text passages) a comprehension question was aurally presented. Participants had to wait for a beep before they could answer, and the response period ended after a maximum of five seconds, marked with another beep. After a pause of 15 seconds the next trial started.

----- insert Figure 2 about here -----

Following the experimental scans, participants were instructed to rest for another seven minutes, during which structural scans were recorded. Finally, all but one participant answered the short questionnaire outside of the scanner. The entire session took approximately 1.25 hours.

### ***MRI Data Acquisition and Preprocessing***

All scans were acquired with a 3T Siemens TIM TRIO Scanner. For functional scans a T2-weighted Echo Planar Imaging sequence was chosen. The whole brain was measured non-interleaved in 36 slices with  $3 \times 3 \times 3.6 \text{ mm}^3$  voxels and a TR of 2190ms. The experiment was divided into two blocks containing 12 experimental trials and three control trials each, with a short break in between. These functional scans lasted approximately 45 minutes total, and yielded about 1280 functional volumes per participant. After the functional scans structural scans were collected in 176 slices with  $1 \times 1 \times 1 \text{ mm}^3$  voxels and a TR of 2200 seconds. The processing of the imaging data and statistical analyses were performed using SPM8 (Wellcome Trust Centre for NeuroImaging, 2017c). For each participant the first five functional volumes were discarded due to signal saturation effects. After a spatial realignment an artefact control was conducted using the SPM toolboxes ArtRepair (Wellcome Trust Centre for NeuroImaging, 2017b) and tsdiffana (Wellcome Trust Centre for NeuroImaging, 2017a). As a result of this data check two participants were excluded, as their scans showed

too much movement artefacts (scaled variance > 5). Sequential coregistration and segmentation into grey and white matter and cerebrospinal fluid (CSF) plus a normalization to the MNI (Montreal Neurologic Institute) standard space (Evans et al., 1993) followed. At last, to adjust for anatomical differences between participants, the functional volumes were spatially smoothed with an 8-mm Gaussian kernel.

### ***Behavioral Data Analyses***

For the analyses of the reaction times and the response accuracy a ANOVA with the within-subject factor ‘language’ (Standard German, Alemannic) and the between-subject factor ‘group’ (bilectal, monolectal) was conducted. Vietnamese was excluded as there were no test questions for this condition.

Additionally, Pearson correlations between neuroimaging data and the behavioral data were calculated.

### ***fMRI Data Analyses***

For all participants the hemodynamic responses were time-locked to the stimulus onset and the duration of each condition and convolved with the canonical hemodynamic response function of SPM8. Whole-brain-analyses were done in a 1<sup>st</sup> level analysis using a general linear model with the five regressors Standard German, High Alemannic, Vietnamese, and the other two control conditions (Bavarian and English) A high pass filter of 256 seconds was used to filter out low frequent interfering signals.

For the present analysis, two contrasts of interest were calculated. First, all intelligible conditions were compared to the control condition (Standard German and High Alemannic, as well as the two other controls vs. Vietnamese). Second, Standard German was compared with the High Alemannic dialect. Results involving the other conditions are reported in Schmitt (2017).

In the second level analysis across the entire group of participants, one-sample t-tests in both directions were performed using the contrast images created at the first (single-participant) level. For detecting group differences between bilectals and monolectals, two-sample t-tests were conducted.

For the analyses of the fMRI data, a significance level of  $p < .05$  (uncorrected) on the cluster level and a peak-level of  $p < .001$  (uncorrected) were chosen, with an extent threshold of 120 voxels. In the Tables, the clusters are marked that were still significant when using the more conservative FDR (false-discovery rate) correction. The peak coordinates were mapped

onto Brodmann areas (BA) using the online tool ‘MNI to Talairach Coordinate Converter’ (Lacadie, Fulbright, Arora, Constable, & Papademetris, 2014). With the help of the web based ‘Brodmann’s Interactive Atlas’ (Bernal & Perdomo, 2008) and the ‘Co-Planar Stereotaxic Atlas of the Human Brain’ (Talairach & Tournoux, 1988) the Brodmann areas were mapped onto structural areas.

Subsequent Region of Interest (RoI) analyses were performed using *marsbar* (Brett, Anton, Valabregue, & Poline, 2002). The RoI was defined as a sphere of five mm radius around the peak coordinates of the left anterior temporal lobe (see Results section). The average percent signal change in this ROI was then extracted for each participant and each condition.

A time course analysis was conducted for the two conditions High Alemannic and Standard German. Using *rfxplot* (Gläscher, 2009), the percent signal change was extracted for each scan and each participant, and averaged across the trials in each of the two conditions. The time window was 61 seconds from the onset of the stories. For further statistical comparison, the window was further subdivided into five different periods (beginning, period 2, period 3, period 4, story ending). Each section contained about 13 seconds, including approximately six scans (given the TR of 2190ms).

## Results

### ***Behavioral Data***

The overall percentage of correctly answered comprehension questions for the Standard German and the Alemannic conditions was 82.9% (85.0% for the bilectals, 81.3% for the monolectals). The percentage of correct answers for the Standard German condition was 85.6% (bilectals) and 87.7% (monolectals). For the High Alemannic condition the percentage of correct answers was 84.2% (bilectals) and 74.5% (monolectals). There was no effect of participant group ( $F(1,34)=0.89$ ;  $p = .35$ ), condition ( $F(1,34)=2.2$ ;  $p = .15$ ) and no interaction effect ( $F(1,34)=1.08$ ;  $p = .31$ ). Thus, the dialect condition was intelligible even for Standard German speakers.

The response times for the Standard German and the Alemannic conditions were 1.23 s on average ( $sd=.5$ ) (1.2 s for the bilectals ( $sd=.49$ ) and 1.24 s for the monolectals ( $sd=.51$ ). The bilectals required on average 1.2 s ( $sd=.45$ ) for the Standard German condition and 1.25 s ( $sd=.54$ ) for the High Alemannic condition. The monolectals required on average 1.16 s ( $sd=.45$ ) for the Standard German condition and 1.31 s ( $sd=.57$ ) for the High Alemannic

condition. There were neither significant main effects (group:  $F(1,34)=.00$ ;  $p = 1.0$ ; condition:  $F(1,34)=1.17$ ;  $p = .29$ ), nor an interaction ( $F(1,34)=.00$ ;  $p = 1.0$ ).

In contrast to the accuracy rates, the comprehensibility ratings varied. While Standard German was rated as perfectly comprehensible ( $M=6.97$ ,  $sd=.17$ , range 6-7), High Alemannic was less easily comprehended ( $M=5.03$ ,  $sd=1.8$ , range 1-7). The bilectal participants rated the High Alemannic condition ( $M=6.6$ ,  $sd=.51$ , range 6-7) as well as the Standard German condition ( $M=6.9$ ,  $sd=.25$ , range 6-7) as perfectly comprehensible. In contrast, the monolectals rated the Standard German condition also as perfectly comprehensible ( $M=7.0$ ,  $sd=.0$ , range 7-7), but the High Alemannic condition only as moderately comprehensible ( $M=3.7$ ,  $sd=1.45$ , range 1-6). There were highly significant main effects of participant group ( $F(1,33)=50.1$ ;  $p < .0001$ ) and condition ( $F(1,33)=91.56$ ;  $p < .0001$ ), as well as an interaction between the two ( $F(1,33)=57.7$ ;  $p < .0001$ ). Post hoc t-tests revealed a significant group difference for the High Alemannic condition ( $t(33)=7.42$ ;  $p < .001$ ), but not for the Standard German condition ( $t(33)=-1.1$ ;  $p = .28$ ). Within-group analyses revealed a significant difference between Standard German and High Alemannic both for the bilectal ( $t(15)=3.0$ ;  $p < .01$ ), as well as the monolectal participants ( $t(18)=9.8$ ;  $p < .001$ ).

The pleasantness ratings were comparable to the comprehensibility ratings. Standard German was rated as more pleasant ( $M=6.29$ ,  $sd=1.05$ , range 2-7) than High Alemannic ( $M=5.14$ ,  $sd=1.78$ , range 2-7) in the group as a whole. The bilectal participants rated the High Alemannic condition ( $M=6.38$ ,  $sd=1.36$ , range 2-7) as well as the Standard German condition ( $M=6.19$ ,  $sd=.83$ , range 4-7) as pleasant. The monolectals rated the Standard German condition as pleasant as well ( $M=6.37$ ,  $sd=1.21$ , range 2-7), but the High Alemannic condition as only moderately pleasant ( $M=4.11$ ,  $sd=1.41$ , range 2-7). Again, the main effects of participant group ( $F(1,33)=12.18$ ;  $p < .001$ ) and condition ( $F(1,33)=12.59$ ;  $p < .001$ ), as well as the interaction ( $F(1,33)=17.54$ ;  $p < .0001$ ) were reliable. Within-group analyses revealed no differences between the Standard German and the High Alemannic ratings for the bilectals ( $t(15) < 1$ ; n.s.), whereas there was a significant difference between these two conditions for the monolectals ( $t(18)=4.88$ ;  $p < .001$ ).

### ***Neuroimaging data***

The results of the whole-brain analyses are displayed in Figure 3 and 4 and Tables 3 and 4.



### ***Intelligible languages/varieties versus unintelligible language***

The contrast intelligible languages/varieties (Standard German, English, Bavarian, High Alemannic) > unintelligible language (Vietnamese) revealed significant activations within the ELN (Ferstl et al., 2008; see Figure 3). Most prominent were bilateral activations along the superior temporal sulcus. In particular, peak activations were found in the left middle temporal gyrus (MTG, (1)) extending to the anterior temporal lobe (aTL), in the right aTL (2) and in the superior temporal gyri bilaterally (STG, (3)). In the frontal lobe the left inferior frontal gyrus (IFG, (4)) mainly the pars opercularis and triangularis were significantly activated as well as the PMA (5). Activations were also found in the right cerebellum (6) (see Table 3).

----- insert Table 3 and Figure 3 here -----

### ***Standard German versus High Alemannic***

The contrast of Standard German > High Alemannic revealed a significant region of activation in the right temporo-parietal junction, including the posterior STS and reaching into the angular gyrus (AG) (7). A small region in the right aTL failed to reach cluster-level significance. The inverse contrast High Alemannic > Standard German revealed significant activations primarily outside the ELN: in the right STG (3) and the left Heschl's gyrus (8), in the right anterior MFG (9), left and right PMA/SMA (5) and the Cerebellum (6). Finally, activations were found in the supplementary motor area (SMA) (10) and in the visual cortex (see Figure 3 and Table 4).

----- insert Table 4 -----

### ***Group Comparison: Standard German versus High Alemannic***

For investigating the influence of bilingualism the group comparison between Standard German and High Alemannic was of special interest. As Figure 3 shows, the contrast Standard German versus High Alemannic (for bilinguals versus monolinguals) revealed a significant activation in the left aTL (2) (see also Table 5). The inverse contrast did not yield any significant clusters.

A RoI analysis for the left aTL (-48, 2, -28) was conducted and the results are displayed in Figure 4. The peak coordinate was chosen as a result of the whole brain group analysis (see above). The results of an ANOVA confirm that aTL activation depended on the language presented ( $F(1,34)=4.17$ ;  $p < .05$ ), and this effect interacted with participant group

( $F(1,34)=12.22$ ;  $p < .001$ ). Bilectal participants showed larger percent signal change in the aTL than monolectal participants. Post-hoc comparisons revealed a significant group difference for High Alemannic ( $t(34)=3.0$ ;  $p < .05$ ), but not for Standard German ( $t(34)=-0.72$ ; n.s.). Significantly more activation in the left aTL for Standard German than for High Alemannic was found for the monolectal group ( $t(18)=-3.29$ ;  $p < .005$ ). No such difference could be found for the bilectal group ( $t(16)=-1.51$ ; n.s.).

----- insert Figure 4 here -----

### ***Time Course Analysis***

For the time course analysis (see Methods), the same peak coordinates of the left anterior temporal region were taken. The results are shown in Figure 5.

----- insert Figure5 here -----

Figure 5 shows a continuous increase in the evoked response for both groups, leveling out approximately in the middle of the stories. Consequently, the ANOVA including language, participant group and time period yielded a highly significant main effect of time period ( $F(4,136)=35.9$ ;  $p < .0001$ ). The difference between bilectal and monolectal activation levels for High Alemannic was reflected in the interaction language x participant group ( $F(1,34)=10.7$ ;  $p < .005$ ). Post hoc t-tests showed significantly more aTL activation for the bilectals in the 2<sup>nd</sup> to 4<sup>th</sup> time period ( $t(34) > 2.2$ ;  $p < .05$ ). There were no other significant effects.

### ***Correlations between behavioral and neuroimaging data***

To test whether the individual differences in aTL activation might be related to cognitive or emotional factors, correlation analyses with behavioral measures were conducted. For this analysis, only the High Alemannic condition was considered. The variables included were: the percent signal change (PSC) in the left aTL (taken from the RoI analysis), the accuracy and reaction times (RTs) for the yes-no-questions, and the individuals' ratings of comprehensibility and pleasantness. Pairwise correlations between these variables were calculated for the two groups separately. For the bilectal participants aTL activation correlated with the pleasantness rating ( $r=.71$ ;  $p < .002$ ). Higher aTL activation was found for participants who liked the dialect more. A negative correlation between accuracy and RTs ( $r=-.59$ ;  $p < .01$ ) shows that participants with higher accuracy responded faster.

The monolectal participants showed a different pattern. For this group, pleasantness ratings for High Alemannic were more varied and they were correlated both with comprehensibility ( $r=.59$ ;  $p < .01$ ) and RTs ( $r=-.48$ ;  $p < .05$ ). The latter two variables were also related ( $r=-.59$ ;  $p < .01$ ). Importantly, aTL activation correlated also highly significantly with pleasantness ratings ( $r=.71$ ;  $p < .001$ ). Figure 6 illustrates the relationship between aTL activation and pleasantness ratings for both groups.

----- insert Figure 6 here -----

To further confirm the relationship between the pleasantness ratings and the aTL activation, multiple regressions were calculated for both groups separately. PSC scores in the left aTL were predicted by RTs and error rates for the comprehension questions, and the ratings of comprehensibility and pleasantness of the dialect condition. For the bilectal group, this multiple regression was significant overall ( $F(4,11) = 3.8$ ,  $p < .05$ ), and the only variable significantly contributing over and above the others was the pleasantness rating ( $T = 3.7$ ,  $p = .003$ ; all other  $T$ -values  $< 1.12$ ). For the monolectal group, the results were very similar. The overall analysis was highly significant ( $F(4,14) = 6.4$ ,  $p = .004$ ), with unique variability again explained by the pleasantness ratings ( $T = 4.4$ ,  $p = .001$ ), but not by the other variables (error rates:  $T = -1.8$ ,  $p = .09$ ; RTs:  $T = -.3$ ; comprehensibility ratings:  $T = -1.3$ ).

## Discussion

The present study investigated auditory text comprehension in High Alemannic dialect, as spoken in the South-West of Germany, and in Standard German in bilectal and monolectals listeners. During an fMRI scan, participants listened to fairy tales read in the two varieties. The unknown language Vietnamese served as a baseline. As, to our knowledge, this study is the first neurodialectal fMRI study on the text level, the hypotheses were based on results from research on bilingual text comprehension.

Despite the length of the stories, comparison of all comprehensible conditions to the baseline condition (Vietnamese) yielded an activation pattern closely resembling that of previous studies on text comprehension (e.g., Xu et al., 2005; see Ferstl et al., 2008). In particular, there was an extended activation along the entire extent of the temporal lobes bilaterally, posteriorly reaching into the inferior parietal cortex. In the left frontal lobe, there was activation in the left inferior frontal gyrus (BA44/45) and the premotor area (PMA) in the dorsal precentral sulcus. Both of these regions were also described in the meta-analysis by

Ferstl et al. (2008) for a global contrast comparing language comprehension to a low level baseline. Finally, the contra-lateral (i.e., right-sided) cerebellum also responded to intelligible language. The lack of activation in dorso-lateral prefrontal regions related to task difficulty, are in line with studies using auditory stimuli and low task demands (e.g., Xu et al., 2005). Although some researchers recommend a trial duration of less than 35 seconds to avoid signal loss due to low-frequency noise (Poldrack, Mumford, & Nichols, 2011), the present results converge with those of previous research. This finding confirms the suitability of the experimental paradigm, and in particular, of the use of extended stories for studying language processing in context.

### ***Bilectal story comprehension***

Listening to High Alemannic, when compared to Standard German, elicited a very large, connected cluster of activation, encompassing both superior temporal lobes as well as the supplementary motor area (SMA). The temporal activations reached from the very anterior temporal lobes across the entire length of the superior temporal gyri. In the left hemisphere, the maximum peak lay in the auditory cortex (Heschl's gyrus). These results suggest that for the dialect variety, unfamiliar to half of the participants, auditory perception and phonological processing were more difficult than for Standard German. This result is in line with findings from ERP studies on dialect comprehension that show immediate effects of phonetic or phonological features in dialect comprehension (e.g., Brunelliere et al., 2011; Conrey, et al., 2005; Lanwermyer et al., 2016). Additional activations in the right cerebellum and the PMA bilaterally were found. Finally, an increased SMA activation, paired with an active region in the left putamen might be interpreted as related to motor processes, but is not readily interpretable in the context of the present experiment.

The reverse contrast, comparing Standard German to High Alemannic, resulted in higher activation in the right temporo-parietal junction (TPJ, pSTS/AG) for the Standard German condition. This region has been related to Theory-of-Mind processes (e.g., Saxe, Carey & Kanwisher, 2004), which are often studied using narrative language materials. Since fairy tales are stories revolving around the intentional behavior of the protagonists, contributions of the ToM network to comprehension are plausible. However, the conclusion, that comprehension difficulties in High Alemannic prevented participants from engaging in these higher-level interpretations are admittedly post hoc and could be equally applied to other subprocesses of comprehension.

The main finding was obtained in the group comparison between monolectal and bilectal listeners. In line with fMRI studies on bilingual text comprehension (Perani et al. 1996; 1998; Hesling et al. 2012), the left anterior lobe emerged as the only region differentially activated in both groups. While the left aTL was highly activated for bilectal listeners in both varieties, monolectal participants engaged this region more strongly when listening to Standard German, but less for High Alemannic. Interestingly, there were no corresponding activation differences in other brain regions. For instance, the extended activations in the superior temporal lobes, found in the whole group analysis, did not differ between groups, and neither were there activation differences in brain regions related to lexico-semantic processing (e.g., BA 45, ITG, or pSTS). Finally, both participant groups activated medial regions (dmPFC, PCC) to a similar degree, indicating that both groups engaged in comparable inferencing processes in both varieties.

### ***Anterior temporal lobe and text comprehension***

That the left anterior temporal lobes are often involved in higher level language comprehension has been shown numerous times. However, there is some debate about the functional attribution of this region (see Wong & Gallate, 2012, for review), including Theory-of-Mind (Frith & Frith, 2003), domain specific conceptual processing, or as a semantic hub (Rogers, Lambon-Ralph, Garrard et al., 2004), in which multimodal inputs are integrated. In neuroimaging studies on language comprehension, aTL activation is reliably observed during the processing of sentences, but not word lists (e.g., Stowe, Haverkort, & Zwarts, 2005; Xu et al., 2005). While there are many studies using text materials that also show this activation, it is not specific to language beyond the sentence level (e.g., Xu et al., 2005). In the framework of text comprehension theories, it can therefore be interpreted as facilitating the combination of words into phrases (Bemis & Pyllkkänen, 2013; Brennan & Pyllkkänen, 2017) or idea units (cf. propositionalization, Kintsch, 1998).

If this attribution is correct, we can conclude that the most obvious differences of processing by more or less proficient listeners lie in this sub-process of facilitating linguistic combination or propositionalization, rather than in more basic (e.g., phonology, lexical access) or more overarching functions (such as situation model building or inferencing across sentence boundaries). In the present study, the whole-group analysis yielded evidence for an impact of basic linguistic functions for both groups of participants. Comprehension of High Alemannic activated a large network of brain regions, including perceptual areas and the perisylvian language cortex. On the other hand, the monolectal participants' good

performance on the comprehension questions suggests that they were also able to establish a situation model of the dialect texts (Kintsch, 1998). Based on the linguistic proximity of Standard German and High Alemannic, Standard German (their L1) could be used as a comprehension bootstrap (cf. Tracy & Gawlitzek-Maiwald, 2000, for L2 acquisition). Thus, despite their low proficiency in the dialect, monolectal listeners may have used a comprehension strategy that skips the text base level (Kintsch, 1988) in favor of a more elaborate situation model representation.

An alternative role of the aTL has been discussed by Wong & Gallate (2012). In their review of aTL functions they refer to social and emotional functions: aTL activation increases, for instance, during ToM processing, when processing familiar versus unfamiliar faces, emotional versus neutral images or stories (Ferstl & von Cramon, 2007), or when parents view videos of their own children as compared to others'. In the present study, an influence of emotional factors on aTL activity in the left aTL was supported by the results of correlation analyses. In bilectals as well as in monolectals, the pleasantness ratings for the High Alemannic dialect were correlated with the extent of aTL activation. Participants who liked the dialect more, showed more aTL activation for the High Alemannic condition. In contrast, neither the accuracy scores on comprehension questions, nor the comprehensibility ratings were related to either of these variables. While this result is consistent with an influence of affective factors, the correlations do not allow a causal attribution. In addition, the relationship between comprehensibility ratings and pleasantness ratings for the monolectal groups shows that the cognitive and affective factors are not completely separable. Further research is needed in which emotional attitudes toward the dialect are assessed in more detail (cf. Schmitt, 2017), and groups with different emotional attitudes but comparable proficiency are directly compared.

### ***Active Dialect Competence***

Participants were selected based on a questionnaire assessing language background and dialect competence (DEAP-Q, Schmitt 2017). In the tested population of young adults, it was rather difficult to find bilectal participants with active dialect knowledge, and inclusion in the group was therefore also based on passive dialect competence (as necessary for the processing of the text stimuli spoken in the traditional dialect) and dialect exposure in the family context. This observation is in line with general sociolinguistic changes in Germany, which include a decline of traditional dialects in contact with the standard language (Auer, 2011; Auer & Schwarz, 2014; Auer & Spiekermann, 2011). As the importance of Standard German or

standard-near ways of speaking (Auer, 2011) increases, active dialect knowledge of younger speakers decreases (e.g. Auer, Breuninger, Huck, & Pfeiffer, 2015).

An open question is whether the strong activation differences between High Alemannic and Standard German would be replicated in a group of participants with more active dialect proficiency. One possibility would be to test older participants in rural areas (cf. Lanwermyer et al., 2016). Another possibility is to investigate dialect text comprehension in Swiss German speakers, where dialect loss is absent and dialect/standard-levelling is minor.

Even though the use of the traditional dialect in the younger population in Germany is on the decline, fMRI revealed systematic differences in the neuroanatomy of dialect text processing in young bilingual and monolingual speakers. The convergence of the present results with studies on bilingual text comprehension, such as higher left aTL activation for the more familiar language or variety, suggests that the linguistic status of a variety as ‘foreign language’ or a ‘foreign dialect’ does not have a strong impact on the type of comprehension processes induced. More important are proficiency and attitudes.

### ***Conclusions***

The present study on story comprehension in bilingual and monolingual speakers converged in large parts with previous studies on bilingual language comprehension. Presenting narrative texts, rather than stimuli on the word or sentence level, allowed us to evaluate the effects of dialect not only on the word or sentence level, but also on language comprehension in context. An increased activation in the left aTL during the processing of dialect stories as compared to Standard German stories depended on the listeners’ linguistic background. While the exact function of this region for language processing is still under debate, these results confirm the role of aTL in text comprehension processes and add to our understanding of the neuronal correlates of dialect comprehension.

## Author Notes

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## Disclosure of Interest

The authors report no conflict of interest.



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Table 1. Differences between Standard German (SG) and the dialect variety High Alemannic (HA). Shown are characteristic examples on various linguistic levels.

Examples of differences between Standard German (SG) and High Alemannic (HA)				
Linguistic Level	Variety	Examples	Phenomenon	English Translation
Phonology	SG	Kind	Word initial [k] (SG)= [x] (HA)	child
	HA	Chind		
Morphology	SG	Kind <b>chen</b> /Kind <b>lein</b>	Word final diminutive formation '-chen/-lein (SG) = '-li' (HA)	little child
	HA	Chind <b>li</b>		
Syntax <sup>2</sup> / Morphosyntax <sup>1</sup>	SG	Das Kind, <b>das</b> <sup>1</sup> seinen Paten <b>besuchte</b> <sup>2</sup> , ist 6 Jahre alt.	<sup>1</sup> relative pronoun 'der, die das' ( <i>who/that</i> ) (SG) in HA expressed by the question marker 'wo' ( <i>where</i> )  <sup>2</sup> past tense (SG) not existing in HA, use of present perfect in HA	The child, who visited his/her godfather, is 6 years old.
	HA	S Chind, <b>wo</b> <sup>1</sup> si Göddi <b>bsöcht hätt</b> <sup>2</sup> , isch 6 Johr alt.		
Lexicon	SG	Pate	HA lexicon contains dialect specific words	godfather
	HA	Göddi		

Table 2. Stimulus examples in Standard German and High Alemannic: the first two sentences of the fairy tale ‘The fox and the geese’.

English translation	The fox once came upon a meadow where a lot of nice fat geese were sitting. He laughed and said: “I’m just in time; you’re all sitting together so nicely, I can eat you one after the other.” [...]
Standard German	<b>D</b> er Fuchs kam einmal auf eine Wiese, wo eine Schar schöner fatter Gänse saß. Da lachte er und sprach: „Ich komme ja wie gerufen, ihr sitzt so schön beisammen, da kann ich eine nach der andern fressen.“ [...]
High Alemannic	<b>D</b> Fugs isch emool uf e Madde chuu, wuu ne Herd schöni, faischedi Gäns ghogd isch. No hed er glachd un gsaid: „Ich chum jo wie gruefe, iir hoge so näd bynand, no chaan i aini noch der andre frässe.“ [...]



**Table 3.** Significant brain activations with  $p < .001$  (uncorr.) on the peak level and  $p < .05$  (uncorr.) on the cluster level, for the contrast comparing the intelligible languages/varieties to the unknown language Vietnamese (control condition). All clusters marked with an asterisk are also significant using FDR correction ( $p < .05$ ). The label in the rightmost column refers to the numbers of the regions in Figure 3.

Intelligible Stories > Unintelligible Control Condition									
Cluster Size k	Cluster: p(unc)	T	MNI Coordinates			Hemisphere	Brain Area	BA	Label
			x	y	z				
* 4924	.0001	12.16	-54	-38	2	left	MTG	21	1
		11.27	-56	-12	-10	left	MTG	21	1
		10.83	-56	-2	-14	left	STG	22	3
* 2773	.0001	8.27	54	6	-18	right	aTL	38	2
		8.20	52	-18	-6	right	STG	22	3
		7.90	46	12	-24	right	aTL	38	2
* 473	.000	6.80	-52	20	18	left	IFG / pars opercularis	44	4
		5.66	-54	28	6	left	IFG / pars triangularis	45	4
* 228	.009	6.13	-42	0	50	left	PMA	6	5
* 334	.002	5.64	20	-76	-36	right	Cerebellum	-	6
		5.32	18	-70	-26	right	Cerebellum	-	6

*Note.* MTG = middle temporal gyrus; STG = superior temporal gyrus; aTL = anterior temporal lobe; IFG = inferior frontal gyrus; PMA = primary motor cortex; BA = Brodmann Area.

**Table 4.** Significant brain activations with  $p < .001$  (uncorr.) on the peak level and  $p < .05$  (uncorr.) on the cluster level (extent  $> 120$  voxels), for the contrast comparing Standard German to High Alemannic. Clusters that are significant using FDR correction ( $p < .05$ ) are marked with an asterisk. The label in the rightmost column refers to the numbers of the regions in Figure 3.

Standard German (S) vs. High Alemannic (A)									
S > A									
Cluster Size	Cluster p(unc)	Peak T	MNI Coordinates			Side	Brain Area	BA	Label
			x	y	z				
* 651	.0001	4.75	54	-60	18	right	pSTS / AG	39	7
		4.57	42	-54	20	right	pSTS / AG	39	7
		3.83	46	-46	24	right	pSTS / AG	40	7
A > S									
* 10682	.0001	9.79	-4	2	64	left	SMA	6	5
		8.92	-64	-22	8	left	STG / Heschl's Gyrus	41	8
		8.33	60	-2	-4	right	STG	22	3
* 946	.0001	6.47	36	-64	-24	right	Cerebellum	-	6
		5.14	22	-60	-22	right	Cerebellum	-	6
		4.38	16	-52	-24	right	Cerebellum	-	6
* 649	.0001	5.11	-24	-62	-24	left	Cerebellum	-	6
		4.13	-24	-58	-32	left	Cerebellum	-	6
		3.99	-8	-54	-14	left	Cerebellum	-	6
124	.034	4.76	-50	-4	42	left	PMA	6	5
		3.84	-46	0	52	left	PMA	6	5
121	.036	4.65	52	-2	46	right	PMA	6	5
156	.020	4.41	50	42	10	right	anterior MFG	46	9
172	.015	4.02	22	-80	4	right	Visual cortex	17	-
		3.91	28	-64	2	right	outside BAs / WM	-	-
		3.82	34	-52	2	right	outside BAs / WM	-	-

Table 4 (continued).

S > A: Monolectal Group vs. Bilectal Group									
160	.018	5.06	-48	2	-28	left	aTL	38	2
		3.51	-38	2	-28	left	outside BAs / WM	-	-

*Note.* AG = angular gyrus; STG = superior temporal gyrus; SMA = supplementary motor area; PMA = primary motor cortex; MFG = middle frontal gyrus; aTL = anterior temporal lobe; WM = white matter; BA = Brodmann Area.

## Figure Captions

Figure 1. Map of the geographical regions in which Upper German dialects are spoken. The one discussed in this paper is High Alemannic (5) as it is spoken within the German border.

Source:

[https://upload.wikimedia.org/wikipedia/commons/thumb/3/3f/Upper\\_German\\_Languages.PNG/516px-Upper\\_German\\_Languages.PNG](https://upload.wikimedia.org/wikipedia/commons/thumb/3/3f/Upper_German_Languages.PNG/516px-Upper_German_Languages.PNG)

Figure 2. Trial sequence.

Figure 3. Renderings of the main results of the fMRI study. The exact coordinates of the numbered regions are shown in Tables 3 and 4. The numbers refer to: MTG (1); aTL (2); STG (3); IFG (4); SMA/PMA (5); cerebellum (6); pSTS/AG (7); Heschl's gyrus (8); anterior MFG (9).

Figure 4. Signal change in the aTL (peak coordinates: -48, 2, -28) for the conditions Standard German and High Alemannic for both groups (Vietnamese is just displayed for ease of comparison). Error bars denote one standard error of the mean, and arrows indicate the results of post-hoc t-tests.

Figure 5. The time course of left aTL activation. The upper panel displays the percent signal change for High Alemannic texts, the lower panel for Standard German texts. The hatched areas indicate significant activation differences between mono- and bilingual participants.

Figure 6. Scatterplot illustrating the relationship between left aTL activation and the individuals' pleasantness ratings for the High Alemannic dialect (1=I do not like this dialect/language at all, 7=I like this dialect/language very much).

Figure 1



Figure 2

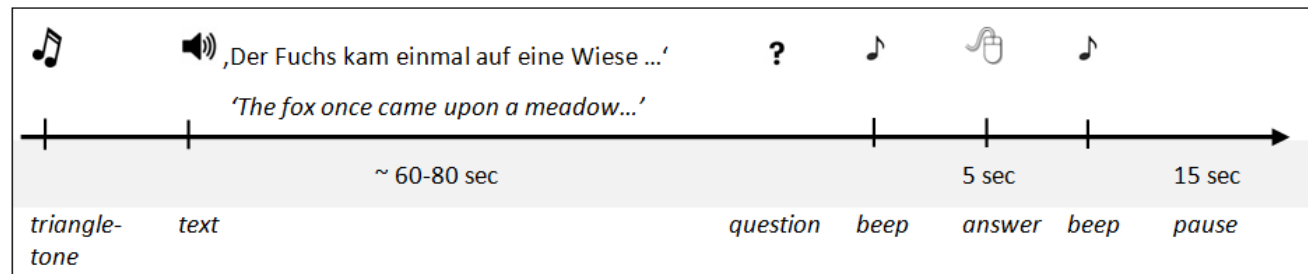


Figure 3

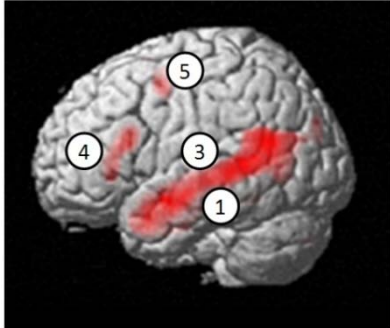
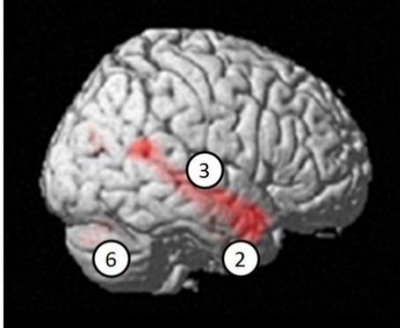
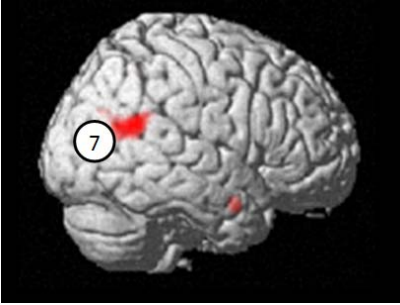
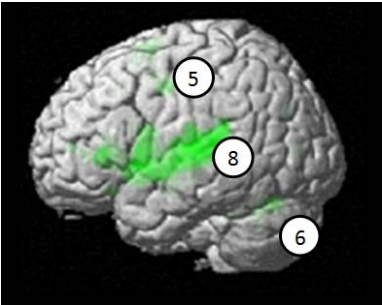
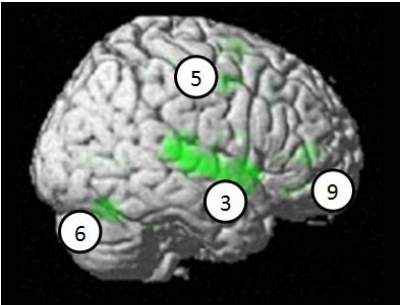
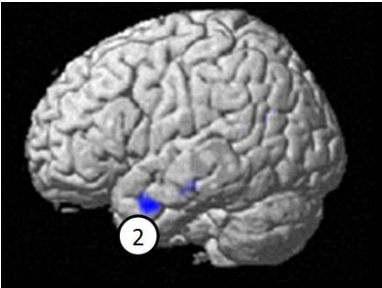
Contrast	Left Hemisphere	Right Hemisphere
Standard German, English, Bavarian, High Alemannic > Vietnamese		
Standard German > High Alemannic	no significant activations found	
High Alemannic > Standard German		
High Alemannic > Standard German (bilectals vs. monolectals)		no significant activations found

Figure 4

## Percent Signal Change in left aTL

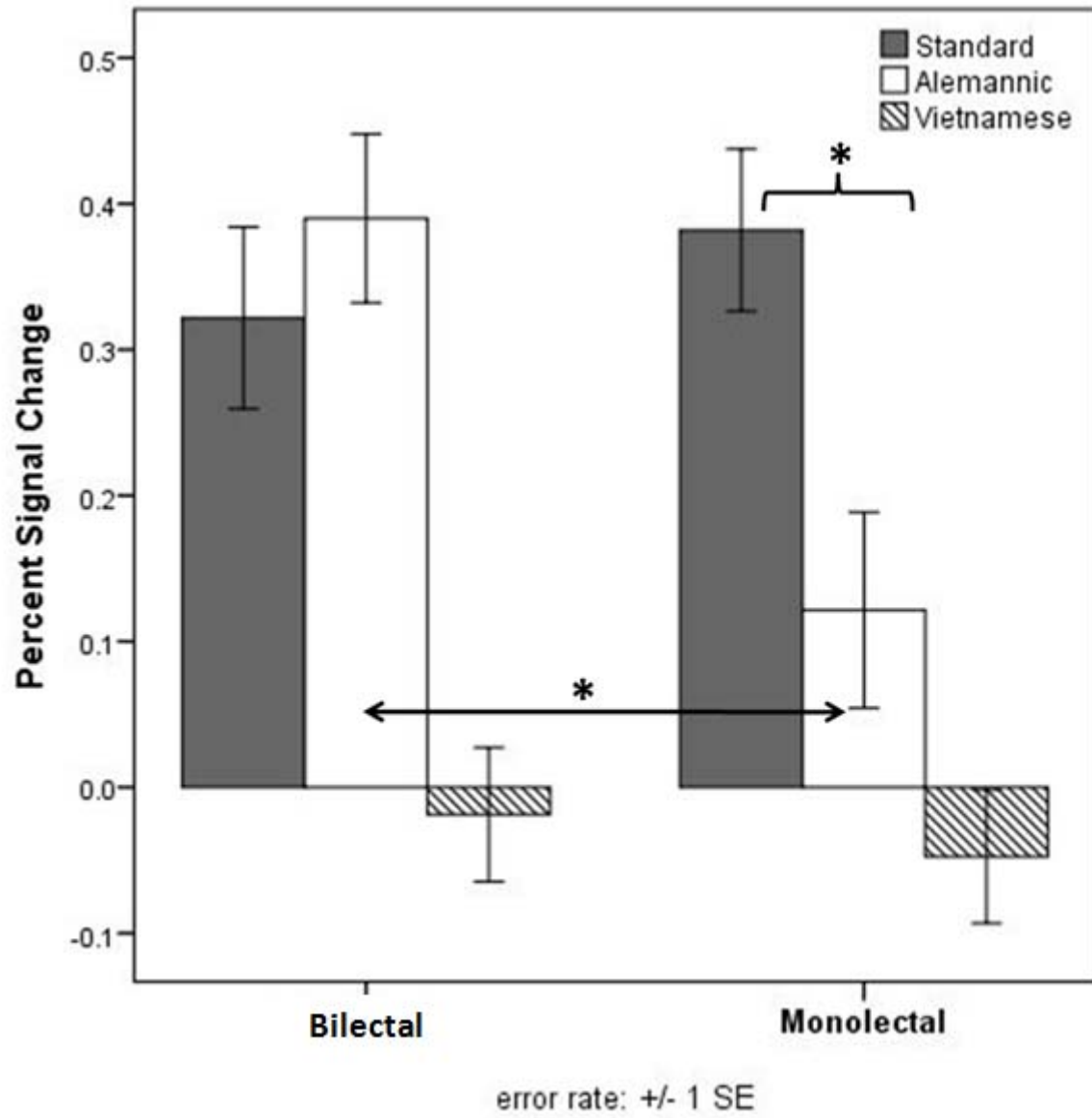




Figure 5

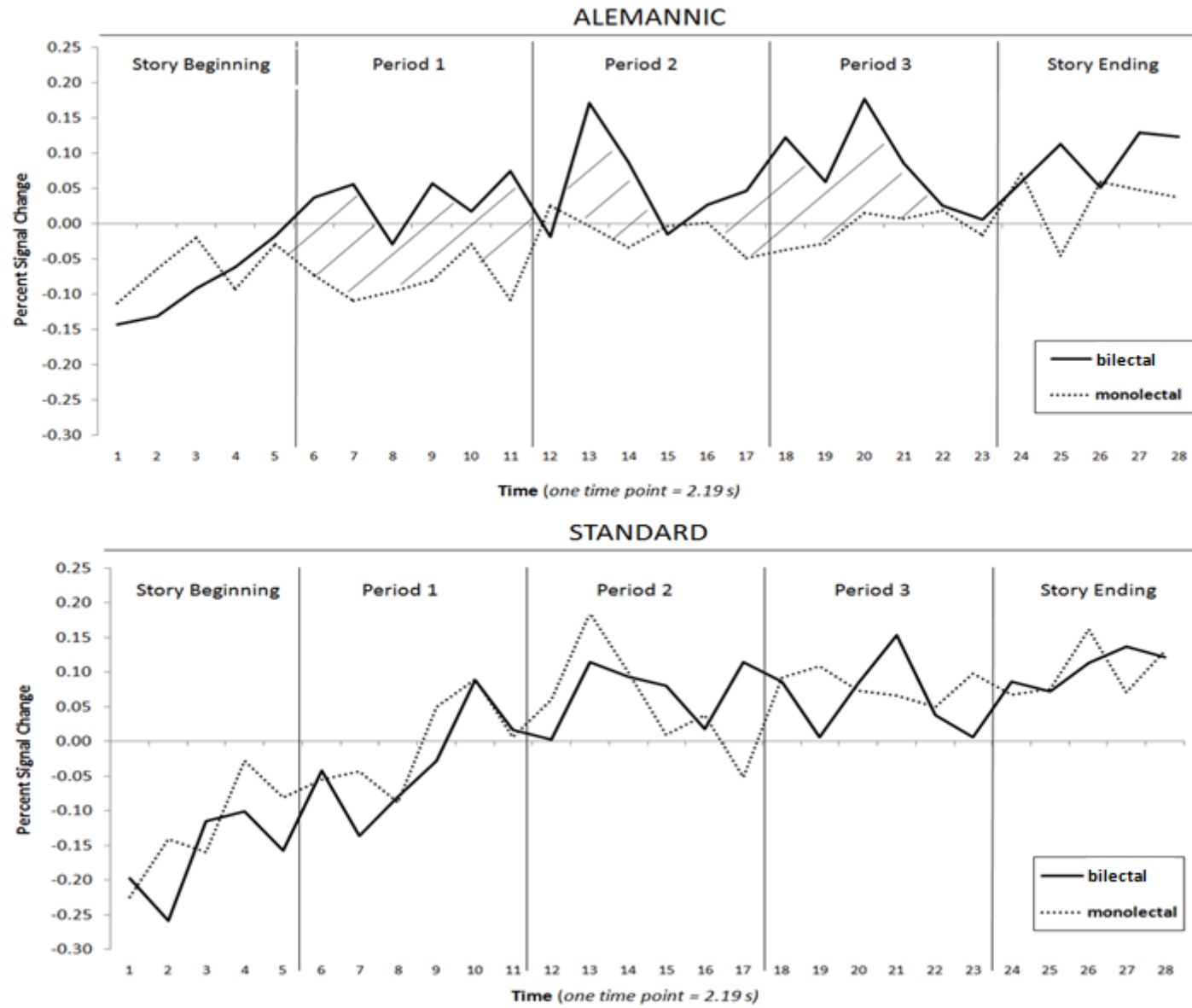


Figure 6

