# Neural mechanisms of linguistic mismatch in adults and children based on dialect familiarity and the impact of speaking Swiss German dialect on early reading and spelling acquisition

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*For Edna, Grossvati and Joshua*

Amicitiae nostrae memoriam spero sempiternam fore.

– Cicero

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# Summary

This PhD thesis examines neural mechanisms of linguistic mismatch in adults and children based on dialect familiarity and the impact of speaking Swiss German (CHG) dialect on early reading and spelling acquisition in Standard German (StG).

Study 1 investigated familiarity effects for dialect-based phonological processing in adults and employed an EEG-based MMN paradigm with pseudowords. MMN ERP measures revealed that a higher degree of familiarity with dialect-specific allophonic variants impacted neural processing efficiency to the extent that less familiar variants demanded more wide-spread activation processes.

Study 2 investigated how familiarity with dialect-specific pronunciation and lexicality of spoken words impacted phonological and semantic processing at the neural level in CHG and StG native children, shortly before literacy acquisition in school. Results revealed a semantic mismatch (N400-LPC) effect for neural processing of unfamiliar words, but not for pronunciation variants (only LPC).

Study 3 investigated how speaking CHG dialect (together with other variables) impacted reading and spelling learning after one year of formal instruction in school. Although no differences in Grade 1 reading and spelling were found between groups of children with different CHG exposure, SEM revealed that high CHG exposure was negatively associated with Grade 1 spelling and reading, when statistically controlling for early literacy-related-skills.

# Zusammenfassung

Diese Dissertation befasst sich mit den neuronalen Mechanismen von sprachlichen Nicht-Übereinstimmungen bei schweizerdeutschem Dialekt (CHG) und Hochdeutsch (StG). Ferner untersucht sie den Einfluss von CHG Dialekt auf den frühen Lese-/Rechtschreiberwerb.

Studie 1 untersuchte dialektbasierte Vertrautheitseffekte bei der phonologischen Verarbeitung bei Erwachsenen mittels EEG und verwendete dabei ein MMN Paradigma mit Pseudowörtern. Das MMN EKP wies eine höhere Verarbeitungseffizienz beim vertrauten Laut auf und zeigte, dass der weniger vertraute Laut breitere neuronale Aktivierungsprozesse erforderte.

Studie 2 untersuchte auf der neuronalen Ebenen wie vertraut CHG-sprechende Kinder mit der StG-spezifischen Aussprache und dem StG-Vokabular sind kurz vor der Einschulung. Die Ergebnisse zeigten, dass StG-Wörtern, die in CHG nicht vorkommen, erhöhte N400-LPC Effekte bei der semantischen Verarbeitung auslösten. StG-Aussprache-Unterschiede lösten zwar keine N400 Effekte aus, doch aber LPC-Effekte.

Studie 3 untersuchte den Einfluss von CHG-Dialekt (zusammen mit anderen Variablen) auf das Lesen und Schreiben nach einem Jahr Schule. Ende 1. Klasse gab es keine signifikanten Unterschiede in der Lese-/Rechtschreibleistung bei Kindern mit unterschiedlichem CHG-Bezug. Wurden bei der Analyse aber frühe Lese-/Rechtschreibvorläuferfertigkeiten berücksichtigt (per SEM-Analyse), hatte ein hoher CHG-Bezug einen signifikant negativen Einfluss auf den frühen Lese-/Rechtschreiberwerb.

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# Abbreviations

| | |
|---|---|
| AAE | African American English |
| ANOVA | analysis of variance |
| BAKO | Basiskompetenzen für Lese-Rechtschreibleistungen |
| BISC | Bielefelder Screening |
| CHF | Swiss Francs |
| CHG | Swiss German |
| DRT | Deutscher Rechtschreibtest |
| MAE | mainstream American English |
| EEG | electroencephalography/electroencephalogram |
| ERP | event-related potential |
| fMRI | functional resonance imaging |
| GFP | global field potential |
| HAWIE-R | Hamburger Wechsler Intelligenztest (Revision) |
| HAWIK | Hamburg-Wechsler-Intelligenztest für Kinder |
| HSET | Heidelberger Sprachentwicklungstest |
| Hz | hertz |
| ISI | inter-stimulus interval |
| IQ | intelligence quotient |
| LDN | late difference/discriminative negativity |
| LORETA | low resolution brain electromagnetic tomography |
| LPC | late positive component |
| MMN | mismatch negativity |
| ms | milliseconds |
| PA | phonological awareness |
| PCA | principal component analysis |
| PET | Psycholinguistischer Entwicklungstest |
| PSP | post-synaptic potential |
| RMS | root mean square |
| SD | standard deviation |
| SEM | structural equation modeling |

| | |
|---|---|
| sLORETA | standardized low resolution electromagnetic tomography |
| SLRT-II | Salzburger Lese- und Rechtschreibtest, 2nd edition |
| SLS | Salzburger Lese-Screening für die Klassenstufen 1-4 |
| SPT | Swiss German proficiency test |
| Swiss-StG | Swiss Standard German |
| StG | Standard German |
| RAN | rapid automized naming |
| TANOVA | topographic analysis of variance |
| TEPHOBE | Test zur Erfassung der phonologischen Bewusstheit |
| y | year |
| μV | microvolt |

# 1. General Introduction

*"At the heart of language, and much of human action and thought, is a system of mental representations and computations. The goal of linguistics, then, is to discover these systems, and more deeply, to discover the fixed, invariant biological endowment that enables each child to develop a very rich and highly articulated system of knowledge on the basis of quite fragmentary and limited evidence."*

Noam Chomsky, fall of 1987

Noam Chomsky's response to the question pertaining to his interest in the study of language in an interview titled 'Language, Language Development and Reading' (conducted by Lillian R. Putnam, a journalist of the *Reading Instruction Journal*) not only illustrates the significance of language and its development for the scientific domain of Linguistics, but that this train of thought is also highly relevant for research in the areas of Developmental Psychology, Cognitive Neuroscience and Neurolinguistics. In particular, these domains pertain to the investigation of neural and behavioral mechanisms for language *processing* and language *learning*. In order to process language, it is essential to break down information into individual units. Hereby *phonology* and *semantics* play a vital role. From a linguistic perspective, phonology and phonological units are the key prerequisites to understanding the role speech sounds play within or across specific languages. Whereas, phonetics describes each speech sound at the level of articulation, perception, or acoustics, phonology relates to how these speech sounds are arranged into systems for each individual language (Davenport & Hannahs, 2005). Semantics, on the other hand, represents the study of meaning and specifically focuses on the interrelation of signifiers, for example, by determining how words, phrases and chunks of discourse are associated with each other (Blakemore, 2002)

Chomsky's statement above ties in several key issues that are of highly relevant for language processing and language learning and that are related to this PhD thesis: Firstly, language and language learning is something that happens at the mental level. Boldly, this mental aspect can be seen as a cognitive mechanism and as such addresses an issue concerning the brain. In corroboration with this notion, research has shown that native speech sounds (i.e., phonological units) are processed differently in the brain than unfamiliar speech sounds (e.g., Näätänen et al., 1997). Kuhl's (Kuhl, 1994; Kuhl et al., 2006) native language neural commitment theory further states that children are primed to speech sounds specific to their native mother tongue by implicitly acquiring a set of rules and principles pertinent to said language. Accordingly, different neural processes take place when a language is known compared to when it is foreign, because the innate language has previously established a mental representation. Moreover, developmental processes of language learning are essential for later reading and spelling acquisition, which does not happen automatically unlike native language learning. Instead, literacy acquisition needs to be introduced and trained explicitly in order for children to attain high levels of reading and spelling proficiency, and this likely is similar for any language (Vaessen & Blomert, 2010).

When children learn to read and spell they are required to match spoken and written language at various linguistic levels (e.g., Goswami, Ziegler, & Richardson, 2005). To date, it is relatively unclear how this occurs in children who speak a dialect and whether they show impairments due to a linguistic mismatch between spoken and written language during the initial stages of literacy learning. As thousands of different dialects are spoken world-wide that differ from their written standard language form, it thus is important to examine how speaking a dialect may affect learning to read and write in school, and how dialect-based processing is characterized at the neural level. To date, several studies have already examined effects of dialect on literacy acquisition at the behavioral level in the English language context by e.g., comparing literacy scores of African American English speakers with the ones found in Mainstream American English speakers (Brown et al., 2015; Terry, Connor, Thomas-Tate, & Love, 2010). However, dialect use in African Americans strongly correlates with living in poor neighborhoods and/or having a low socio-economic status (SES). Such factors may however confound the influence speaking dialect has on learning to read and spell. To this effect, the language situation in the German-speaking part of Switzerland, where speaking dialect is not linked to socio-economic variables, provides the ideal grounds to further investigate dialect-based influences on early literacy acquisition.

In particular, Swiss German native children grow up speaking Swiss German (CHG) dialect, however, as soon as they are enrolled in elementary school, they are required to speak Standard German (StG), a language variety of German that strongly corresponds to the German written form, but differs from CHG dialect at the phonological, lexical and even syntactic level. CHG native children thus seem to be relatively untrained in StG before school enrollment in comparison to for example children raised in (northern) Germany, who already grow up speaking the StG language variety. As a result, CHG native children likely encounter a larger gap between spoken and written language when they begin literacy learning in school compared to StG native speaking children (see later sections for details). To this end, it is essential to determine the extent to which speaking CHG dialect may impair learning to read and spell in StG at the behavioral level in the first school year. As previous research has underscored the importance of phonological skills (e.g., Goswami, 1990; Ziegler & Goswami, 2006) and semantics (e.g., Nation & Snowling, 2004) for literacy acquisition, it is critical to additionally examine what kind of neural mechanisms for language processing underlie e.g., phonological and (lexico-)semantic differences between CHG and StG, that may influence letter-to-sound mapping as well as lexical processing in the initial stages of learning to read and spell. The neuroimaging method of electroencephalography (EEG) has frequently been used to examine phonological and semantic processing mechanisms in the brain (Kutas & Federmeier, 2000, 2011; Pulvermüller, 2002), because it gives great opportunity to visualize neural correlates - in real time - that are involved when specific (auditory, visual, perceptive or cognitive) experimental tasks are executed (Cicchetti & Posner, 2005).

The central hypothesis surrounding this PhD thesis thus was that phonological and semantic differences between CHG and StG may drive different sensitivities at the neural level for language processing, and, that speaking a dialect may impair matching written and spoken language while learning to read and spell. In the following, I first will give a brief introduction into reading and spelling acquisition at the behavioral level, and, I will address what kind of phonological and cognitive-behavioral skills carry weight for later reading and spelling outcomes. I will then deliver some insights into selected neural processes associated with tools relevant for successful literacy learning. This section is followed by a rather explicit introduction into the neuroscientific method of EEG (electroencephalogram). In a third section, I will address the issue of phonological and semantic processing together with their neural correlates and experimental paradigms associated with them. Subsequently, I will introduce the topic of dialect and will give information on the sparse number of findings reporting on how dialect is connected with literacy learning at the behavioral level. Afterwards, I will briefly summarize the literature on neural mechanisms of phonological and semantic processing in the brain based on dialect familiarity. Towards the end of the general introduction, I will provide more detailed information on how German-speaking Swiss children fair with literacy acquisition in the bi-dialectal language situation that occurs in the German-speaking part of Switzerland, together with some specifications on the CHG-StG language variety contrast. In the last section, I will summarize the specific project pertaining to this PhD thesis and will finalize the general introduction by concluding on how a dialect-based language context may impact behavioral literacy acquisition as well as related neural correlates of language processing.

## 1.1. Reading and spelling learning and the involvement of phonological and semantic mechanisms at the behavioral level

While learning to speak happens quite naturally during early child development, learning to read and spell needs to be acquired through extensive practice. Current theories on reading development emphasize the importance of phonological skills during literacy acquisition (Goswami, 1990). One of the first steps in learning to read and spell is to match printed letters (graphemes) onto speech sounds (phonemes) that exist in one's native language inventory (Goswami et al., 2005). Hereby, phonemes represent the smallest units of speech sounds that are necessary to form words (Goswami, 2008). By building phoneme-grapheme links, associations are formed between the visual representation of lexical units and their phonological attributes (Mann & Wimmer, 2002; Nation & Snowling, 2004). Research on literacy acquisition in various language contexts has shown that children who hold a large vocabulary and show strong phonological processing skills before school enrollment later progress to become better spellers and readers (Ennenmoser, Marx, Weber, & Schneider, 2012; Niklas, Cohrssen, Tayler, & Schneider, 2016). Notwithstanding, word reading does not only encompass letter-by-letter word decoding. Much more, children need to understand the semantic meaning of what they encoded just instances before (Nation & Snowling, 2004).

In line with this, reading research frequently links dual-route models with literacy development, where phonological and semantic reading mechanisms develop sequentially (e.g., Coltheart, 2006) or with connectionist models where these mechanisms are shaped in parallel (e.g., Nation & Snowling, 2004; Plaut, McClelland, Seidenberg, & Patterson, 1996). Although these two types of models differ extensively, they have certain fundamental aspects in common: Early in reading learning, reading aloud results from segmenting printed words into letters and their phonological counterparts (phonemes) and piecing them back together by using grapheme-phoneme mapping strategies in order to form pronounceable entities, which (in consequence or parallel) activates semantic information. Later on in literacy learning, word (or word unit) processing mechanisms become more automatized and entire words (or units) are recalled from memory according to their visual representations and the semantic meaning associated with them (Castles & Coltheart, 2004; Jobard, Crivello, & Tzourio-Mazoyer, 2003; Nation & Snowling, 2004). For the purpose of this PhD thesis, however, the dual route model for reading seems to be more fitting, as it differentiates between a *lexical* and a *non-lexical* route (Coltheart, 2006; Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001): The lexical route enables a reader to swiftly identify a printed word using the orthographic lexicon and to simultaneously access the semantic word meaning stored in memory (i.e., the semantic lexicon) which is linked to a specific pronunciation (i.e., the phonological lexicon). In principle, the lexical route is primarily used to process words with irregular spelling, because the visual word representation directly accesses its memorized pronunciation (Ziegler & Goswami, 2006). However, when unfamiliar words or nonwords are being read, the non-lexical route is activated. Here, a seen letter string is translated piece-by-piece into speech by adhering to native grapheme-phoneme-correspondence rules (e.g., Coltheart, 2006; Ziegler et al., 2008; Ziegler & Goswami, 2006).

The ease at which reading and spelling acquisition is learned, however, also depends on letter-to-sound consistency and orthographic complexity of a learner's native language. This is strongly linked to the feedforward (grapheme-phoneme correspondence) and feedback (phoneme-grapheme correspondence) consistency of a specific language (Caravolas, 2004; Mann & Wimmer, 2002; Seymour, Aro, & Erskine, 2003; Ziegler & Goswami, 2005). Languages with high letter-to-sound consistency, and thus low orthographic complexity, are associated with high grapheme-phoneme (feedforward) and high phoneme-grapheme (feedback) correspondence (e.g., Finnish). In such languages, phonemes typically have only one form of spelling or pronunciation, which makes literacy acquisition relatively straightforward once alphabetic letters are known (Ziegler & Goswami, 2005). In contrast, languages with low orthographic consistency show low grapheme-phoneme and low phoneme-grapheme correspondence (e.g., English). This results in the fact that graphemes/phonemes often have multiple spelling/pronunciation variants and that words often need to be learned explicitly because a letter-to-sound mapping strategy would result in incorrect spelling/pronunciation (Landerl et al., 2013; Stone, Vanhoy, & van Orden, 1997). Evidence for the fact that orthographic complexity seems to impact literacy learning has been shown in a cross-language reading skill comparison conducted over 13 European countries (Seymour et al., 2003) and could reveal that children who grew up in language contexts with a high letter-to-sound mapping consistency showed rather proficient reading skills after half a year of literacy training. In contrast, children who spoke a language without a one-to-one letter-to-speech sound correspondence still showed rather poor to moderate reading accuracy after the same amount of schooling.

Moreover, orthographic complexity may also be associated with age of literacy learning, which typically commences between the ages of 4 and 7. In particular, literacy instruction begins relatively early in countries where languages with high orthographic complexity are spoken or where multifarious language contexts exist, but somewhat later for languages with high letter-to-sound transparency (e.g., Mann & Wimmer, 2002; McBride, 2015).

### 1.1.1. Predictive value of behavioral precursor abilities on early reading and spelling

In the field of early literacy, research has shown that several tasks can be used to investigate literacy outcomes in children even *before* they are able to read and spell by examining so-called literacy precursor skills (e.g., Caravolas, 2004; Wimmer, Landerl, Linortner, & Hummer, 1991) or literacy-related skills. The most commonly investigated literacy precursors are phonological awareness (PA), letter knowledge, invented spelling and rapid automatized naming (RAN).

In brief, *PA* entails the capability to perceive and manipulate basic units of language at the level of phonemes, onsets, rimes, and syllables (e.g., segmenting the word *map* into the phonemes /m/ /a/ /p/) (Moll et al., 2014). A vast body of research has uncovered that children who are sensitive for individual speech sound components of words are likely to become better readers (e.g., Castles & Coltheart, 2004; Goswami & Bryant, 1991). *Invented spelling* describes a method where pre-readers and beginning spellers implicitly analyze words based on their phonological composition and spell out words by using symbols (or letters, if that knowledge is already established) they associate with a specific speech sound. An example for such a spelling strategy is e.g., writing *KAM* for the verb *came* (Chomsky, 1971; Clarke, 1988). Research has shown that the early translation of spoken language into print, as is carried out in an invented spelling task, not only correlates with later spelling skills, but that invented spelling also represents an adequate predictor for later word decoding abilities (Clarke, 1988; McBride-Chang, 1998; Morris & Perney, 1984). In contrast, *RAN* is a task that examines how quickly a person can name objects, numbers or letters that are presented as a sequential and recurrent set of stimuli (Denckla & Rudel, 1976). Despite the fact that the precise characteristics of RAN are still rather unclear, studies have frequently reported that high scores in RAN tasks positively correlated with later scores for reading speed and reading accuracy (Fricke, Szczerbinski, Fox-Boyer, & Stackhouse, 2015; Furnes & Samuelsson, 2011; Moll, Fussenegger, Willburger, & Landerl, 2009; Moll et al., 2014) and, furthermore, RAN also seems to play a significant role in spelling development (Furnes & Samuelsson, 2011).

## 1.2. Neural measures and literacy acquisition

Neuroimaging studies have proven crucial for our understanding of how the brain processes spoken and written language (see, e.g., meta-analyses by Jobard et al., 2003; and Vigneau, Beaucousin, Herve, et al., 2006). For the scope of this PhD thesis, however, I will only mention a selected number of neurophysiological studies that report findings on tools that are pertinent to reading and spelling acquisition. The tools discussed here are (a) alphabetic letter knowledge, (b) letter-to-sound mapping strategies and (c) phonological as well as semantic processing in the brain.

In terms of neural mechanisms for alphabetic letter learning, electrophysiological studies using electroencephalography (EEG) could show that pre-literate children, who already had acquired wide-ranging alphabetic letter knowledge prior to literacy teaching, did not show a robust specialization for print tuning at the neural level until Grade 2 in a task where letter strings and symbol strings were presented (Maurer, Brem, Bucher, & Brandeis, 2005; Maurer et al., 2006). Notwithstanding, neuropsychological evidence exists for the fact that the development of print-specific neural responses seems to occur relatively early in reading development. By conducting a controlled EEG-/fMRI-based longitudinal phoneme-grapheme training study on pre-literate Kindergarten-aged children, Brem and colleagues (Brem et al., 2010) could show that print sensitivity in the brain seems to arise promptly once children learn letter-to-speech sound correspondences.

With regards to letter-to-sound mapping strategies, neuroscientific findings for literacy predictions largely stem from dyslexia research, where impairments in phonological awareness (at the level of auditory analysis to relate sound to print) result in reading difficulties (Gabrieli, 2009). Findings from a recent functional magnetic resonance imaging (fMRI) study revealed that activation for letter-speech sound associations was reduced in the superior temporal sulcus in dyslexic adults when compared with non-impaired adult readers (Blau, van Atteveldt, Ekkebus, Goebel, & Blomert, 2009). The researchers argued that the reduced audio-visual integration is directly linked to a general deficit in auditory speech sound processing, which in turn should predict phonological skills at the behavioral level. As such, Blau and colleagues (2009) could provide neurophysiological evidence for the circumstance that reading difficulties found in dyslexics seem to derive from deficits in audio-visual integration, and further reinforced the notion that impairments in phonological processing may be key in explaining reading disabilities (Torgesen & Wagner, 1992).

In addition, EEG studies on auditory stimulus processing could demonstrate that adult dyslexic readers showed reduced neural responses for the processing of speech sound stimuli in an oddball paradigm compared to controls. However, no group differences occurred for tone stimuli (Schulte-Körne, Deimel, Bartling, & Remschmidt, 1998, 2001). Schulte-Körne and colleagues' findings thus not only support the hypothesis that dyslexia seems to be related to deficits in mechanisms for pre-attentive speech processing, but furthermore indicate that EEG recording is an excellent tool to examine how auditory stimuli are processed in the brain, both in healthy and impaired sample groups.

Regarding semantic processing and literacy, fMRI and EEG studies investigating good and poor school-aged readers could show that weak reading skills were associated with reduced activation for sentence reading in inferior parietal and frontal brain regions (Meyler et al., 2007; Schulz et al., 2008). Moreover, dyslexic children further showed decreased activation in similar regions in a semantic congruity judgment task that entailed full sentences where the final word was either semantically fitting or non-fitting. In addition, dyslexic children also displayed smaller semantic mismatch effects, i.e., N400 effects, in the EEG compared to healthy controls (Schulz et al., 2008). To this effect, investigating the strength of neural activation during a semantic judgment task using the method of EEG seems to represent an adequate measure to take a closer look at how semantic processing relates to literacy abilities in children. Moreover, such a task may even be suited to examine neural correlates related to literacy outcomes in children who are not yet able to read.

### 1.3. Electroencephalography (EEG)

As shown in the previous chapter, neuroscientific research relating to literacy tools, literacy learning (and associated learning deficits), as well as phonological and semantic language processing often makes use of the modern imaging method of EEG. In the following, I will give a brief summary on the history of this imaging technique and additionally will make some specifications that are pertinent to the recording of the EEG.

Almost 90 years ago, Hans Berger demonstrated that a sudden change in electric potential difference between two electrodes can be measured from the human scalp with a double-coil galvanometer and thus provided the earliest report for high-quality electroencephalographic (EEG) tracings (Millett, 2001). Much has changed since Berger’s 1929 recordings. Nowadays, EEG recordings are made with 19, 21, 32, 64, 128 or even 256 electrodes. Although numerous electrode arrangements exist, they are all based on the internationally accepted 10-20 system reliant on four reference points: The *inion* which is located at the indentation of the posterior of the scalp, the *nasion* which refers to the indentation on the nose ridge, and, both *pre-auricular notches* which are represented by the small indentations on the bilateral ear conches in front of the ear canal. Within the 10-20 system, scalp electrodes are arranged along either 10 or 20% of the total distance between inion and nasion or both pre-auricular notches (Jasper, 1958; Jäncke, 2005).

In general, *electroencephalography* refers to a non-invasive and relatively inexpensive medical and/or research-based instrument to measure temporal dynamics of electrical activity at the scalp that is produced by different brain structures. In turn, *electroencephalogram* makes reference to the graphic output of said electrical activity, which is detected by electrodes and a conductive medium. However, both terms are abbreviated with *EEG* (Quinonez, 1998; Teplan, Krakovská, & Stolc, 2006). Due to its excellent temporal (from tens to hundreds of milliseconds) and moderate spatial resolution, EEG has become a highly favored method for investigating brain activity for e.g., visual and auditory stimuli using a vast number of experimental paradigms.

### 1.3.1. Generation of a signal

Electro-chemical processes take place in the axons, dendrites, neurons, and in the synapses, and this lastly result in an electrical current. The magnetic field of this current can be measured at the scalp (Jäncke, 2005). In order to understand the nature of these currents and their voltage, it is necessary to understand how they are generated in the brain. Action potentials and postsynaptic potentials (PSP) make up the two major types of electrical activity produced in the brain. The term action potential refers to voltage spikes that travel from the tip of an axon to the terminal and subsequently release neurotransmitters. PSPs, however, resemble the voltage that results from when the neurotransmitters connect to receptors on the membrane of a postsynaptic cell. Hereby, cell-specific ion channels open or close and this leads to a potential change in the cell membrane. Both types of electrical activity can be documented by placing an electrode into the intra-cellular space in the human brain. However, as EEG only records electric potential differences that occur at the scalp, but not in the brain itself, EEG electrodes only measure PSPs (Olejniczak, 2006).

PSP duration can last between tens to hundreds of milliseconds and PSPs are mainly restricted to dendrites and cell bodies. The perpendicular orientation of cortical neuron groups, e.g., pyramidal cells, leads to a current distribution at the cells that produce field potentials, and these are detectable at a distance. The distribution of these field potentials at the scalp is described as a dipole structure (Jäncke, 2005). The summation of dipoles from many neurons (thousands to millions) that passively propagate to the scalp can be measured if they occur at approximately the same time (Luck, 2005), and this ultimately leads to the EEG signal that can be recorded.

However, it is also important to note, that EEG only provides a two-dimensional projection of a three-dimensional reality (Olejniczak, 2006). Accordingly, it is impossible to irrefutably determine the location of the EEG generator based on the information obtained from the scalp. This is also referred to as the *inverse problem* in EEG research. Methods to circumvent this problem have been suggested by Pasqual-Marqui and colleagues (e.g., Pascual-Marqui et al., 2006): By using low resolution brain electromagnetic tomography (LORETA), it becomes possible to pinpoint the quantitative neuroanatomical localization of neuronal electric activity.

### 1.3.2. Event-related potentials (ERPs)

In general, event-related potentials (ERPs) resemble any kind of electro-cortical potential that occurs before, during or after a sensory, motor or mental event that can be measured with EEG. ERPs are usually much smaller than raw EEG electrical voltage fluctuations (1-40 μV) and are time-locked to specific mental and/or physical states. However, they are not easily detectable among the noise created during the raw EEG recording. One of the first to describe ERPs was Davis in 1939 who determined a relatively large negative deflection 100-200ms after an auditory stimulus was presented (Jäncke, 2005).

The underlying neurophysiological cortical process of an ERP is assumed to stay (more or less) the same, if a stimulus is presented over and over. In contrast, background noise in the EEG is distributed rather randomly. Accordingly, it is possible to identify the specific temporal epoch in the EEG during which the cortical reaction to the stimulus occurs. By averaging many of these same (time-locked) epochs, the underlying neural correlate in reaction to the stimulus becomes visible with a relatively high signal-to-noise ratio, independent for each measured electrode (Brandeis & Lehmann, 1986).

The positive and negative deflections of the ERP are assumed to reflect individual brain sub-processes (Lehmann & Skrandies, 1984). The troughs and peaks of an ERP represent independent components that occur temporally together or reveal similar amplitude deflections over many individuals. The statistical approach to determine separate components is called principle component analysis (PCA). PCA components represent the independent input each deflection gives to the variance of different wave shapes and should be interpretable on their own. However, PCA components need not correspond with the peaks and troughs of the analysis wave in the raw EEG (Brandeis & Lehmann, 1986).

ERP components are classifiable based on polarity and temporal occurrence. Typical ERP components are P1, N1 and P3, where P and N indicate a positive or negative polarity. The number refers to the temporal occurrence, e.g., the first or third positive deflection in the case of P1 or P3, respectively. ERPs are also frequently described using the precise point of occurrence, e.g. P300, indicating that it is a positivity that occurs 300ms after the stimulus presentation (Jäncke, 2005; Luck, 2005). However, component latency may differ depending on experimental paradigm: For example, it is possible that a P300 may occur only around 450ms. Yet, if systematic changes in the paradigm to elicit such a P300 component are known (e.g., if a task is manipulated by using stimulus degradation), then the component will still be considered the same despite the latency delay (Brandeis & Lehmann, 1986). Furthermore, polarity differences may occur for specific ERP components based on the topographic position of a recording electrode and/or the reference (Murray, Brunet, & Michel, 2008).

Aside from giving information on changes over time, ERPs also indicate the strength of the electrical activity measured. Global field power (GFP) represents an ideal measure to indicate voltage strength differences, because it results in a measure of potential (μV) as a function of time. Mathematically, GFP equals the root mean square (RMS) across average-referenced electrode values at a given moment. Simply put, GFP gives information about the strength of a recorded potential averaged across all electrodes at a given time, however, not for electrodes individually (Murray et al., 2008).

### 1.4. Phonological processing and its neural correlates

Mechanisms for phonological processing are strongly involved in the analysis and manipulation of speech sound information and help to make sense of spoken language, both at the neural and the behavioral level (Ayora et al., 2011; Wagner, 1986). Hereby, verbal and acoustic information is looped into and briefly stored in working memory (Baddeley, 2003). Brain research has revealed key information on how different languages are processed in the brain and has extensively investigated how such processing is interlinked with the phoneme inventory of a given language (Dehaene-Lambertz, 1997; Näätänen et al., 1997). Research has shown that the ability to perceive phonetic contrasts is relatively language-universal in early infancy (Kuhl, Coffey-Corina, Padden, & Dawson, 2005). However, by the age of 6 to 12 months, young children lose this discrimination sensitivity and are primed to the phonemic regularities specific to their mother tongue (Kuhl, 2004). Hence, as soon as children become more skilled in their native language, perceptual discrimination abilities of non-native speech sounds become reduced (Kuhl, 2000), both at the behavioral as well as at the neural level.

### 1.4.1. Mismatch negativity

At the neural level, differences in speech sound processing are frequently investigated by using experimental mismatch negativity (MMN) paradigms while the EEG is recorded (Näätänen et al., 1997; Näätänen, Paavilainen, Rinne, & Alho, 2007; Tervaniemi et al., 2006). MMN studies examine the brain's ability to perceive rare acoustic changes (i.e., deviants), that are randomly distributed into a chain consisting of the same auditory stimulus (i.e., standards) (for details see review by (Näätänen, Tervaniemi, Sussman, Paavilainen, & Winkler, 2001). Mathematically, the MMN ERP component represents the difference ERP between deviants and standards. In adults, the MMN is typically represented by a negative-going peak between 100 and 250ms post-stimulus presentation and shows strongest negativity at fronto-central electrodes paired with a polarity inversion at mastoid electrode sites (e.g., Maurer, Bucher, Brem, & Brandeis, 2003a; Sebastián-Gallés, Vera-Constán, Larsson, Costa, & Deco, 2009). Similar topographic and temporal effects for MMN elicitation have also been found in infants and children, however, with slightly later latencies, e.g., 200-400ms, most likely due to still ongoing neural maturation processes (Cheour, Shestakova, Alku, Ceponiene, & Näätänen, 2002).

The basic assumption is that the MMN results from a discrimination process where the neural response to a deviant stands in conflict with the memory trace generated for the previously presented standards (Näätänen, Tervaniemi, Sussman, Paavilainen, & Winkler, 2001). Thus, by extracting regularities from the auditory environment, the brain seems to generate predictions about upcoming stimuli. Now, if both the heard and the predicted stimulus correspond with each other, then activation decreases. However, if they do not match, then a MMN occurs (Winkler, Denham, & Nelken, 2009). MMN studies investigating native and non-native phonemic speech sound contrasts have been able to show that greater MMN amplitudes occurred for familiar than for unfamiliar speech sounds (Näätänen et al., 1997; Winkler, Kujala, Tiitinen, Sivonen, Alku, Lehtokoski, Czigler, Csépe, et al., 1999).

## 1.5. Semantic processing and its neural correlates

Although several frontal and temporal regions in the brain are linked to language processing and language comprehension, it is still relatively unclear which regions are specifically involved in semantic processing (Démonet et al., 1992; Pulvermüller, 2002; Rodd, Davis, & Johnsrude, 2005). An fMRI study investigating for example semantic processing of sentence ambiguity (e.g., highly ambiguous sentences like "the *shell* was *fired* towards the *tank*" where certain words entailed more than one meaning vs. low ambiguous sentence “her secrets were written in the diary”) could show that high-ambiguity sentences produced an increase in neural signal in the left posterior inferior temporal cortex and the bilateral inferior frontal gyri. Accordingly, sentences which entailed high semantic ambiguity required additional neural involvement to compute and select the contextually most appropriate word meaning, despite the fact that both sentence types encompassed similar acoustic and prosodic properties (Rodd et al., 2005).

### 1.5.1. N400 effect for semantic mismatch

In EEG research, the N400 effect represents a very frequently investigated neural mechanism for semantic processing (Kutas & Federmeier, 2011). Earliest accounts of N400 elicitation have been reported in the 1980’s: By using sentences that either entailed a fitting or non-fitting word at the end, Kutas and colleagues (Kutas & Hillyard, 1980b) were able to measure the brain’s electrophysiological response to congruity of expectancy (or the lack of it) and thereby explored the modulation of the ERP surrounding the N400 effect. The negative-going N400 displays the difference ERP between congruous and incongruous conditions. It typically occurs ca. 250-500ms post-stimulus onset peaking mainly around 400ms and shows a wide-spread centro-parietal scalp topography in adults (for a review see Kutas & Federmeier, 2011). Similar N400 topographies have also been detected in children, but seem to be more widely distributed over the scalp and display higher ERP amplitudes with longer peak latencies and/or a slight temporal delay, due to still ongoing neural maturation processes (Atchley et al., 2006; Friedrich & Friederici, 2004, 2006; Hahne, Eckstein, & Friederici, 2004).

The function of the N400 effect is linked to semantic context in an inverted fashion. Large semantic violations trigger increased N400 amplitudes, whereas smaller violations show weaker elevations (Dunn, Dunn, Languis, & Andrews, 1998). For example, sentences with high cloze probability like “For the sake of his safety, the millionaire hired a bodyguard” elicit only minor N400 deflections resulting from neural mechanisms for semantic processing, whereas substituting the final word with a highly improbable word (e.g., wire) elicits a large N400 amplitude in response to a substantial violation of expectancy (Kutas & Hillyard, 1980a; Li, Shu, Liu, & Li, 2006). The N400 thus not only reflects ongoing neural mechanisms to make sense of presented information, but additionally, it reveals the intensity with which the presented information overlaps with the concept stored in memory (Kutas & Federmeier, 2000; Nigam, Hoffman, & Simons, 1992). Several studies have also triggered N400 effects by presenting simple prime-target paradigms (e.g., Hagoort, 2008; van Berkum, Hagoort, &

Brown, 1999). In a children's study conducted by Friedrich and Friederici (Friedrich & Friederici, 2004, 2006) it could be demonstrated that "spoken word-colorful image" dyads elicited larger N400 effects when spoken words were paired with non-matching images than when congruent spoken word-image pairings were presented.

## 1.6. Dialect

World-wide, more than 7,000 spoken languages are documented (i.e., language varieties, vernaculars, dialects, slangs etc., for details see *Ethnologue* catalogue[1]). However, the number of standardized language norms in which languages are typically written, is fairly limited (Anderson, 2012). Accordingly, vocabulary, word pronunciation, and, even syntax may differ between a dialect and a corresponding standard language. The difference can be large as in the case of Swiss German (vs. Standard German) in Switzerland or as in the case of African American English (AAE) (vs. Mainstream American English; MAE) in the US or Cantonese (vs. Chinese) in Hong Kong, China or spoken vernacular Arabic (vs. formal Arabic) in Israel. As studies investigating early literacy achievement could show that consistency of word pronunciation and word spelling seems to promote early reading and spelling acquisition (e.g., Ziegler & Goswami, 2005), speaking a dialect that differs in phonology and lexicality from the standard language may have a negative impact on early literacy learning (e.g., Labov, 1995).

### 1.6.1. Evidence of dialect-based influences on reading and spelling acquisition at the behavioral level

All beginning readers and spellers encounter at least some level of phonological, morpho-syntactic or lexical discrepancies while attempting to map spoken language onto print. However, dialect speakers may experience such challenges in an increased manner (Charity, Scarborough, & Griffin, 2004). The underlying assumption is that the linguistic mismatch (i.e., the non-correspondence between spoken and written language form) encountered by dialect speaking children seems to lead to a higher level of complexity during literacy acquisition. Evidence for negative effects based on linguistic mismatch has been presented in studies contrasting speakers of AAE with MAE speakers (Brown et al., 2015). Children who spoke AAE at home and who were instructed in MAE in school made more errors during a word reading task compared to children who spoke only MAE, because they associated certain spelled words with a different dialect-specific pronunciation (Brown et al., 2015). Similar

[1] https://www.ethnologue.com/world (updated in 2009)

challenges have also been observed in children speaking Arabic, who grow up in a diglossic language context (Saiegh-Haddad, 2012; see section 1.7.1. for definition of diglossia): Up until school enrollment, these children only have contact with informal spoken Arabic, but in school they are required to learn to read and spell in Standard Arabic, a language variety that only exists in writing or is spoken in formal discourse. During literacy acquisition, dialect speaking children thus not only need to learn to match letters to speech sounds, but they additionally are required to decode words that phonologically or even lexically differ from their native dialect.

### 1.6.2. Influences of dialect on phonological and semantic processing in the brain

Every single language holds a unique phonetic inventory, and this circumstance also is true for dialects. Accordingly, speakers of the same language - but of a different dialect - may have different pronunciations for the same speech sound or the same word (e.g., *water* is pronounced with /ɑ/ in American English but with /ɔ/ in British English). Or, they may even hold a completely different lexical entry in their native inventory to describe a specific object (e.g., American English *truck* vs. British English *lorry*). Accordingly, unfamiliar accents and/or dialects may make it more difficult to understand spoken language, even for speakers of the same language, because specific phonemic or lexical entries do not occur in the listener's native inventory (Best, McRoberts, & Sithole, 1988). Linguistic complexities of native compared to non-native language processing can also be determined at the neural level. The majority of studies that examine neural computation of phonemic contrasts typically employ MMN paradigms and have investigated such effects in both adults and children across different language contexts (e.g., Kirmse et al., 2008; Näätänen, 2001; Näätänen & Alho, 1997; Rinker, Alku, Brosch, & Kiefer, 2010; Tervaniemi et al., 2006; Tervaniemi, Schröger, Saher, & Näätänen, 2000). However, only a few studies exist that have examined effects of dialect familiarity on phonological processing (Brunellière, Dufour, Nguyen, & Frauenfelder, 2009; Conrey, Potts, & Niedzielski, 2005; Dufour, Brunellière, & Nguyen, 2013). As such, neuroscientific research on dialect-based language processing is generally rare and primarily involves adults study populations. Indeed, only two studies exist that have examined neural correlates of dialect familiarity at the semantic level (Lanwermeyer et al., 2016; Martin, Garcia, Potter, Melinger, & Costa, 2015). In the following, I will briefly summarize findings published to date on dialect-based effects for phonological and semantic processing.

**In adults.** Previous MMN research has shown that adult native speakers of a given language frequently have difficulties to perceive phonemic contrasts at the neural and behavioral level that do not occur in their native mother tongue (Nätäänen, 1997). This effect also seems to occur of phonemic differences that exist among dialects: A few studies could show that non-native dialectal pronunciations trigger different neural responses compared to native and thus familiar pronunciations (Conrey et al., 2005; Martin et al., 2015). For example, Conrey and colleagues (2005) asked American English speakers, who either did or did not employ a vowel merger for the phonemes /ɪ/ and /ɛ/ in pronunciation, to discriminate minimal word pairs that either encompassed the critical vowel merger or not (e.g., *pin*/*pen* (merged) vs. *pain*/*pine* (unmerged)). Additionally, they recorded electrophysiological measures using EEG during this discrimination task. Their findings revealed that merged dialect speakers had more difficulties to discriminate incongruent vowel mergers and showed reduced later ERP amplitudes in response to mismatch detection in comparison to unmerged dialect speakers. However, also unmerged dialect speakers also seemed to have had more difficulties to discriminate in the *pin/pen* condition. In a similar vein, Brunellière and colleagues (2009) found differences in latency and ERP components for a (Southern) French merged (/e/-/ɛ/) and unmerged (/ø/-/y/) vowel contrast using an MMN paradigm. Although the French speakers examined in their study themselves did not merge the vowels /e/ and /ɛ/, the participants were more error-prone in a behavioral discrimination task for trials involving the merged vowels than the unmerged vowels. It seems that, mere exposure to a merger (via TV and discourse with merger-speakers) likely led to changes in phonological processing mechanisms at the behavioral as well as the neural level. Converging results from both studies mentioned above thus lead to the assumption that frequent exposure to a non-native pronunciation variant may at some level evoke dynamic adjustments in a hearer’s phonological representation. This may likely be related to general speaker variability for pronunciations (McQueen, Norris, & Cutler, 2006). In such a manner, it is possible that exposure to non-native phonological inventories may thus impact behavioral and neural mechanisms of speech sound processing to the extent that one’s native phonemic category boundaries may become slightly weakened (e.g., Brunellière et al., 2009; Lanwermeyer et al., 2016).

Regarding semantic processing and dialect familiarity, Martin and colleagues (2015) conducted one of the few ERP studies that examined lexical processing for cross-dialectal vocabulary differences. By presenting sentences spoken either in British or American English (dialect) to adult native speakers of British English, they could show that target word integration was easiest when British English vocabulary and dialect were used. Furthermore, words spoken inconsistently with the presented dialect (e.g., *vacation* uttered by a British speaker vs. *holiday* uttered by an American speaker) elicited larger negative electro-physiological responses than consistent words, similar to an N400 effect. Their results suggest that word integration seems to rely highly on dialect-based familiarity and further seems to be contingent on context-specific information (Martin et al., 2015). Accordingly, in the case of adult speakers, integration of prior knowledge for lexical variations across dialects seems to influence vocabulary processing as speech unfolds itself to the hearer. Furthermore, a very recent ERP study by Lanwermeyer and colleagues (2016) examined how dialect-specific competencies may influence cross-dialectal comprehension in adult native speakers of the Central Bavarian dialect (German dialect). The main focus of their study was whether certain dialect phonemes /o͡a/-/o͡ʊ/), that are attributed to different lexical entries depending on dialect (Central Bavarian vs. dialect of the Bavarian-Alemannic transition zone) evoked higher neural cost during sentence processing. During EEG recording, participants listened to sentences where sentence-final words were either native or non-native to their dialect, and had to rate these sentences according to context goodness. Results revealed that ERPs for incomprehension as well as incongruency both entailed a biphasic N400-LPC pattern, indicating that lexeme mismatch and lexeme unfamiliarity evoked similar effects for semantic anomaly detection (Kutas & Federmeier, 2011).

**In children.** To date, to my knowledge no research has yet been published on how dialect familiarity influences phonological and semantic processing in the brains of young children.

### 1.7. Literacy acquisition in the German-speaking part of Switzerland

In the German-speaking part of Switzerland, CHG is the primary language variety spoken in everyday life, i.e., on playgrounds, in grocery stores, post offices, banks, and even sometimes is the language of theater plays. However, most news broadcasts and official governmental reports are communicated in StG, which strongly corresponds with the German "book language". Moreover, the Swiss educational system requires school to be taught in StG from the elementary level on. In such a manner, CHG and StG co-exist as spoken language varieties in Switzerland, but are employed in different domains (formal vs. informal). Based on the bi-dialectal language situation in the German-speaking part of Switzerland, native CHG speaking children need to learn to manage both German language varieties alongside each other. However, as a consequence of a recent popular vote in the Canton of Zurich (commenced in autumn of 2012), CHG dialect is the primary language variety spoken in Swiss Kindergartens. This may likely limit exposure to StG before school. As such, it is indeed possible that speaking CHG dialect may impede early German reading and spelling acquisition in Switzerland, as suggested by studies in the English or Arabic language context (e.g., Brown et al., 2015; Charity et al., 2004; Saiegh-Haddad, 2012; Terry et al., 2010), due to the fact CHG native children may have limited knowledge of StG when they enter Grade 1 of elementary school, where they begin to learn to read and spell.

Evidence for the fact that speaking CHG dialect may have a negative influence on literacy skills can further be surmised based on the scores obtained in the PISA (Program of International Student Assessment) 2009 and 2015 study for reading comprehension. Specifically, German-speaking Swiss Grade 9 students showed slightly weaker reading comprehension skills than their same-aged counterparts living in Germany (OECD, 2010, 2016). Moreover, a recent study examining spelling abilities in CHG primary school children could show that, throughout Grades 2 to 6, children showed substandard German spelling skill (i.e., scores below the norms of a standardized spelling task which was gauged on a sample of German and Austrian same-aged children), especially for words with irregular spelling. However, when words held a strong letter-to-sound correspondence, Grade 2 to 6 aged children continuously spelled words above average (for details see *20Minuten* article published on 10. August, 2016; http://www.20min.ch/schweiz/news/story/Schweizer-Schueler-haben-Muehe-mit-Rechtschreibung-28372191).

A reason as for why CHG native children seem to spell irregular words worse than regular ones may be linked to the "spelling-by-sound" instruction methodology promoted by the Swiss educational system, where orthographic errors are only minimally marked up until Grade 3. As a result, this may lead to the learning of orthographically incorrect spellings in early school years, which at later school levels then need to be re-learned. Notwithstanding, relatively weak spelling skills seem to be a common occurrence in Switzerland. In order to avoid too many false-positive diagnoses for spelling difficulties in terms of dyslexia, Swiss school psychologists have begun to employ Swiss specific norms for the SLRT-II spelling evaluation (Salzburger Lese-/Rechtschreibtest; Bernese norms of the SLRT), which are less stringent than the standard norms. However, the sparse amount of research on dialect-specific influences on early literacy acquisition in Switzerland reveals that more research is needed to thoroughly investigate whether and to what extent dialect use influences reading and spelling acquisition, particularly in the first year(s) of school.

### 1.7.1. Diglossia in the German-speaking part of Switzerland

According to Ferguson (1959), *Diglossia* describes "a relatively stable language situation in which, in addition to the primary dialects of a language (which may include a standard or regional standards), there is a very divergent, highly codified (often grammatically more complex) superposed variety, the vehicle of a large and respected body of written literature, either of an earlier period or in another speech community, which is learned largely by formal education and is used for most written and formal spoken purposes, but is not used by any sector of community for ordinary conversation" (p. 336). Taking Ferguson's (1959) definition under account, the language situation in the German-speaking part of Switzerland can be referred to as "medial diglossic" (Werlen, 1998). In medial diglossic language situations the usage of a dialect and the standard language are functionally tied to different situations. In principle, a multitude of CHG dialects is *spoken* and StG is mainly used for *written* language in the German-speaking part Switzerland.

However, it is also important to note, that a Swiss variety of spoken StG known as Schweizer Hochdeutsch (Swiss-StG) exists, as well. Notwithstanding, spoken Swiss-StG encompasses relatively large differences in phonology and syntax and thus also strongly varies from standardized StG spoken in Germany (Ammon, 2003; Hove, 2002). For the scope of this PhD thesis, however, there will be no differentiation between the Swiss-StG and standardized StG in sections to follow. Expressly, the focus of this thesis lies on one specific CHG dialect, namely the variety spoken in and around the city of Zurich, and on the relatively neutral standardized variety of StG that corresponds to the rather "dialect-free" variety spoken in (northern) Germany, which is highly similar to the German "book language". In the following specific linguistic differences between CHG and StG are illustrated:

**CHG vs. StG vocabulary.** Although there are many lexical correspondences between CHG and StG, certain words use different realizations in CHG for the semantically matching StG word (Siebenhaar & Wyler, 1997). An example of this is the CHG word *Rüebli* which is expressed as *Karotte* in StG.

**CHG vs. StG pronunciation**. Differences occur at the phonological level as well. In spoken CHG, plosives (e.g., /p/, /t/, /k/ and doubled-consonant clusters) are pronounced as long consonants. However, in StG they are realized as short plosives. Furthermore, unvoiced plosives are generally not aspirated before stressed vowels in CHG but are indeed aspirated in StG (Fleischer & Schmid, 2006). Additionally, differences between CHG and StG pronunciation can be determined in regards to vowel length, where CHG words may hold a short vowel but have a long vowel in StG, e.g., the word *Adler* (Eng. eagle) is spoken in CHG as [adlɐ] but in StG as [aːdlɐ].

**CHG vs. StG syntax.** Furthermore, differences between CHG and StG can be found for sentence structures (e.g., Siebenhaar & Voegeli, 1997). For example, in short imperative clauses word order of CHG is typically verb - reflexive pronoun - object, whereas in StG the order is usually verb - object - reflexive pronoun. Accordingly, a StG speaking child will say *Gib ihn mir!* in the case where he/she wants to receive an object (e.g. a ball). In contrast, the CHG speaking child will utter *Gib mer en!* for the same request.

### 1.8. PhD project surrounding the thesis

The present PhD thesis was embedded into a larger project led by Prof. Urs Maurer entitled *"Neural mechanisms of linguistic mismatch: Reading and spelling difficulties and their predictions of neural measures in children speaking Swiss German"*. The project investigated phonological, semantic as well as syntactic neural processing differences of CHG and StG, in both CHG or StG native speaking adults (N = 30, $mean_{age}$ = 23.3y) and pre-literate children (N = 71, $mean_{age}$ = 6.6y) who either lived in Switzerland or in Germany. During this project, the same EEG-based experiments investigating neural measures were administered in the adults' and in the children's study population. The central objective of this research endeavor was to determine (1) to what extent speaking a dialect impacts phonological and semantic processing at the neural level, and (2) whether speaking a dialect that differs from the standard written language form has a negative effect on learning to read and spell in its early stages.

In adults, additional behavioral data was assessed to examine CHG and StG language skills, German reading and spelling competencies, as well as phonological differences discrimination abilities based on dialect familiarity. Of key relevance in the adults' study was to determine neural and behavioral processing differences of CHG and StG. In the children's sample, we instead conducted a longitudinal study design over 2 years: In year one, we examined CHG and StG native children living in Switzerland or Germany shortly before school enrollment and investigated levels of literacy precursor skills (PA, letter knowledge, invented spelling, RAN) as well as phonological and semantic neural processing mechanisms based on dialect familiarity. One year later we re-examined the same children at the end of Grade 1 and tested them for newly acquired reading and spelling abilities as well as Standard German grammar skills.

### 1.9. Conclusions

During early reading and spelling attempts children are required to focus on phonological instances they detect in spoken words and to ignore others that sound similar. For this purpose, basic auditory processing skills are indispensable (Goswami, 2008). Several studies have noted that impairments in phonological processing may be key in explaining reading disabilities, i.e., dyslexia (Torgesen & Wagner, 1992). Furthermore, previous research has shown that the ability to perceive phonological patterns belonging to one's native language, and to detect similarities and differences between specific speech sounds, enables children to develop and structure mental phonological and lexical representations (Goswami, 2008; Ziegler & Goswami, 2005). As speaking a dialect seems to lead to the learning of a phonological mental lexicon encompassing (slightly) different native phonological representations than the ones found in the standardized language used for reading and spelling, it is possible that a dialect-based linguistic mismatch between spoken and written language may lead to difficulties in early literacy acquisition. As such, exploring to what extent phonological awareness (and other literacy precursor skills) impacts Grade 1 reading and spelling abilities based on dialect background should provide evidence for whether and how dialect speaking children are impaired when learning to read and spell.

Although certain literature already exists on how speaking a dialect influences literacy acquisition at the behavioral level, to date no study can be found that investigated neural mechanisms for dialect-based language processing in children. Accordingly, it is of great importance to examine phonological processing of CHG and StG specific speech sound at the neural level and to investigate what kind of dialect-based differences in neural response pattern can be found. To this end, we first examined neural mechanisms of consonant-specific speech sounds processing in CHG or StG native adults using an MMN paradigm. Two speech sound stimuli functioned as deviants, that encompassed a consonant-specific pronunciation variant that either occurred in one's native dialect-based phonological inventory or not. These two deviants were contrasted with a speech sound stimulus (standard) that encompassed a consonant variant that occurred similarly in both CHG and StG. Additionally, we used the same three speech sound stimuli to test dialect-based phonemic discrimination abilities at the behavioral level. Given that dialect-based phonological processing has so far principally been investigated using vowel contrasts, the here used dialect-based consonant contrast should provide new insight into this topic.

Additionally, in another experiment, we examined neural processing mechanisms for dialect-based pronunciation and lexem differences using a spoken word-image semantic mismatch paradigm in pre-literate CHG and StG native children. Research on dialect-based semantic mismatch effects has so far only been conducted in adult speakers who were familiar with different variants of the language examined (e.g., Martin et al., 2015). Yet the question still remains unanswered as to how these mechanisms occur for dialect speakers with only limited (or no prior) knowledge of a presented language variety. This issue is particularly important as it attempts to elucidate neural processing that occurs in dialect-speaking children before they are exposed to the normative influences of learning the standard language variety in school. Given that to date no literature exists on how children process dialect-based semantic mismatches at the neural level, this investigation should provide a better understanding of language development in a dialect-standard language context.

Based on the fact that only limited knowledge exists of how speaking a dialect impacts learning to read and spell at the behavioral and neural level, additional research in this field is duly needed. Examining both behavioral and neural measures in the same study population should thus give some new insight into the specificity at which neural mechanisms of phonological and semantic processing are affected by dialect-based linguistic differences. A next step would then be to combine neural and behavioral measures with each other. Once the behavioral and neurophysiological mechanisms are known that impact literacy acquisition in a dialect-based language context, teaching instructions and educational policies could be adapted to help dialect-speaking children learning to read and spell even better.

# 2. Empirical Part

## 2.1. Study I: Influence of dialect use on speech perception: A mismatch negativity (MMN) study [1]

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**Abstract**

Using an EEG-based mismatch negativity (MMN) paradigm, we investigated whether higher familiarity with a dialectal variety of German (Swiss German (CHG) vs. Standard German (StG)) impacted speech perception at the neural and the behavioral level.

Specifically, we examined 30 CHG & StG native adults, by contrasting a pseudoword containing an allophonic phoneme variant found in both dialects (i.e., standard) with two deviant stimuli encompassing allophonic phoneme variants, of which one was more familiar for CHG-natives and the other was more familiar for StG-natives. The same stimuli were used in a behavioral "same-different" discrimination task.

Behavioral pseudoword differentiation was better for more familiar allophonic phoneme variants. MMN measures revealed significant fronto-central and temporal deviance-by-language-group interactions, primarily driven by larger MMN-responses for less familiar deviants in StG-natives.

We conclude that a higher degree of familiarity with allophonic variants seems to impact neural processing efficiency, to the extent that less familiar variants demand more wide-spread activation processes.

## 2.2. Study II: Neural processes associated with vocabulary and vowel-length differences in a dialect: An ERP study in pre-literate children[1]

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[1]Bühler et al. (2017). Neural Processes Associated with Vocabulary and Vowel-Length Differences in a Dialect: An ERP Study in Pre-literate Children. *Brain Topography*, 1-19. DOI: 10.1007/s10548-017-0562-2.

**Abstract**

Although familiarity with a language impacts how phonology and semantics are processed at the neural level, little is known how these processes are affected by familiarity with a dialect.

By measuring event-related potentials (ERPs) in kindergarten children we investigated neural processing related to familiarity with dialect-specific pronunciation and lexicality of spoken words before literacy acquisition in school. Children speaking one of two German dialects were presented with spoken word-picture pairings, in which congruity (or the lack thereof) was defined by dialect familiarity with pronunciation or vocabulary. In a dialect-independent control contrast, congruity was defined by audio-visual semantic (mis)match. Congruity effects and congruity-by-dialect group interactions in the ERPs were tested by data-driven Topographic Analyses of Variance (TANOVA) and theory-driven focal analyses.

Converging results revealed similar congruity effects in the N400 and late-positive-complex (LPC) in the control contrast for both dialect groups. In the dialect-specific vocabulary contrast, topographies of the N400- and LPC-effects were reversed depending on familiarity with the presented dialect words. In the dialect-specific pronunciation contrast, again a topography reversal was found depending on dialect familiarity, however, only for the LPC.

Our data suggest that neural processing of unfamiliar words, but not pronunciation variants, is characterized by semantic processing (increased N400-effect). However, both unfamiliar words and pronunciation variants seem to engage congruity judgment, as indicated by the LPC-effect. Thus, semantic processing of pronunciations in dialect words seems to be rather robust against slight alterations in pronunciation, like changes in vowel duration, while such alterations may still trigger subsequent control processes.

## 2.3. Study III: Influence of dialect use on early reading and spelling acquisition in German-speaking children in Grade 1[1]

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**Abstract**

During literacy acquisition, children learn to match written and spoken language. Little is known about how this is achieved by children who grow up speaking a dialect. The present study examined literacy-related skills before school in 71 children ($mean_{age}$: 7.61y) with a differing degree of exposure to Swiss-German (CHG) dialect and tested their reading and spelling skills at the end of Grade 1. No differences in Grade 1 reading and spelling were found between groups of children with different CHG exposure. Structural Equation Modeling (SEM) revealed that CHG exposure was negatively associated with Grade 1 spelling and reading, when statistically controlling for early literacy-related-skills. At the same time, CHG exposure was positively associated with early literacy-related skills that drive reading and spelling development. Thus, literacy acquisition in children speaking a dialect is characterized by disadvantages due to a linguistic mismatch, but also by compensatory advantages of higher metalinguistic skills.

# 3. General Discussion

In the following section, the most substantial findings reported in this PhD thesis are recapitulated and discussed. In quintessence, this research project gives new insight into how neural measures of brain specialization differ depending on dialect use. Secondly, it broaches the issue of how speaking a dialect impacts literacy acquisition at the behavioral level. And thirdly, it discusses to what extent speaking a dialect together with literacy precursor skills obtained before school enrollment (e.g., phonological awareness amongst others) impacts reading and spelling skills at the end of Grade 1.

## 3.1. Dialect familiarity influences phonological and semantic processing in adults and children

In study 1 and study 2 we sought to identify neural mechanisms that underlie differences in phonological and semantic processing in adult and child native speakers of Swiss German (CHG) and Standard German (StG). Generally, it is a difficult endeavor to combine child and adult EEG data with each other, especially when both groups tested used different experimental paradigms and examined different neural ERP components. In order to make comparisons across study 1 and study 2 more comprehensible, first a brief summary of the most important finding of each EEG study is given. Then, these findings are discussed at a more general level:

***Summary of findings in study 1.*** Results from the MMN study investigating adult native speakers of CHG and StG revealed that the size of the neural MMN mismatch response in reaction to a deviant stimulus was tied to dialect familiarity. In study 1, we contrasted a pseudoword standard stimulus ([ˈd̥ɑtɑ]) containing an allophonic /t/ consonant variant found in both the CHG and the StG dialect with two deviant pseudoword stimuli ([ˈd̥ɑtːɑ] and [ˈd̥ɑt$^{h}$ɑ]) encompassing allophonic /t/ consonant variants, of which one was more familiar for CHG-natives and the other was more familiar for StG-natives. In the MMN time window, we were able to determine a *deviance x language variety group* interaction. In particular, the MMNmax analysis, defined by the strongest potential difference between fronto-central and inferior temporal electrodes (Jost et al., 2015), showed larger amplitudes for the speech sound contrast incorporating the allophonic /t/ variant *more unfamiliar* to the hearer. As such, study 1 uncovered familiarity effects for within-category allophones that differed from the wide range of literature on MMN elicitation. Previous research mainly reports greater amplitudes for native deviant speech sound contrasts than for non-native ones. However, these studies primarily examined familiarity effects based on differences between phoneme categories arising from language experience (e.g., Dehaene et al., 1997; Lovio et al., 2009; Näätänen, 2001; Näätänen et al., 1997; Pakarinen et al., 2009; Rinker et al., 2010; Zhang et al., 2005). Neural mechanisms of the MMN underlying familiarity effects for within-category comparisons thus seem to differ from between-category comparisons.

Dialect-based familiarity effects were also found at the behavioral level for allophonic speech sound processing: In the "same-different" discrimination task, we detected a similar *deviance x language variety group* interaction which was primarily driven by the fact that StG native participants were less able to perceive differences in contrasts encompassing the more unfamiliar long consonant [ˈd̥ɑtːɑ] and the familiar unaspirated reference stimulus [ˈd̥ɑtɑ], compared to when [ˈd̥ɑtɑ] was paired with the more familiar [ˈd̥ɑtʰɑ] stimulus. Notwithstanding, all participants had more difficulties detecting differences when the long consonant stimulus was paired with the short unaspirated reference stimulus. This is best explained by the fact that the aspirated plosive in the stimulus [ˈd̥ɑtʰɑ] differed more strongly acoustically (e.g., spectral differences) from the reference stimulus than did the long consonant [ˈd̥ɑtːɑ]. This spectral difference may have made it easier to detect the aspiration difference as opposed to the minute duration difference in the long consonant stimulus.

In contrast to the MMN effects that were driven by dialect-familiarity, the later P3a and LDN (late discriminative negativity) components were only influenced by stimulus-specific properties: In both dialect-specific groups, the aspirated deviant elicited a stronger P3a amplitude modulation than the long consonant deviant in reaction to the strong sudden alteration of attention focus following the MMN (Escera et al., 2000). Furthermore, the aspirated deviant also generated a larger LDN as compared to the long consonant deviant in both groups. This was most probably due to a larger degree of late attention re-orientation after the more prominent aspiration was heard (Wetzel, 2014).

***Summary of findings in study 2.*** To my knowledge, the here presented N400 semantic mismatch study in Kindergarten-aged children was one of the first that examined neural processing mechanisms based on dialect familiarity using word-picture pairs. To date, research either reports studies conducted in adults or slightly older children (e.g., 11.5 year olds in Schulz et al., 2009) and these studies primarily employ whole sentence contexts to induce semantic congruity judgment (for review see Kutas & Federmeier, 2011; Schulz et al., 2009 for 11.5 year olds; Friedrich & Friederici, 2004 for a picture-word paradigm in adults). Or, very young children aged 12-19 months are being investigated (Friedrich & Friederici, 2004, 2005). However, all these studies so far only examined lexical incongruity effects based on stimuli that were familiar to the hearer and which occurred in the hearer's native language repertoire. In contrast, we chose word stimuli that children comprehended well at the semantic level, but that encompassed wide-ranging (phonological and lexical) naming differences between CHG and StG dialect.

As such a dialect-based word-picture paradigm is new, no literature exists as to when and where neural responses to unfamiliar dialect-specific vocabulary and pronunciation should occur in the brain. In order to overcome this difficulty two different analysis methodologies were employed to examine semantic anomaly detection effects: The data-driven approach using a Topographic Analysis of Variance (TANOVA) identified significant within- and between-subject effects as well as their interactions across all time points and electrodes. In turn, the theory-driven approach made use of selected electrodes at centro-parietal locations, which in previous studies revealed largest semantic anomaly detection effects (for full review see Kutas & Federmeier, 2011). Given the lack of similar paradigms reporting ERP latencies for (dialect-based) semantic anomaly detection in young children, GFP values of the difference ERPs from the dialect-independent mismatch condition formed the basis to identify significant ERP peaks in all 3 experimental contrasts (e.g., Hauk et al., 2006). This made sure that time window selection in the vocabulary and pronunciation contrast was not biased by effects of interest. As such, we identified three GFP peaks in each experimental contrast and determined short time windows of +/- 20ms around the peaks that then were used for further analysis (e.g., Brem et al., 2009; Hauk et al., 2006).

Converging results from both analyses revealed that mono-dialectally raised CHG and StG native children showed very similar N400 and LPC (late-positive-complex) incongruity effects in the control contrast, where stimulus names were familiar to all children. Also, timing and topography of these effects strongly corresponded with findings on semantic violations of expectancy reported previously for children (Henderson et al., 2011; Schulz et al., 2008). In the dialect-based vocabulary contrast, however, we found *incongruity* x *language variety group* interactions that revealed a centro-parietal N400 and LPC effect in response to the unfamiliar dialect-specific word, similar to the effects found in the control contrast. Counter to this, the dialect-based pronunciation contrast only indicated an *incongruity* x *language variety group* interaction effect in the later occurring LPC, but not in the preceding N400 segment. Semantic processing of dialect-based pronunciation thus seems to be rather robust against slight articulatory alterations, like the here examined vowel duration difference between the CHG and StG specific pronunciation. However, these minor changes still triggered later processing mechanisms that resulted in the elicitation of the LPC. As such, the findings in study 2 suggest that the visually presented stimuli seem to have acted as primers that triggered expectations of specific lexical units that the participants hold in their native mental lexicon (Aitchison, 2001). However, if the spoken word item did not overlap with the concept retained in memory, be it based on dialect familiarity or expectancy in general, then a non-correspondence triggered a semantic mismatch effect. In such a manner, the word-picture semantic mismatch experiment reported here could, on the one hand, replicate the fact that N400 and LPC effects seem to be linked directly with lexical appropriateness and the linguistic certainty of the stimulus provided (Samuel & Larraza, 2015). On the other hand, we could extend this finding by the circumstance that such effects also may occur for dialect-based lexicality and pronunciation differences. Contrary to expectations based on previous research examining semantic incongruity detection (e.g., Connolly et al., 1994, 2001; Desroches et al., 2009; Schulz et al., 2008), however, we did not find a robust pre-N400 or PMN effect in either the control contrast or the dialect-based vocabulary contrast, where spoken word stimuli could have elicited such an effect. This may likely have occurred due to stimulus-matching issues, because it was not possible to explicitly yoke all auditory and visual stimuli to the extent that each mismatching or non-native word contrast encompassed a word-initial phoneme that differed from the expected word-onset.

To my knowledge, only two other studies exist so far that examined similar dialect-based neural processing mechanisms for semantic mismatch. However, they both investigated adult participants (Martin et al., 2015; Lanwermeyer et al., 2016). What is interesting, however, is that both of these studies showed similar topographic dialect-based familiarity N400 effects as the one found in the children's dialect-based vocabulary contrast, and Lanwermeyer and colleagues (2016) further reported similar LPC effects to occur in a comparison of two German dialects, when dialect-based pronunciation anomalies were re-analyzed for semantic fit (Lanwermeyer et al., 2016; Domahs et al., 2009). Although both these dialect-based studies employed experimental paradigms encompassing entire sentence structures and examined adults – and thus strongly differed from our experimental design – the self-developed N400 experimental paradigm used in this PhD thesis brought forward surprisingly similar results and, furthermore, could give new insight into the field of dialect-based children's research for how differences in lexicality and pronunciation impact semantic language processing at the neural level.

***Similarities and differences in phonological and semantic processing based on dialect and age.*** Although study 1 and study 2 examined different age groups and used different experimental paradigms, we nevertheless were able to determine significant effects based on dialect-based familiarity in both experiments. Obviously, linguistic specialization for one's native mother tongue leads to the development of a unique phonological and lexical mental repertoire (Kuhl, 2000; Kuhl et al., 2008). In both study 1 and study 2, mechanisms of native priming seem to have led to more extensive neural processing for linguistic units non-correspondent with what was stored in the individual's native mental lexicon, as reflected by larger MMN, N400 and LPC amplitudes in response to the non-native stimuli.

The direction of the effect in the MMN adults' study, i.e., smaller MMN for the more familiar allophone, suggests that neural processing was more efficient in comparison to the processing of the less familiar allophone. Putting this effect into the framework of *neural efficiency* based on a predictive coding model, this result may be understood as more precise prediction (and thus smaller prediction errors) based on higher familiarity with one allophonic variant compared to another one. In such a manner, it seems that predictions of an upcoming stimulus were not just determined by what was heard just moments before, but much more, that a feedback mechanism following initial fast feedforward processing was involved, similar to mechanisms reported for models of visual processing (Bar, 2007). Furthermore, this mechanism seems to be highly contingent on one's native phonological repertoire. Neural efficiency is also key to explaining why the *deviance x language variety group* interaction in the MMN paradigm was primarily driven by the StG-native speakers' MMN response. In contrast to CHG native adults who grew up in the German Swiss diglossic language context and who were exposed to both German dialectal variants in question, StG native speakers had had substantially less contact towards CHG dialect. The intense bi-dialectal exposure and language use of CHG natives may thus have led to a facilitation for the perception of the StG-specific [$t^h$] allophone deviant at the neural level. This may have slightly altered CHG natives' mental representation of the allophonic phonemes [t] and [tː], extending it by the allophonic variant [$t^h$]. In contrast, it seems that the StG native speakers' exposure to CHG had not been sufficient enough to impact the native phonetic inventory at the same level. Notwithstanding, the phonemic boundaries of StG native speakers may have also become influenced by living in Switzerland: Evidence of this is found in the fact that StG natives did not match the long consonant [tː] deviant directly onto the phonological representation they held for the short unaspirated [t] phoneme as postulated by Kuhl's (1994, 2008) native language magnet (NLM) theory (because this would have resulted in no MMN at all), but did indeed show processing differences in terms of an MMN for the more unfamiliar long consonant deviant.

Neural efficiency can also be brought into context with larger N400 and LPC amplitudes in response to dialect-based violations of expectancy (Kutas & Federmeier, 2011): In study 2, stimuli highly correspondent with dialect-based expectations involved lesser neural processing compared to when the stimuli were spoken in a non-native dialect. Our results suggest that the lack of familiarity (or priming), together with the absence of a robust manifestation of a mental lexicon for non-native phonology and lexicality, seems to have demanded more intricate neural processing, because the non-native auditory stimulus first needed to be checked for potentially meaningful information (Kutas & Federmeier, 2000) and only then could be compared with the concept stored in memory that was primed by the visual stimulus (Nigam et al., 1992).

Although the here examined CHG native adults and children both lived in the same diglossic language context in Switzerland, it seems that CHG native pre-literate children have not yet developed a robust mental representation for StG vocabulary and phonology. This effect is most likely due to the fact that CHG native children are primarily exposed to CHG dialect before they are enrolled into elementary school, and only begin to receive formal instruction into spoken and written StG in school classrooms.

In conclusion, study 1 and study 2 could show that neural response patterns to native phonological speech sound contrasts differed distinctly to the one's found for non-native variants. As such, early exposure to a specific linguistic environment seems to impact the development of one's mother tongue and the phonetic inventory associated with it (Peltola et al., 2003). In addition, the presented results suggest that exposure to a non-native dialect may, at least to some degree, have influenced within-category phoneme processing at the neural level, to the extent that phonetic boundaries may become slightly weakened. Evidence for such an effect was provided by the fact that (1) StG native adults did indeed reveal an MMN for the unfamiliar long consonant deviant and did not match the unfamiliar speech sound stimulus onto their native pronunciation variant, and (2), because the pronunciation contrast in the audio-visual semantic mismatch did not elicit an N400 and thus demonstrated that the non-native pronunciation activated the same semantic concept as the simultaneously presented image. Notwithstanding, mere exposure to a dialectal variation, however, did not suffice to acquire a strong mental representation of non-native vocabulary in the children sample. This could be seen in the robust N400 semantic mismatch effect that was elicited in CHG native children for StG lexemes. However, further research is needed to determine whether similar neural processing effects for non-native phonological variants are also detectable in other language contexts than German (and dialectal varieties of it).

### 3.2. Impact of Swiss German dialect on reading and spelling acquisition

Based on earlier findings (e.g., Grade 2 to 6 study by Hartmann, 2016; unpublished) that report substandard spelling scores in CHG native children, study 3 aimed at identifying differences in reading and writing abilities in native CHG and StG speaking children. Different from study 1 and study 2, we here examined three (and not only two) groups of participants with different language background characteristics: (1) CHG native children who lived in Switzerland and spoke CHG at home and attended kindergarten in CHG dialect, (2) StG native children who lived in Switzerland and spoke Standard German (StG) at home, but attended CHG kindergarten and (3) StG native children who lived in Germany, spoke StG at home and attended StG daycare. Again, a brief summary of the most important findings is given. Then, these findings are discussed at a more general level:

Grade 1 reading and spelling skills did not differ for CHG and StG native children living in Germany or Switzerland on the basis of standardized test scores. This was rather unexpected given the fact that CHG native children grow up speaking a native Swiss dialect that differs strongly from the Standard German language form used in spelling and conversation in German-speaking Swiss school settings, and the fact that less stringent norms are often used to evaluate spelling scores in Switzerland (e.g., Swiss norms of the SLRT-II reading and spelling test). All children also showed relatively high scores Grade 1 reading skills (compared to age-specific norms) irrespective of native dialect background. However, word reading fluency was generally better for real words than for pseudowords. These findings go in line with previous studies investigating early reading in German (e.g., Moll et al., 2009; Schneider & Näslund, 1993; Wimmer & Hummer, 1990). Word reading fluency is strongly linked to quick retrieval abilities for (word and letter) information stored in the mental orthographic lexicon (Moll et al., 2009). Accordingly, the lower scores for pseudoword reading most probably originated due to the fact that pseudowords required step-wise letter-by-letter decoding. In the Grade 1 spelling tasks used in study 3, all children revealed relatively strong spelling skills. However, the here examined children frequently based their spelling outputs on their native pronunciation. Thus, we were able to determine dialect-driven spelling errors. Comparable spelling errors based on native pronunciation have previously been reported by Schmidlin (2003), who examined early spelling outputs of German-speaking 7-year olds with different dialect-based backgrounds of German (CHG, StG and a southern Bavarian German dialect). Together with findings for early spelling outputs from our study and other studies (Schmidlin, 2003; Treiman, 1997; Williams & Masterson, 2010), results suggest that, proper or faulty early spelling attempts in young literacy learners are strongly linked to the representation the natively spoken word holds in the child's mental lexicon.

Reasons as for why we did not find any group differences based on native German language variety exposure in standardized reading and spelling scores may be explained with the different levels of preschool literacy-related skill abilities found in CHG and StG native children (in Switzerland and Germany) before school enrollment and their potentially compensatory effects on reading and spelling outcome. Specifically, CHG native children showed the highest levels for all preschool literacy-related skills and strongly outperformed the StG children in Germany. They also showed higher mean values of literacy-related skills than StG native children in Switzerland, although this difference only reached significance for invented spelling. How can the better scores for preschool literacy-related skills in CHG speaking children be explained? Even before entering school, CHG native children likely have developed at least some understanding for phonological and lexical differences that occur between CHG and StG and thus possibly have developed a higher sensitivity towards phonological differences that occur between the two German language varieties. Moreover, children living in Switzerland receive some alphabetic letter training in Kindergarten, and have developed at least some low-level letter-to-sound matching strategies before school enrollment. However, the higher alphabetic letter knowledge in CHG native children may, at least to a degree, also be driven by parental influences of home-literacy training, and as such this may represent a confounding variable that would need to be accounted for in future studies. This may also explain why StG native children in Switzerland showed lower letter knowledge scores compared to CHG native children, although both groups lived in Switzerland and received the same exposure to letter knowledge training in Kindergarten. Furthermore, as the literacy-related 'invented spelling' task makes use of both PA skills and letter knowledge, it was to be expected that children who performed well in both individual skills would also fair relatively well the invented spelling task. Indeed, this effect was also found in CHG native children.

Based on previous reports suggesting that preschool literacy-related skills seem have the means to predict later reading and spelling outcomes (e.g., Ennenmoser et al., 2012; Niklas et al., 2016; Ziegler & Goswami, 2006), it was of great importance to include this variable into the examination of Grade 1 reading/spelling scores. By using structural equation modeling (SEM) it became possible to include preschool literacy-related skills while investigating the effects of CHG vs. StG exposure on Grade 1 reading and spelling scores. To recapitulate, the variable *degree of CHG vs. StG exposure* was formed to investigate the ratio of CHG vs. StG heard by the children examined in this study and was calculated using the answers given by parents regarding the CHG vs StG ratio employed while children played outside (e.g. on the playground etc.) and during storybook reading time at home. SEM results revealed that increased SwissG dialect exposure was significantly negatively associated with Grade 1 spelling, and slightly less (but still significantly) with Grade 1 reading, when factoring in preschool literacy-related skills. As such, study 3 could confirm that preschool literacy-related skills seem to drive later reading and spelling development (e.g., Furnes et al., 2011; Caravolas et al., 2004; Moll et al., 2009). But what is new, study 3 could also demonstrate that when reading and spelling acquisition in children is examined in a dialect-based context, adding literacy precursor skills into the investigation (which can very well be done with SEM) is paramount for understanding literacy learning.

A reason as for why we found a slightly more significant effect for Grade 1 spelling than for reading in the SEM models may be explained by the higher feedforward consistency for reading compared to the lower feed-backward consistency for spelling in the German language (Landerl et al., 2013). The non-correspondence between spoken and written language found for CHG dialect, resulting from the linguistic mismatch, seems to make spelling acquisition in German slightly more challenging for CHG native children than for StG native children: CHG natives first need to learn to match their CHG-specific linguistic representations onto new linguistic units of the German standard language, and this requires time and practice. Notwithstanding, CHG native children also seem to reap some benefits from the Swiss diglossic language situation, and this may add to explaining why CHG native children did not perform worse in the Grade 1 reading and spelling tasks. This also seems to be highly linked to the previously mentioned superior PA skills: Together with the understanding that the colloquially used spoken CHG dialect differs phonologically and lexically from the language used in school, CHG native children seem to employ their relatively well developed phonological processing skills as a compensation mechanism by adhering strongly to phonological cues, in order to achieve the same level of reading and spelling accuracy at the end of Grade 1 as found for both native StG speaking children's groups. Accordingly, it may be stipulated that by growing up in a diglossic language setting, dialect speaking children develop increased levels of literacy-related skills which are likely driven by better metalinguistic skills for phonological processing. Comparable effects of higher metalinguistic skills have been previously found in studies examining literacy acquisition in bilingual children (Bialystok et al., 2003; Vygotsky, 1962).

Aside from examining influences of dialect and literacy precursor skills on Grade 1 literacy scores, the SEM analysis in study 3 also took under consideration that the Swiss and German school system encompassed a wide-ranging difference in letter-to-sound matching instruction before school enrollment, and that this may have impacted Grade 1 reading and spelling skill development. Although differences between the Swiss and German school system revealed predictable effects for early literacy-related skills (i.e., better PA skills, letter knowledge, invented spelling in both groups living in Switzerland), the influence of school system onto Grade 1 reading and spelling was non-significant. Hence school system differences in Germany and Switzerland are not large enough to procure effects on Grade 1 reading and spelling outcome.

### 3.3. Linking neural and behavioral findings

Several findings from the behavioral and the neural examinations seem to be connected and this will be discussed as follows. However, it is important to note, that no investigation was conducted in this PhD thesis that directly combined neural and behavioral measures.

Key to literacy learning is to build associations between the visual form of lexical units (i.e., alphabetic letters and letter-clusters) with familiar phonological and semantic attributes of spoken language. This is done by learning about grapheme-phoneme correspondence, but also by developing mechanisms for audio-visual (e.g., sound-letter) integration at the neural level (Blau et al., 2009; Jost et al., 2014). Although neural mechanisms underlying audio-visual integration are still relatively unknown, recent neuroimaging research in literate adults could show that the neural response to synchronously presented congruent speech sound-letter pairings was enhanced in the auditory association cortex, but was reduced for letter-speech sound incongruity (van Atteveldt, Formisano, Goebel, & Blomert, 2004; van Atteveldt, Formisano, Blomert, & Goebel, 2007). However, similar studies examining entire spoken and printed word pairings have reported directly inverse effects (Hocking & Price, 2009). As one of the few studies investigating audio-visual processing in children, Jost and colleagues (2014) could show that audio-visually matching words elicited different responses in neural modulation in native (Swiss-)German Grade 1 literacy learners than when audio-visually presented stimuli mismatched or were unfamiliar (i.e., English words). Together with findings showing that neural networks are shaped by our experience (Kuhl et al., 2008) and with effects that were seen in study 2 in terms of N400 and LPC modulation based on familiarity of lexicality and pronunciation, as well as the notion that lexical familiarity promotes audio-visual integration, it can be assumed that neural mechanisms underlying literacy learning are highly linked to one’s native language (or language variety) repertoire. Accordingly, a strong correspondence between spoken and written language should promote literacy acquisition both at the neural and behavioral level. During early stages of literacy learning children decipher and blend words letter-by-letter and hereby retrieve semantic meaning by accessing what is stored in the mental lexicon (Aitchison, 2001). However, this may be more challenging for dialect speakers because certain spelled words are associated with different dialect-specific pronunciation or lexical entries (e.g., Brown et al., 2015). Due to this, retrieval mechanisms for semantic meaning may be less successful in dialect speaker until they have learned the word and pronunciation equivalents of the standard language.

In view of the effects for neural processing differences determined in the non-native pronunciation and the vocabulary contrast in study 2, one could have expected that CHG native children might perform worse Grade 1 reading and spelling than StG native children based on the linguistic mismatch reflected by dialect familiarity. The rather low familiarity (or inexperience) with StG before school enrollment, however, did not influence reading and spelling scores to the extent that CHG children showed lower reading and spelling test scores at the end of Grade 1 compared to StG native children in Germany and Switzerland. It seems that by (1) latest developing an awareness for lexical and phonological differences between CHG and StG while attending the first year of literacy learning in an StG-only school context and by (2) being taught letter-to-sound correspondence already shortly before school enrollment (which seems to have promoted the early development of sturdy literacy-related skills in terms of PA and letter knowledge), the CHG native children examined in this PhD project seem to have made use of compensation mechanisms (likely through higher metalinguistic skills) that protected them from worse reading and spelling performance at the end of Grade 1.

### 3.4. How does dialect influence standard language grammar skill development?

In study 3, aside from looking at literacy skill development, we also examined the developmental progression of StG grammar learning in the three experimental groups (CHG vs StG in Switzerland vs. StG in Germany). The results revealed that shortly before school enrollment, all children showed adequate levels of StG grammar skills (compared with standardized norms and under consideration of IQ). CHG native children showed equally high perceptive StG grammar skills as StG native children in Germany, and slightly better (but not significantly higher) scores than StG natives living in Switzerland. The rather high perceptive StG grammar skills in CHG native children before school enrollment probably resulted from early StG exposure based on the Swiss diglossic language situation (e.g., through television and radio programs) and, because these children at least at some level were familiarized with the fact that the German language variety spoken in German-Swiss schools encompasses distinct differences from their native CHG dialect. These factors seem to have promoted StG understanding competencies in CHG native even before formal schooling (e.g., Häcki Buhofer, 1993).

At the end of Grade 1, all children performed above the norm for the productive StG grammar task. Both StG native groups performed equally well, however, CHG native children performed (significantly) worse. It seems that by the end of Grade 1, CHG native children still have not yet acquired all the necessary rules to produce grammatically correct StG sentence structures and composites, although they already have a relatively high understanding of StG (Häcki Buhofer, 1993; Suter Tufekovic, 2008).

In cross-linguistic research, grammatical skills have shown to play a significant role in reading and writing acquisition in inflected languages (e.g. Greek and German; Fricke et al., 2008; Goulandris, 2003). In our study, however, the StG grammar task at the end of Grade 1 (but not before) showed a weak but significant correlation with Grade 1 reading. However, no such effects were found for spelling. It is possible that notable facilitatory effects of grammar skills onto literacy outcomes only become visible once children have encountered a large range of words in print, and, with a rise in linguistic complexity for reading and spelling materials (i.e., from simple words to entire sentences) (e.g., Muter, Hulme, Snowling, & Stevenson, 2004; Share, 1995). As feedforward complexity is lower than feedback complexity in the German language, this likely could explain why study 3 only determined a significant intercorrelation for Grade 1 grammar and reading, but not (yet) for spelling.

### 3.5. Implications – What can researchers and educators learn from this PhD thesis?

Several results of this PhD thesis have practical relevance. Firstly, study 3 could show that CHG native children performed equally well in standardized reading and spelling tests compared to StG native children living in Germany or Switzerland. This result thus lets the question arise of whether speaking CHG dialect does indeed lead to difficulties in early literacy learning in the German-speaking part of Switzerland - as postulated by use of less stringent norms of standardized reading and spelling tests e.g. for the SLRT-II in Switzerland. The brief answer to this question is: Yes, dialect does have a negative effect on reading and spelling outcome for dialect-speaking children, when accounting for (preschool literacy-related skills that predict later reading and spelling outcome). But growing up speaking a dialect seems to have a positive effect on (preschool) literacy-related skills which seems to mitigate the negative influence, as seen with the SEM analysis. CHG native children seem to develop higher metalinguistic skills due to the diglossic language context. Another reason as to why we did not find any significant group differences in reading and spelling skills at the end of Grade 1, however, may also be explained by the study sample of CHG and StG native children examined in this PhD project. Additional research with a more diverse children’s sample may help to clarify this issue. Moreover, it was shown in this PhD thesis that neural response patterns to native dialect-specific phonology and lexicality differed distinctly to the ones found for non-native variants. As such, we could determine that early exposure to a dialect impacts the development of one's mother tongue and the phonetic inventory associated with it, similar to the situation found across different language contexts. As previous research has shown, reading and spelling learning is highly linked to the building of robust (audio-visual) associations between letters/graphemes and speech sounds/phonemes at the behavioral as well as neural level and, additionally relies on a strong correspondence between spoken and written language. Regarding letter-to-sound matching abilities, CHG native children seemed to benefit from the early phonics instruction taught in Kindergarten (or that maybe arose from parental home-literacy trainings) and this likely promoted the development of solid PA skills even before formal schooling. However, high PA skills alone might not suffice to remedy the weaker correspondence between spoken CHG dialect and written StG (compared to spoken and written StG) and its impact on literacy learning.

In order to tackle the disadvantages of linguistic mismatch on early reading and spelling acquisition, the author of this thesis suggests the development of a schooling tool with which CHG native children could become systematically introduced to the characteristical differences that occur between their colloquially spoken native dialect and the standardized German language form used for reading and spelling parallel to literacy learning in Grade 1. This could be done by employing a "specialization training for difference detection between CHG and StG" in a whole-classroom setting during 1-2 German lessons per week, already from the beginning of Grade 1 on. In such a training setting, educators could for example read from a story book, where each sentence or even short paragraphs would be read aloud in StG and translated directly into CHG afterwards, and where dialect-based phonological and lexical differences would be examined, discussed and practiced in teacher-led group setting. A targeted intervention training to become aware of lexical and phonological differences between CHG and StG could thus promote the learning process in CHG native children to match lexical and phonological representations of StG onto the CHG dialect-specific vocabulary items they have already stored mentally. As a result of this, it would be expected that CHG dialect-speaking children would fall back less frequently into their native colloquial repertoires for word de- and recoding, especially in a "standard language-only" school setting like the one found in Switzerland. As young school children tend to spell words by means of speech sound blending, they would most probably benefit from such a training. Importantly, such a learning training would also require a scientific evaluation, in order to determine the (educational) costs and benefits of restructuring 1-2 German lessons per week. Moreover, it could be expected that children with different language-context backgrounds (e.g., bilinguals or children with migration background) would likely benefit from a learning training, where differences between CHG and StG would be discussed and practiced openly, as well.

Furthermore, speaking CHG dialect natively also seems to impact active but not passive StG-specific grammar skill acquisition. CHG native Grade 1 school children still seem to have rather limited active StG grammar knowledge, although they understand StG already at a very high level. An explicit teacher-based sensitization toward grammatical differences between CHG and StG would possibly help to overcome these challenges. A feasible setting to actively train StG grammar skills would be to investigate e.g., sentence structure differences between CHG and StG in a whole-classroom setting. This could be done e.g., during interactive story-telling sessions or be wrapped into a game context. During such a setting, educators and young school children could then systematically compare explicit differences between both German language varieties and simultaneously practice StG oral skills in a safe and pleasurable environment. Simultaneously, children would directly receive constructive and corrective feedback from the teacher. As such, children could quickly learn from the mistakes they make themselves, but also learn from mistakes made by others. However, such an explicit grammar training would probably be most effective only after Grade 1, when active StG grammar skills have already reached at least some level of expertise.

Notwithstanding, a high quality of oral language skills of CHG and StG in educators is essential for StG instruction in school. As children frequently acquire skills by learning from examples, it is important that school teachers themselves have acquired proficient expertise in speaking both German language varieties and, that they are able to convey specificities of StG and CHG dialect to their StG learning students in a well-understandable manner.

### 3.6. Limitations and future directions

The findings presented in this PhD thesis give new and important insights into how speaking a dialect that differs from the language’s standard form influences neural processing of phonological and lexical instances. Several similarities and differences could be found for mechanisms of neural processing based on dialect familiarity in adults and children. Furthermore, it could be established that CHG dialect-speaking children did not read or spell worse at the end of Grade 1 (according to standardized test scores) than children growing up speaking StG, a language variety that conforms better to the written language form of German than CHG dialect. However, speaking CHG dialect did indeed reveal a negative influence on early reading and spelling in German as seen in the complex SEM models (encompassing multiple variables), and, this effect seems to be contingent on the linguistic mismatch between (spoken) CHG and (written) StG. Notwithstanding, all three studies reported in this thesis as well as the thesis itself hold certain limitations and leave some questions unanswered that could be of relevance for future research. These issues are discussed as follows:

The key notion of the PhD project surrounding this thesis was to examine dialect-based brain-behavior interrelations and their impact on literacy acquisition. By combining behavioral and neural measures, it was anticipated to be possible to reveal the specificity to which covert neural mechanisms mediated the linguistic mismatch at the brain level. The analyses run in this PhD thesis, however, only investigated (1) how and to what extent neural measures for language processing are impacted by speaking a dialect, and, (2) how behavioral effects influence learning to read and spell in a dialect-based language context. As such, one of the greatest limitations found in this PhD thesis is, that it consists of two rather independent parts that are not linked very well. However, there are several reasons as for why neural and behavioral measures were not combined: It turned out that the prediction model used in study 3 was already very complex when only the behavioral indices were investigated. Based on the time available to accomplish this PhD project, it was not possible to construct an additional SEM model and to conduct the corresponding analyses to inspect neural measures for language processing and behavioral literacy (-related) measures with each other. However, such an analysis is planned for future research and should provide evidence for how measures of brain specialization for dialect use, as well as behavioral measures for literacy-related skills, could both be used to predict reading and spelling outcomes in Grade 1. Specifically, it would be interesting to examine neural mechanisms for semantic mismatch detection (in terms of the N400 effect resulting from comparing amplitudes for deviance and match detection) from the control contrast used in study 2 and to employ this as a measure for semantic processing. It is hypothesized that children who show larger N400 effects would have lesser semantic integration difficulties (e.g., Schulz et al., 2008) and that N400 effects would correlate for example with measures for German reading comprehension, where semantic information needs to be processed efficiently. With the help of a similar analysis, it furthermore could be examined whether amplitude size of N400 effects in for example the dialect-based vocabulary contrast would show an inverse relation to Grade 1 reading and reading comprehension (and maybe even spelling) in CHG native children. Such an effect would indicate that a high degree of priming towards native CHG lexicality would negatively impact Grade 1 literacy outcomes in StG.

A further limiting circumstance for the inclusion of neural measures into study 3 was, that we did not specifically test for StG vocabulary knowledge in CHG native children prior to or after running the N400 experiment. Neural measures for semantic anomaly detection revealed that CHG native children were not yet primed to StG vocabulary or phonology, but instead showed a high predisposition towards stimuli spoken in their native CHG dialect, as seen in the smaller N400 and LPC effects. However, as it was not specifically determined to what extent CHG native children already knew and could produce StG-specific vocabulary equivalents, it remains unclear whether the N400-LPC effects stemmed directly from a lesser degree of auditory stimulus expectancy or rather from general nescience of StG vocabulary. In a future study where dialect-based semantic mismatch effects are examined, it would be of great importance to collect additional data on the active production level of standard language vocabulary, by e.g., picture naming of previously seen as well as new (but equally difficult) stimuli. Additional testing would have provided better insight into the level of StG-specific language skills in CHG native children shortly before school enrollment. Furthermore, such knowledge could have been used as a covariate when analyzing amplitude differences between matching and mismatching dialect-based stimuli.

A further critical general limitation in this PhD thesis was the size of the examined study sample. Although EEG studies often have relatively small sample sizes, effect robustness could strongly profit from examining larger study populations. Notwithstanding, the fact that the data for this PhD project was collected in and aroung Zurich, Switzerland as well as in Magdeburg, Germany using the same equipment (EEG system, computers, screens and behavioral test batteries) may give this research project additional experimental strength and robustness that similar studies may often lack. In other studies which are run in different places, often different equipment is being used and this may have uncontrolled effects when group comparisons are carried out, like the ones conducted in this PhD project. Moreover, SEM analyses generally use rather large study populations (> 100 participants) in order to achieve statistically meaningful prediction analyses. Yet the behavioral SEM analysis conducted in study 3 revealed rather good fit indices although only 71 participants were examined. Additionally, study 3 could replicate the existing finding that preschool literacy-related skills impacted later reading and spelling scores (e.g., Moll et al., 2014), underscoring the robustness of the reading and spelling models. Additionally, study 3 also could provide evidence for the previously unexamined issue of whether CHG dialect negatively influenced Grade 1 spelling in StG (together with literacy-related skills obtained prior formal schooling). In future research, however, it would be important to replicate these findings and to employ a more wide-ranging longitudinal design with an even larger data pool.

Regarding the individual studies reported in this PhD thesis, study designs of study 1 and study 2 also held some notable limitations: In particular, it is difficult to make generalizations about the dialect-based familiarity effects found in study 1 for phonological within-category deviance detection. While CHG native speakers were fluent in both dialects, StG native adults only spoke their native language variety and did not show any proficiency in understanding or speaking CHG, although they were expose to the CHG dialect due to living in or around the city of Zurich. As such, study 1 compared adult participants, who were exposed to both the CHG and StG dialect, but who had different degrees of familiarity and competencies in either language variety. Based on the profound exposure to CHG of StG native adults, the CHG-specific long consonant deviant most probably was not treated as an entirely unfamiliar or non-native speech sound, nor was it mapped onto a native StG-specific speech sound as proposed by Kuhl's NLM theory (2008). It is to be assumed that the long consonant deviant stimulus was treated as an allophone in study 1. However, this cannot be said with complete certainty. In a future investigation, it would be essential to examine an additional StG native group, who has not had any contact to CHG dialect at all. Only then could this question be answered to its fullest extent. Furthermore, stimulus quality of the standard stimulus lacked phonotactic typicality, once at the intervocalic short /t/ and again at the /a/ ending. This may have had an influence on the MMN effect reported in study 1. Controlling for phonotactic typicality/legality in a future dialect-based MMN experiment would thus bring clarity.

Regarding study 2, the analysis of neurophysiological markers for dialect-based processing of native and non-native vocabulary and pronunciation was limited by prior knowledge on topography and timing in children before school enrollment. In order to overcome this issue two separate analysis methodologies were used. However, it cannot be denied that this strategy may have led to oversight of significant effects, i.e., the pre-N400 component in all three experimental contrasts. Furthermore, the block-wise presentation of the audio-visual stimulus pairings for each of the three experimental contrasts may have led to pattern learning of whether a sequence of matching or mismatching (control or dialect-based) audio-visual stimuli would occur after observing the first audio-visual pair of each block. While setting up the experiment, it was discussed at length whether to mix conditions (matching and mismatching pairs based on expectancy) and contrasts (dialect-based and control), or not. In order to avoid confusion in the participants, blocks were kept consistent, both in condition and contrast. Although, study 2 did indeed reveal dialect-based semantic congruity effects, additional research is duly needed. Only then can temporal occurrences and the stability of dialect-based semantic mismatch effects be distinctly determined. Accordingly, dialect-based research would benefit from investigating different dialects of German with a similar semantic mismatch paradigm. Once neural mechanisms of semantic and phonological mismatch detection based on German dialects are better understood, this could lead to similar investigations that examine different dialect and language contexts, i.e., in English, Arabic or even Chinese.

Previous research across different languages has shown that other factors than examined in this PhD thesis may influence literacy skill development, as well. For example, parent-child reading strongly affects early literacy skills and likely is especially crucial for skill development when it occurs before or latest around the time when children begin to read (Hood et al., 2008; Scarborough & Dobrich, 1994). This effect is largely based on the fact that parents often introduce their child to letter-to-speech sound correspondences during such reading sessions. In study 3, where preschool literacy-related skills and reading and spelling outcome were examined in a longitudinal design, an examination of home-literacy training effects did however not take place. Accordingly, it was not examined whether and to what extent home literacy training may have mitigated dialect-specific influences on early reading and especially on early spelling acquisition. Additional studies where all children's groups received the same letter-to-sound matching training prior to school enrollment and where data collection begins much earlier (e.g., in preschool) would surely help to determine potential home-literacy training effects and the impact of parental involvement for literacy acquisition in German dialects. Moreover, dialect-specific literacy research would highly benefit from conducting replication studies on a broader range of dialectal variations of German. This would allow to make more generalized conclusions for dialect-specific influences on early reading and spelling acquisition based on a larger and more diverse data sample.

Another well-established fact in literacy learning literature is that literacy-related skills prior to formal schooling seem to drive later reading and spelling skills (e.g., Furnes et al., 2011; Caravolas et al., 2004; Moll et al., 2009). In study 3, this finding was replicated and, additionally, it was demonstrated that speaking CHG dialect was negatively associated both with Grade 1 spelling and reading, when accounting for preschool literacy-related skills. Considering the effect that speaking a dialect seems to influence early reading and spelling outcome, it would be important to also investigate whether such effects persist on into later grades of primary school in CHG native children. In line with this, further research is also needed to identify whether (phonological, lexical or even grammatical) dialect-specific traits impact later reading and reading comprehension skills. This might also bring potential for new insights as to why CHG native children seem to show worse reading (comprehension) scores compared to StG native children in Germany, as seen time and again in the Grade 9 PISA reading scores (cf. OECD, 2010, 2016). As a means of investigating this, it would be important to obtain additional neurophysiological data on how CHG native children processed StG vocabulary and phonology after prolonged exposure to the StG language variety. Such effects could for example be examined by analyzing changes in neural measures of linguistic mismatch detection in CHG native children in a longitudinal design during German literacy learning, e.g., across a time period ranging from before school enrollment (T1) when children are pre-literate up to Grade 4 (T2) when basic reading and spelling skills (in terms of phoneme-grapheme and grapheme-phoneme mapping) have become relatively robust. In Grade 4, however, it would be important to not only use picture stimuli as primes to determine dialect-based semantic (lexical and phonological) mismatch detection at the neural level, but instead also use printed words as visual primes that are spelled properly or encompass dialect-based spelling errors. Aside from neural processing mechanisms for dialect-based semantic mismatch effects, such a study could additionally reveal potential dialect-based influences for audio-visual integration processes of reading. Furthermore, data on Grade 4 reading, reading comprehension and spelling skills would need to be collected in order to determine developmental aspects of literacy learning at the behavioral level. On top of that, it might be important to even examine Grade 4 mathematics skills and to compare whether numerical-only math problems are solved more quickly and better as compared to math problems embedded in a story context. Ideally, such a study would examine the same children tested in study 2 and 3 of this PhD project, or at a minimum, the previously examined CHG and StG native children living in Switzerland.

Altogether, this PhD thesis is one of the first research projects to shed light onto how speaking a German dialect impacts learning read and spell in children who encounter a bi-dialectal language context, as the one found in the German-speaking part of Switzerland. Additionally, evidence for the fact could be provided that speaking CHG dialect (and the linguistic mismatch associated with it) indeed seems to impact reading and spelling acquisition negatively, when literacy-related skills prior to formal schooling are accounted for. Furthermore, this PhD thesis gives new insight into how familiarity with a German dialect impacts phonological processing at the neural level. It was shown that adults (study 1) and children (study 2) both seem to hold a strongly primed inventory for native phonemes (and allophones) and accordingly required more extensive mechanisms to process non-native (and thus more unfamiliar) variants than native ones. Moreover, the auditory presentation of non-native lexical items elicited strong incongruity effects similar to the processing mechanisms found for semantically unfitting stimulus pairings in Kindergarten-aged children. As such this result indicates that CHG native children have not formed robust mental representations of StG vocabulary before they are enrolled into Grade 1 of elementary school. Notwithstanding, this PhD thesis also addresses gaps in research that still need to be investigated. By further identifying neural and behavioral mechanisms pertinent for literacy learning in a bi-dialectal language context and with similar research to come, it should soon become possible to successfully determine and develop learning strategies that address problems in literacy acquisition that arise from speaking a dialect.

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# 5. Curriculum Vitae

## Personal information

Name: Jessica Carolyn Bühler

Address: Sonnenbergstrasse 57, 8800 Thalwil

E-Mail: jessica_buehler@gmx.net

Date of birth: 09.03.1985 (born in Berne, Switzerland)

Nationality & place of citizenship: CH, Felsberg (GR)

## Education

| | |
|---|---|
| May 2013 - | LIFE PhD program, International Max Planck Research School “The Life Course: Evolutionary and Ontogenetic Dynamics”, where I was the Fellow-speaker for the Zurich LIFE site from Oct 2014 to Nov 2015 |
| March 2013 - | PhD program, Center for Neuroscience Zurich (ZNZ) |
| March 2013 - | PhD program of the University of Zurich (30 ETCS): Institute of Psychology |
| Oct 2004 - May 2012 | University Studies in Psychology at the University of Zurich<br>Major: Clinical Psychology - Neuropsychology<br>1. Minor: Psychopathology for Children and Juveniles<br>2. Minor: English Linguistics |
| Aug 1997 - July 2003 | Kantonsschule Freudenberg<br>Langzeitgymnasium Typus B (Englisch & Latein) |

## Positions and Internships

| | |
|---|---|
| Oct - Nov 2015 | 4 week research exchange at the University of Virginia (UVa) in Charlottesville, VA at the Quantitative Psychology Laboratory (Advisor: Prof. Timo von Oertzen) to develop SEM model for longitudinal children's study (as part of dissertation project) |
| March 2013 - (funded until Nov 2016) | PhD position (100% work capacity) at the Department of Psychology of the University of Zurich, Division of Cognitive Neuroscience and Division of Developmental Psychology: Infancy and Childhood |
| June 2012 - Nov 2012 | Temporary position (100% work capacity during 6 months) as a post-graduate Neuropsychologist in the Department of Neuropsychology at the Rehabilitation Center „Kliniken Valens“ |
| Aug 2009 - May 2012 | Internship and position as Helping Assistant (20-40% work capacity) at the "Neurofeedback" practice of Marietta Chatzigeorgiou (lic. phil. Psychologist, SPV); working with patients with ADHD, epilepsy, learning deficits etc. (children & adults) |
| Dec 2009 - Nov 2010 | Internship as a Helping Assistant (20% work capacity) at the Division of "Verkehrspsychologie" of the University of Zurich |
| Jan 2009 - Apr 2009 | 13 week internship (100% work capacity) at the "Sleep Laboratory" of the Children's Hospital of Zurich led by Prof. Reto Huber |

## Qualifications

| | |
|---|---|
| Feb 2009 | MRI Safety Course at the MRI Center of the Children's Hospital of Zurich |
| Dec 2002 | Cambridge Proficiency Certificate: Grade B |

## Language skills

German: mother tongue

English: Proficiency (2nd mother tongue)

French: fluent (6 years at Gymnasium and sporadic current use)

Spanish: moderate verbal skills, better perceptive skills

## List of publications

**Publications:**

Journal articles:

Bühler, J.C., von Oertzen, T., McBride, C., Stoll, S., Maurer, U. (In preparation for Frontiers in Education: Educational Psychology). *Influence of dialect use on reading and spelling acquisition in German speaking 1st grade children.* (Expected submission in Jan 2017).

Bühler, J.C., Waßmann, F., Buser, D., Zumberi, F., & Maurer, U. (submitted to Brain Topography, currently under review). *Neural processes associated with vocabulary and vowel-length differences in a dialect: An ERP study in pre-literate children*.

Bühler, J.C., Schmid, S., & Maurer, U. (accepted by Language, Cognition and Neuroscience in December 2016). *Influence of dialect use on speech perception: Evidence from a mismatch negativity (MMN) study.* DOI: 10.1080/23273798.2016.1272704

Layman articles:

Bühler, J.C. (2017). *Do children who speak a dialect really have a harder time learning to read and write?* Online-Blog article on Learning and Development BOLD. (http://bold.expert/).

Bühler, J.C. (2015). Hochdeutsch lernen in der Schweiz. *Das Schweizer Elternmagazin Fritz & Fränzi*. 2/15, 44- 45.

**Presentations:**

Posters:

Bühler, J.C., & Maurer, U. (2015). Influence of dialect use on reading and spelling acquisition in German speaking 1st grade children: A behavioral data analysis. Poster presented at the LIFE fall Academy on Schloss Marbach, in Öhningen, Germany.

Bühler, J.C., Buser, D., Zumberi, F., & Maurer, U. (2015). Neural processes associated with vocabulary-specific and phonological differences in a dialect: An EEG ERP analysis in pre-literate Swiss and German children. Poster presented at the European Symposium for Neuroscience (ENS 2015) in Tampere, Finland.

Bühler, J.C., Buser, D., Zumberi, F., & Maurer, U. (2014). Influence of dialect use on speech perception in children and adults: Evidence from a mismatch negativity (MMN) study. Poster presented at the LIFE fall Academy at the Max Planck Institute (MPIB), in Berlin, Germany.

Bühler, J.C., & Maurer, U. (2014). Influence of dialect use on speech perception: Evidence from a mismatch negativity (MMN) study. Poster presented am 5. SAN Symposium for Applied Neuroscience, in Utrecht, Netherlands.

Bühler, J.C., Buser, D., Zumberi, F., Raith, M., & Maurer, U. (2013). Lesen und Schreiben mit Dialekt: Lese- und Rechtschreibschwierigkeiten und ihre Vorhersage mittels neuronaler Verarbeitung von Schweizerdeutsch und Hochdeutsch. Poster presented at the 17. Meeting: Schweizer Dyslexieverband, in Zurich, Switzerland.

Bühler, J.C., & Maurer, U. (2013). Neural mechanisms of linguistic mismatch: Reading and writing difficulties and their prediction by neural measures in children speaking Swiss German. Poster presented at the LIFE fall Academy on Schloss Marbach, in Öhningen, Germany.

Talks:

Bühler, J.C., Maffongelli, L. (2016). Motivation im schulischen Kontext. Guest presentation in seminar for Master students at the Department of Developmental Psychology: Infants and Children.

Bühler, J.C., Buser, D., Zumberi, F., & Maurer, U. (2015). Neural processes associated with vocabulary-specific and phonological differences in a dialect: An ERP analysis in pre-literate Swiss and German children and adults using EEG. Presentation held at the LIFE Spring Academy at the University of Michigan (UM), MI.