Bilingual language control:
The effects of sequential predictability on language switching

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Zusammenfassung


Um den Einfluss von Vorbereitung auf Wechselkosten zu untersuchen, wurde ein neues Sprachwechselparadigma entwickelt. Diese Paradigma, namentlich sequenzbasiertes Sprachwechsel-Paradigma, beinhaltet keine visuelle Stimulation. Beides, die Sprach- und die
Konzeptsequenz folgen einer vorhersagbaren, festen Reihenfolge die sich die Probanden zuvor einprägen. Darüberhinaus wurde ein auditives Signal implementiert, welches angab, wann die Probanden die instruierte Reaktion ausführen sollten. Da das sequenzbasierte Sprachwechselparadigma eine feste und daher vorhersagbare Sprach- und Konzeptsequenz nutzt, ermöglicht es beides, Sprache und Konzept, vorzubereiten.

Im ersten Abschnitt dieser Dissertation wurde der Einfluss von vorhersagbaren Reaktionen im Sprachwechsel untersucht. Entsprechend mancher Kontrollmodelle sollten beim Sprachwechsel keine Wechselkosten gefunden werden, wenn Reaktionen vorbereitet werden können (reconfiguration model; z.B., Rogers & Monsell, 1995). Im Gegensatz dazu nehmen das proactive interference model (Allport et al., 1994) sowie seine bilingual Variante (inhibitory control model; Green, 1998) an, dass bei vorhersagbaren Reaktionen Wechselkosten entstehen können.


Im zweiten Abschnitt der vorliegenden Dissertation wurde der Einfluss der Vorhersagbarkeit von Sprache und/oder Konzept unabhängig voneinander untersucht. Entsprechend des reconfiguration model und des inhibitory control model sollten Wechselkosten verringert sein, wenn sowohl die Sprache als auch das Konzept bekannt sind, verglichen dazu wenn entweder nur die Sprache oder nur das Konzept bekannt ist. Darüber hinaus, nehmen beide Modelle ebenfalls eine Reduktion der Wechselkosten an, wenn nur die Sprache bekannt ist, nicht jedoch, wenn nur das Konzept bekannt ist.

Insgesamt gelang es zu zeigen, dass die derzeitigen Kontrollmodelle obgleich sie zwar einen Großteil der Ergebnisse nahelegen, nicht ausreichend sind um alle vorliegenden Ergebnisse zu erklären. Aus diesem Grund wurde im Rahmen dieser Dissertation ein modifiziertes inhibitory control model entwickelt, welches die vorliegenden Ergebnisse sowie darüber hinaus die Ergebnisse vieler weiterer Studien zum Sprachwechsel erklären kann.
Summary

Every time bilinguals produce language they run the risk to involuntarily produce in the non-target language (e.g., Poulisse & Bongaerts, 1994). Yet, selection of words in the non-target language is constrained by a process known as language control, which makes it more probable that words from the target language are selected for production (e.g., Green, 1998).

An important experimental approach to investigate language control is language switching (e.g., Costa & Santesteban, 2004; Meuter & Allport, 1999), which typically requires participants to switch between two languages. A large amount of studies have shown that higher error rates and longer reaction times are obtained when switching from one language to another than when the same language is repeated (e.g., Costa & Santesteban, 2004; Meuter & Allport, 1999). This performance cost is usually referred to as “switch costs”.

The current study investigated whether these switch costs are affected by preparation, which is an effect that has mostly been neglected in language switching. This is surprising, since some models (e.g., Allport et al., 1994) have postulated that switch costs mainly measure interference, whereas language control is a process of language interference resolution. Preparatory effects on switch costs, on the other hand, are assumed to be a more informative marker for endogenous language control, since these allow for advanced (i.e., preparatory) interference resolution.

A novel language switching paradigm was constructed to investigate the effect of preparation on switch costs. This paradigm, named the sequence-based language switching paradigm, contains no visual input. To this end, both the language and concept sequence follow a fixed sequence, which the participants have to memorize. Since the sequence-based language switching paradigm contains a memorized language sequence and concept sequence, both the language sequence and concept sequence are predictable and can thus be prepared.
In the first part of this dissertation, the effect of predictable responses in language switching was investigated. According to some models of control, no switch costs should be observed in language switching when responses can be prepared (i.e., reconfiguration model; e.g., Rogers & Monsell, 1995). On the other hand, according to the proactive interference model (Allport et al., 1994) and its bilingual variant (i.e., inhibitory control model; Green, 1998), predictable responses could instigate switch costs.

The results of the experiments using the sequence-based language switching paradigm showed that switch costs can still be observed in a language switching task with predictable responses. Switch costs were even found when not just the language sequence and concept sequence were predictable, but also the response onset was predictably known. Hence, these results are more in line with the proactive interference model and the inhibitory control model than with the reconfiguration model.

In the second part of this dissertation, the effects of language predictability and/or concept predictability in language switching were investigated. According to the reconfiguration model and the inhibitory control model, knowing both the upcoming language and concept should reduce switch costs to a larger extent than only knowing either the upcoming language or concept. Furthermore, only knowing the upcoming target language should also reduce switch costs according to these two models, whereas no effect on switch costs should occur due to only knowing the upcoming target concept.

By manipulating the predictability of the language sequence and the concept sequence in the sequence-based language switching paradigm, smaller switch costs were found when both the languages and concepts were predictable than when only the language sequence or concept sequence were predictable. Yet, no influence on switch costs was found when contrasting language switching with either a predictable language sequence or concept sequence against language switching with no predictable language sequence and concept
sequence. Hence, these results are somewhat in line with the reconfiguration model and inhibitory control model. Yet, not all the results can be explained with these two models.

In sum, the results obtained in this dissertation indicate that the models of control still lack in some respects. To this end, a modified inhibitory control model is put forward that can explain the data patterns obtained in this dissertation and those of a large number of language switching studies.
Part I

Introduction and Theory
1 Introduction

It has been estimated that more than half the world’s population knows two or more languages (Grosjean, 2010). This ability to communicate with people in a variety of languages has become a necessity for many professional endeavors due to our ever more globalizing society. Furthermore, in countries such as Belgium and Switzerland, for example, it is paramount to be able to speak more than one language, because large sections of the population speak different first languages. It is even commonplace in these countries for job applicants to be able to communicate in several of these languages.

There are of course also benefits to being a bilingual or multilingual outside of a professional setting. Knowing multiple languages makes certain social situations easier, such as ordering food in a foreign country or talking your way out of a car accident while on vacation. There are even some cognitive benefits. Bilinguals are, for example, better at conflict resolution and executive control, in both language-related and language-unrelated tasks (e.g., Bialystok, Craik & Luck, 2008; Costa, Hernández, Sebastián-Gallés, 2008).

Due to these benefits, and our ever more globalizing world, there are more and more bilinguals. This trend is also reflected by an increase of research into the subject of bilingualism (for a review on bilingualism, see Bialystok, Craik, Green, & Gollan, 2009). One interesting bilingual domain, which is very specific for bilinguals, looks into how bilinguals are able to maintain their speech production to the target language without involuntary use of non-target language words, a process known as language control (e.g., Green, 1998).

Language control generally operates without bilinguals being aware of it. However, when this process fails, the bilingual speaker is sometimes alerted that his/her utterance conveyed the right meaning, but was not produced in the correct language (e.g., Poulisse, 1999, 2000). Being a native Dutch speaker myself, living in a foreign country (i.e., Germany), failure of language control occurs on a somewhat regular basis. The involuntary use of non-
target language words seems to occur even more often after being in Belgium for some time and then coming back to Germany or vice versa (for an explanation of this observation, see Levy, McVeigh, Marful, & Anderson, 2007). However, generally the language control process is capable to limit production to the target language (Poulisse, 1999, 2000; Poulisse & Bongaerts, 1994).

To investigate language control, a language switching task was implemented in the current study (e.g., Christoffels, Firk, & Schiller, 2007; Green, 1998). The production version of the language switching paradigm typically consists of the presentation of a language cue and either an object or digit (e.g., Costa & Santesteban, 2004; Meuter & Allport, 1999). Hence, the target language during cued language switching is derived from visually presented language cues (e.g., differently colored squares for different languages), whereas the correct concept can be deduced from the object or digit (see Figure 1).

![Diagram of cued language switching](image)

**Figure 1.** This figure shows a typical progression of a trial during cued language switching. First the visually presented cue and stimulus, respectively, determine the language and concept. The combination of language and concept should then lead to a response. With the sequence-based language switching paradigm, the top two panels (i.e., visual cue and visual stimulus) are bypassed, due to a memory-based language sequence and concept sequence, of which the combination then leads to a response.

Due to the use of two (or more) languages in the language switching task, there are both language repetitions and language switches from one trial to another. Typically, slower responses can be observed when switching between languages than when the same language has to be repeated as on the previous trial (e.g., Costa & Santesteban, 2004; Linck, Schwieter,
& Sunderman, 2012; Meuter & Allport, 1999; Philipp, Gade, & Koch, 2007). The performance difference found between these two types of trials is known as “switch costs”.

Next to the cued language switching paradigm, another language switching paradigm was used in this dissertation, named the sequence-based language switching paradigm (SBLS). This novel paradigm uses no visual objects/digits or language cues, but a memorized language and concept sequence. This means that in Figure 1 the SBLS paradigm does not require the top two panels (i.e., visual cue and visual stimulus), but can elicit the required response based on purely endogenous triggers. Since no visual signal is given which instructs the participants to produce a response in this paradigm, an auditory response-signal indicates that the next concept can be named in the correct language.

Because of the memory-based language sequence and concept sequence in the SBLS, sequential predictability-based preparation of responses is possible. Hence, participants can prepare for the upcoming trial in the SBLS paradigm, whereas this is typically not the case in cued language switching. This entails that with cued language switching, participants are generally unaware of which concept and language will be required in the next trials (i.e., an unpredictable language sequence and concept sequence)

The current study employed the SBLS paradigm, or a combination of both the SBLS paradigm and the cued language switching paradigm, to investigate the role of preparatory processes in bilingual language control.

An overview is given here to provide the reader a fuller idea of the current work: a theoretical and empirical review is presented of the language control literature prior to the empirical chapters, with an emphasis on language switching studies. This segment starts with an overall overview of monolingual and bilingual language processing (Chapter 2), ensued by a discussion on why language control is necessary (Chapter 3). In turn, this chapter is

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1 Note, however, that preparation is possible in the cued language switching paradigm by, for example, increasing the time between the language cue and the stimulus.
followed by an overview of the language switching literature. More specifically, language switching models (Chapter 5), paradigms (Chapter 4) and their corresponding phenomena are discussed. The latter topic has an emphasis on the target(s) of language switching (Chapter 6) and the influence of preparation effects (Chapter 7).

This is followed by the empirical segment. Eight experiments are presented in the empirical segment, all of which use the new SBLS paradigm or a variation of this paradigm. These experiments were divided into two related research questions. The first research question (Experiments 1-4; Chapter 9) revolves around the influence of a predictable language and concept sequence (i.e., a predictable response sequence) on language switching. This is interesting for several reasons: first off, this would give us an indication of language control during more natural language production, since language production is generally predictable and produced in a serial sequence (e.g., Acheson & MacDonald, 2009; Dell, Burger, & Svec, 1997). A second reason is that it allows us to specify certain models of control (e.g., Allport, Styles, & Hsieh, 1994; Green, 1998; Rogers & Monsell, 1995).

The second research question (Experiments 5-8; Chapter 10) depends on a systematical investigation of the different facets of response predictability during language switching. More specifically, the effect of language predictability, concept predictability and the combination of both predictability effects (i.e., response predictability) on language switch costs were examined. These experiments would demonstrate whether both language and concept information are needed to instigate language control or if knowledge of just the language or the concept can already initiate language control. These results are then also contrasted against the assumptions put forward in models of control (e.g., Green, 1998; Rogers & Monsell, 1995).

In the final segment, the findings are discussed in light of models of control, such as the reconfiguration model (e.g., Rogers & Monsell, 1995; Rubenstein, Meyer, & Evans,
2001), proactive interference model (e.g., Allport et al., 1994) and its bilingual variant: the inhibitory control model (Green, 1998). Moreover, a modified inhibitory control model is postulated to account for the results found in the current study. To provide additional evidence for this modified model, there is also a short review that compares results found in task switching and language switching. In the end, an overview of the advantages of each of the language switching paradigms is presented (including the novel SBLS paradigm introduced in the current study) and prospects for future research are discussed (Chapter 11).
Overview of language processing in a monolingual and bilingual setting

Before delving into language control and why we need language control, an outline of the major theoretical constructs of language production is provided. The process of meaning to articulation during monolingual word production results in the following sequence (Levelt, Roelofs, & Meyer, 1999): a nonlinguistic concept is formed, which entails information that the speaker wants to convey. At the lexical level, the corresponding lemma (i.e., semantic-syntactic representation of a word) is selected, after which the sound representations of the response are added (i.e., phonological encoding). Finally, the sequence of sounds can be produced through articulation, which involves activation of the necessary muscles.

This process is even more complex for bilinguals, since almost every level of the bilingual language production process can contain different representations for both languages. The bilingual variants of these different language processing stages will be introduced by prominent bilingual models.

A notable bilingual model of the first two levels (i.e., lexical-semantic level) is the Revised Hierarchical Model (RHM; Kroll & Stewart, 1994; for a review of this model, see Kroll, van Hell, Tokowicz, & Green, 2010). The RHM assumes that there are separate lexicons for each language, with a stronger connection from the second language (L2) lexicon to the first language (L1) lexicon. The concepts, on the other hand, are assumed to be shared across languages. The connection between the shared concepts and the language-specific lexicons is assumed to be stronger between the concepts and the L1 lexicon than between the concepts and the L2 lexicon. Whereas this model has inspired a lot of studies, not all of them are in line with these assumptions (for a critical review, see Brysbaert & Duyck, 2010).

Syntactic information is also assumed to be located at the lexical-semantic level, and thus part of this level. Yet, separate models have been proposed to account for bilingual
syntax studies. One influential model of bilingual syntax is that of Pickering and colleagues (Hartsuiker & Pickering, 2008; Hartsuiker, Pickering, & Veltkamp, 2004; Hatzidaki, Branigan, & Pickering, 2011). Similar to its monolingual counterpart (Pickering & Branigan, 1998), this model assumes that the construction of a sentence sequence is lexically driven. Put differently, lemmas direct the construction of a sentence through their syntactic information. Furthermore, this model assumes syntactic information to be shared across languages. Note, however, that not all bilingual syntax models assume that syntax is shared to a large degree across languages (e.g., De Bot, 1992; Ullman, 2001).

Finally, phonological representations are also assumed to be shared to a large extent across languages (e.g., Costa, Caramazza, & Sebastián-Gallés, 2000; Hermans, Bongaerts, De Bot, & Schreuder, 1998; Nakayama, Sears, Hino, & Lupker, 2012; Roelofs, 2003; for a review, see Roelofs & Verhoef, 2006). This view has been extrapolated to several bilingual models, such as the cascading activation account of cognates (words with a similar etymological background in two or more languages, which often co-occurs with a large phonological overlap; Costa et al., 2000), which will be discussed in greater detail in the following chapter (see “Cross-language influences”). Yet, according to Roelofs and Verhoef (2006), not all processes concerned with phonology are shared across language. Prosodification, for example, is a language-specific process according to these authors.

It can be deduced from this short overview, that there is quite some overlap between languages, but also distinct language-specific representations. This combination of language-specific and language-unspecific representations/processes could cause cross-language influences and even selection of non-target language words if language-unspecific representations can activate non-target language-specific representations to the point that they would be selected. In the next chapter, a review is given about cross-language influences and selection of non-target language words, both of which are imperative to determine the nature of language control.
3 Language control

Language control is the process that makes sure, or makes it more likely, that a spoken message will consist of words of the target language. Yet, bilingual word selection models do not seem to agree on the nature of this process. An overview is provided here of several prominent bilingual word selection models (for a review, see Kroll, Bobb, & Wodniecka, 2006) and their assumptions with regard to language control.

3.1 Bilingual models of word selection

The first of these models is the inhibitory control model (ICM; Green, 1998), which assumes that representations of both the target language and the non-target language(s) can be activated and selected. According to this model, selection of the correct translation equivalent occurs due to inhibition between the two languages. Thus, according to the ICM, language control consist of an inhibitory process on the non-target language which makes it more likely that words from the target language are selected (a more detailed overview of the ICM will follow, see “The proactive interference model”).

The language-specific selection model (Costa, Miozzo, & Caramazza, 1999), on the other hand, assumes that bilingual word selection is restricted to words of the target language. Yet, the representations of the non-target language can be activated, and thus influence bilingual language processing. Kroll, Bobb, Misra, and Guo (2008) appropriately described language control in this model as a “mental firewall” that is set up in such a way that only the representations of the target language can be selected.

A third model (Costa & Santesteban, 2004) combines the ideas of both the ICM and the language-specific selection model. According to this hybrid theory, balanced bilinguals, which are bilinguals with comparable language proficiency levels for both languages, rely on a language-specific selection mechanism, whereas second-language learners rely on inhibitory control processes (see also Kroll et al., 2006; Schwieter & Sunderman, 2008).
Taken together, there seem to be several distinct ideas on how language control takes place. According to the language-specific selection model, language control occurs by a restrictive language selection mechanism, which does not include selection of non-target language words. Similarly, the hybrid model assumes that this is the case for balanced bilinguals. The ICM, on the other hand, assumes that a process is needed to make it more likely that words in the target language are selected, as does the hybrid model for unbalanced bilinguals.

3.2 Empirical evidence for the need of language control

3.2.1 Cross-language influences

Since all three models assume that words of the non-target language can be activated, they all assume that cross-language influences can occur. Put differently, they all assume that processing in one language can be affected by another language. Cross-language influences have been investigated by a multitude of paradigms, such as structural priming (e.g., Hartsuiker et al., 2004), the preparation paradigm (Roelofs, 2003), masked translation priming (e.g., Jiang & Forster, 2001) and many more. One notable paradigm in this respect is the cross-language picture-word interference task (Costa & Caramazza, 1999; Costa et al., 1999; Ehri & Ryan, 1980; Hermans, 2004; Hermans et al., 1998; for a review, see Kroll et al., 2008). In this task, a picture and an overlapping written word are presented. The goal is to name the picture as fast as possible in a specific language, while ignoring the written word that is spelled in the other language. Typically, the data shows that picture naming is interfered by the distracter word when the picture and word are semantically related (e.g., cat and Hund, which means dog in German; e.g., Costa & Caramazza, 1999; Costa et al., 1999). Hence, this provides evidence that there are cross-language lexical-semantic influences. Another finding is that the picture is named faster when it is phonologically related to the distracter word (e.g., pig and Pilz, with the latter meaning mushroom in German; e.g., Costa
et al., 1999; Hermans et al., 1998). As of yet, this phonological facilitation effects has been seen as cross-language priming of phonological representations (for different explanations of this finding, see Starreveld, 2000).

Interestingly, cross-language influences can also be elicited by parallel activation of translation-equivalent items, which means that two translation-equivalent representations are activated to a high extent. Parallel activation across languages has been established by, among others (e.g., Dijkstra, 2005; Marian & Spivey, 2003), the cognate facilitation effect, which entails that cognates are produced and recognized faster than non-cognate words (e.g., Christoffels et al., 2007; Costa et al., 2000; Declerck, Koch, & Philipp, 2012; Hoshino & Kroll, 2008; Libben & Titone, 2009; Verhoef, Roelofs, & Chwilla, 2009). A prominent explanation of the cognate facilitation effect is based on the assumption that lemmas are separated across languages and phonological representations are shared (Costa et al., 2000; for a review on different explanations of the cognate facilitation effect, see Costa, Santesteban, & Caño, 2005). According to this cascading activation account, lemmas in both languages activate to some extent their phonological representations (i.e., parallel activation of translation-equivalent lemmas). Hence, a large amount of phonological representations would receive activation from both translation-equivalent lemmas during the production of cognates, since cognates are phonologically very similar across languages. This increased amount of activation of the cognate’s phonological representations would account for the cognate facilitation effect.

Similar evidence for parallel activation of languages was found in studies that investigated the effect of interlingual homophones, which are words that sound identical across languages, but differ in meaning (e.g., eye – Ei, meaning egg in German; e.g., Schulpen, Dijkstra, Schriefers, & Hasper, 2003), and in studies that investigated the effect of interlingual homographs, which are words with an identical word form across languages, but
that differ in meaning (e.g., *gift* – *Gift*, meaning poison in German; e.g., De Groot, Delmaar, & Lupker, 2000; Dijkstra, Grainger, & Van Heuven, 1999).

Thus, it seems that cross-language influences occur and that there is even parallel activation of translation-equivalent representations. These results are in line with the assumptions of all three bilingual language selection models that were reviewed in the previous section (Costa et al., 1999; Costa & Santesteban, 2004; Green, 1998).

### 3.2.2 Selection of words from the non-target language

Yet, the question remains whether words of the non-target language can also be selected. Some observations seem to indicate that this is in fact possible. In an English debate about the identity of Europe, for example, former Belgian Prime Minister Jean-Luc Dehaene and former Belgian Prime Minister Guy Verhofstadt, who are both native Dutch speakers, were unable to maintain their speech production to the target language (i.e., English). They sometimes noticed their own cross-language errors, which they were able to correct: for example, “*ieder* (meaning each) each house, each bureau can be a source [...]”. Yet, this was not always the case: for example, “[...] should be *meer* (meaning more) in the media [...]”.

While these observations might provide some evidence that non-target language words can be selected, several observational studies (Poulisse, 1999, 2000; Poulisse & Bongaerts, 1994) found that the use of non-target language during bilingual speech production occurs seldom. 35 hours of English speech data was collected in the course of this project, from 45 Dutch-English bilinguals. The speech data consisted of four tasks: an abstract picture description task, a concrete picture description task, an interview and a task consisting of retelling a story. During the course of these four tasks, 771 Dutch words were recorded during English production (approximately 0.6% of the total amount of words), most of which were function words.
The use of non-target language words was also investigated in a more recent study (Gollan, Sandoval, & Salmon, 2011). This study required balanced Spanish-English bilinguals to perform a verbal-fluency task. More specifically, they had to name in English or Spanish as many members of a semantic category (e.g., colors, sports, animals, etc.) or words that start with a specific letter (e.g., F, A, S, etc.) in 60 seconds. The older adults (mean age: 77.0) produced 1% of the words in the non-target language, whereas this was 0.4% for the younger adults (mean age: 19.7). This provides additional evidence that non-target language words can be selected, but that it happens only sporadically.

Hartsuiker and Declerck (2013) also added to this debate, but focused solely on function words. This study implemented a novel paradigm, in which production of the non-target language was elicited by the introduction of pictures of famous people, whose mother language was assumed to create a language context. The task typically consisted of a description task in which the participants had to indicate whether and how three pictures of famous people, all of whose mother language was the same, moved (e.g., Tom Hanks and Madonna went up, while Micheal Jackson stayed put). The production language could either be congruent with the mother language of the famous people or incongruent. The results showed that the function word between the two names (and in the previous example) was produced substantially more in the non-target language when the production language and mother language of the famous people were incongruent. Put differently, the language control process failed significantly more when the production language and the language context, provided by the mother language of the famous people, was incongruent (20.1% - 1.5%) than when it was congruent (7.0% - 0%). This was found with different output modalities (i.e., spoken and written production), different function words (i.e., and and or) and with different language pairs (i.e., Dutch-English and Dutch-French).

Taken together, it appears that words from the non-target languages can be selected during bilingual language production. This finding is contradictory to models that assume
language-specific word selection with balanced and/or unbalanced bilinguals (Costa et al., 1999; Costa & Santesteban, 2004), while it is in line with the ICM (Green, 1998). Thus, some kind of process is required to make it more probable that words of the target language will be selected for production, while words of the non-target language can also be selected.

The next chapter will discuss a prominent task to investigate language control, which was used in the current study. More specifically, an overview will be given of the language switching literature.
4 Language switching and its many facets

4.1 The scope of the language switching literature in a nutshell

Language switching studies have been conducted for several decades to investigate language control (e.g., Macnamara, Krauthammer, & Bolgar, 1968; Macnamara & Kushnir, 1971; for reviews on language switching, see Abutalebi & Green, 2007, 2008; Bobb & Wodniecka, 2013; Kroll et al., 2008). So far this task has been used to investigate both bilingual production (e.g., Declerck et al., 2012; Festman, Rodriguez-Fornells, & Münte, 2010; Linck et al., 2012; Philipp et al., 2007a) and bilingual comprehension (e.g., Grainger & Beavuillain, 1987; Orfanidou & Sumner, 2005; Thomas & Allport, 2000) with older adults (Gollan & Ferreira, 2009; Hernandez & Kohnert, 1999; Weissberger, Wierenga, Bondi, & Gollan, 2012), young adults (e.g., Christoffels et al., 2007; Prior & MacWhinney, 2010; Tarlowski, Wodniecka, & Marzecová, 2012) and children (Jia, Kohnert, Collado, & Aquino-Garcia, 2006; Kohnert, 2002; Kohnert, Bates, & Hernandez, 1999). It has been implemented in behavioral studies (e.g., Costa & Santesteban, 2004; Costa, Santesteban, & Ivanonva, 2006; Meuter & Allport, 1999), neuroimaging studies (e.g., Hosoda, Hanakawa, Nariai, Ohno & Honda, 2012; Price, Green, & von Studnitz, 1999) and in event-related potential studies (e.g., Jackson, Swainson, Mullin, Cunnington, & Jackson, 2004; Verhoef, Roelofs, & Chwilla, 2010).

The following section will go through the different language switching paradigms that have been implemented to investigate language control in these studies.

4.2 Language switching paradigms

4.2.1 Cued language switching

Typical language switching studies (i.e., cued language switching; e.g., Costa & Santesteban, 2004; Declerck et al., 2012; Meuter & Allport, 1999; Philipp et al., 2007a) are
characterized by their use of visual stimuli, such as pictures or digits, as a way to let participants name a pre-determined concept in their L1 or L2 (see top panel of Figure 2). The required language is typically indicated by presenting a visual language cue that precedes the to-be-named stimulus, or is presented simultaneously with the to-be-named stimulus.

Note: Cloud-shape contours indicate the use of endogenous triggers (e.g., a fixed sequence of concepts); straight indicate the use of exogenous triggers (e.g., a stimulus).

**Figure 2.** The top panel shows a typical progression of a trial during cued language switching: first the visually presented cue and stimulus, respectively, determine the language and concept. In turn, the combination of both should then lead to a response. In the middle panel, which shows voluntary language switching/alternating language switching, a similar progression takes place, apart from there being no exogenous language cues, but endogenous language cues. During sequence-based language switching, which is depicted in the last panel, both language cue and visual stimuli are not exogenously presented, but are endogenous.

### 4.2.2 Voluntary and alternating language switching

Whereas other language switching paradigms also use visual stimuli as a way to let bilinguals name a pre-determined concept, they implement language transitions differently from cued language switching. One approach is voluntary language switching, which requires
bilingual participants to choose which language to produce on each trial (Gollan & Ferreira, 2009). This entails that no visual language cues are required. Hence, in the middle panel of Figure 2, there is no need for a language cue to determine the language. An alternative to this approach is alternating language switching (e.g., Festman et al., 2010; Jackson et al., 2004), which uses a language sequence that changes language after every second trial (e.g., L1-L1-L2-L2 etc.). The latter set-up is similar to predictable task switching (e.g., Koch, 2003; Rogers & Monsell, 1995).

A novel language switching procedure is proposed in this dissertation. However, before introducing this procedure, the most relevant language switching phenomena and major models of control are described.

4.3 Markers of control in language switching

Each of the different language switching paradigms allows for the investigation of several markers of cognitive control, such as mixing costs, switch costs, asymmetrical performance costs and N-2 language repetition costs. A short overview of these markers and their characteristics will follow next.

4.3.1 Language mixing costs

Language mixing costs represent the difference between pure language block responses and mixed language block responses, with the typical pattern showing better performance during pure language blocks than during mixed language blocks (e.g., Christoffels et al., 2007; Gollan & Ferreira, 2009; Wang, Kuhl, Chen, & Dong, 2009). This particular performance cost is considered to be a marker of sustained control processes, primarily involved in interference resolution (for a review, see Kiesel, Wendt, Jost, Steinhauser, Falkenstein, Philipp & Koch, 2010; Los, 1996).
4.3.2 Language switch costs

Mixed language blocks generally consist of (at least) two languages, which results in two transitions between trials: one language succeeds the other (switch trials) or the same language has to be repeated (repetition trials). Generally it is harder to switch between languages than to repeat the same language, resulting in switch costs (e.g., Costa & Santesteban, 2004; Costa, Santesteban, & Ivanova, 2006; Declerck et al., 2012; Meuter & Allport, 1999; Philipp et al., 2007a; Verhoef et al., 2009). Unlike mixing costs, switch costs are a marker of transient control processes involved in interference resolution and carry-over effects (for a review, see Allport & Wylie, 1999).

4.3.3 Asymmetrical performance costs

Switch costs can also be asymmetrical across languages, which entails that larger L1 switch costs are observed than L2 switch costs (e.g., Macizo, Bajo, & Paolieri, 2012; Meuter & Allport, 1999; for a review, see Bobb & Wodniecka, 2013; Koch, Gade, Schuch, & Philipp, 2010). These asymmetrical switch costs have been the main focus of several language switching studies (e.g., Costa et al., 2006; Meuter & Allport, 1999), because it was regarded as evidence for persisting, reactive inhibition between languages, as indicated by Green’s ICM (1998). This idea is based on the following logic: since unbalanced bilinguals have more experience with language production in L1 than L2, L1 has a larger activation. Thus, L2 production requires relatively stronger inhibition of the more dominant L1, than inhibition of L2 during L1 production. As a consequence, it is relatively more difficult to switch from L2 to L1 in the subsequent trial, since a relatively larger amount of persisting inhibition has to be overcome when switching from L2 to L1 than when switching from L1 to L2.

However, other studies have found symmetrical switch costs with balanced bilinguals (Calabria, Hernandez, Branzi, & Costa, 2011; Costa & Santesteban, 2004; Costa et al., 2006) and unbalanced bilinguals (Christoffels et al., 2007; Declerck et al., 2012.; Gollan & Ferreira,
2009; Verhoef et al., 2010). Given this unclear pattern of results, the interpretation of asymmetrical switch costs is still under debate (e.g., Finkbeiner, Almeida, Janssen, & Caramazza, 2006; Verhoef et al., 2009), even though there are new, less equivocal markers for inhibition during bilingual language production which will be discussed in the next section (i.e., “N-2 language repetition costs”).

Another interpretation of asymmetrical switch costs comes from Finkbeiner et al. (2006) and relies on response availability. According to this interpretation, correct switch trial responses are rejected when they become available for production too soon. The idea behind this is that switch trials are supposed to be difficult and thus fast responses are probably going to be erroneous. To protect themselves against mistakes, participants will be suspicious of responses that are relatively fast when being in this difficult context (i.e., switch trials). Since L1 production is easier than L2 production, L1 switch trials are responded to slower due to the initial response being rejected for being too fast, relative to L2 trials. In turn, asymmetrical switch costs should occur.

A third interpretation of asymmetrical switch costs comes from Verhoef et al. (2009), who speculated that the switch cost asymmetry across languages is due to a larger L1-repetition benefit than L2-repetition benefit. This interpretation is based on the assumption that interference of the non-target language influences all trial types except L1 repetition trials, which are thus always the fastest. So, because repetition trials are relatively slower in L1 than L2, asymmetrical switch costs should occur.

Asymmetrical performance costs are not restricted to switch costs, but can also be found with language mixing costs (e.g., Christoffels et al., 2007, Gollan & Ferreira, 2009), with larger L1 mixing costs than L2 mixing costs. Interestingly, a difference in asymmetrical performance costs has been observed between switch costs and mixing costs. However, the pattern of results has been inconsistent. Whereas Christoffels et al. (2007) and Gollan and
Ferreira (2009) found symmetrical switch costs and asymmetrical mixing costs, Wang et al. (2009) found asymmetrical switch costs and symmetrical mixing costs, which is exactly the opposite pattern.

4.3.4 N-2 language repetition costs

Unlike the previously discussed markers of control, N-2 language repetition costs require the implementation of three different languages during language switching. Furthermore, N-2 language repetition costs measure a very specific aspect of control, namely inhibition (for a review on inhibition in bilingual language processing, see Kroll et al., 2008). Two studies have looked into this marker in a bilingual setting: Philipp et al. (2007a) and Philipp and Koch (2009) found that when bilinguals responded in a CBA sequence, with “A”, “B” and “C” being different languages, reaction times were faster during the production of language “A” than when the bilinguals had to respond in an ABA sequence. This type of performance cost is known as N-2 repetition costs and is explained by assuming that persisting inhibition will be stronger when producing in the same language as two trials prior to the current trial (ABA), relative to having produced in that language with a longer interval (CBA).
5 Models of control

Based on the robust empirical effects in language switching that were discussed in the previous chapter, theoretical accounts of control processes will be discussed in this chapter. The current study will primarily focus on language switch costs and there are two influential models, which are derived from the task switching domain (for a review of both models in task switching, see Kiesel et al., 2010; Vandierendonck, Liefooghe, & Verbruggen, 2010), that have specified the possible underlying mechanisms of switch costs. While these models are mainly postulated to explain task switching results, they could also be used to explain language switching results. Several studies have assumed that control processes that operate during task switching are similar to those operating during language switching (e.g., Prior & Gollan, 2011; Thomas & Allport, 2000; Von Studnitz & Green, 1997). So, it seems reasonable to explain language switching data with these models.

5.1 The reconfiguration model

The first model is the reconfiguration model (e.g., Mayr & Kliegl, 2003; Rogers & Monsell, 1995; Rubinstein et al., 2001). This model assumes that switch costs reflect the time needed to reconfigure the cognitive system from one task to another. Furthermore, according to a “pure” reconfiguration model, given substantial preparation time, switch costs should disappear. However, since substantial switch costs were still elicited with long preparation time (Rogers & Monsell, 1995), which were termed “residual switch costs”, it was assumed that two stages of reconfiguration occur. The first stage consists of a reconfiguration to the parameters of the new task (i.e., language in the current study) and can be executed before the presentation of the stimulus. Part of the reconfiguration can thus be accounted for by this first stage. A second reconfiguration stage follows during stimulus presentation (i.e., concept in the current study), which requires the task rules to be activated. Taken together, according to
the reconfiguration model, language switch costs indicate the time needed to reconfigure to a novel language with a specific concept.

5.2 The proactive interference model

The second model is the proactive interference model (Allport et al., 1994), which accounts for cognitive control on the basis of task inertia. Task inertia implies persisting activation/inhibition of the previously activated task that influences the current task. Language switch costs can be explained by this model by assuming that activation of the previously used language persists and thus causes either interference with the current language (switch trials) or causes facilitation based on residual activation (repetition trials). Note that the interference from the previous task can also consist of inhibition.

The proactive interference model also has a bilingual variant which is very prominent in the language control literature, named the ICM (Green, 1998). As mentioned earlier, according to Green’s ICM, proactive interference during bilingual language production, mainly consists of persisting inhibition. This means that language switch costs can be accounted for by assuming that when on trial n-1 a certain language has to be produced, the non-target language will be inhibited. Yet, when the previously inhibited language is required for production on trial n (i.e., switch trial), the inhibition that was exercised on trial n-1 will persist into trial n and thus needs to be overcome. This is not the case when producing in the same target language on trial n-1 and trial n (i.e., repetition trial). Hence, it should be harder to switch between languages than repeating the same language due to persisting inhibition in switch trials. Evidence for this account has been found in studies that investigated inhibition processes during language switching (e.g., Linck et al., 2012; Philipp & Koch, 2009).

Language interference resolution (i.e., inhibition) occurs in two places according to the ICM (see Figure 3). First off, the ICM assumes that language interference resolution occurs between language schemas, which are mental devices that are implemented to achieve task-
specific goals\(^2\). In turn, these language schemas affect language tags, which inhibit the lemmas of the other language. Yet, the language tags are not altered until the concepts have activated their lemmas according to the ICM. So, any language interference between translation-equivalent lemmas will not be resolved until the concept is known. However, some interference resolution can occur prior to knowing the concepts, between the language schemas.

![Diagram of inhibitory control model](image)

**Note:** arrow head means activation; circle head means inhibition; lightning bolt means interference resolution.

**Figure 3.** Visual representation of the inhibitory control model. In this model, language control starts between language schemas, which represent the goal to talk in a certain language. In turn, these language schemas activate their respective language tags and inhibit language tags of other languages. Yet, this only occurs after the concepts have activated their respective lemmas. Finally, the language tags influence the corresponding lemmas, which makes it more likely that the correct lemma will be selected.

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\(^2\) In a language switching task, the task-specific goal is to produce words or sentences in the target language.
The locus of language control and possible influences on language control

Similar to the ICM, many studies have assumed that language control occurs at the lexical-semantic level (e.g., Costa & Santesteban, 2004; Meuter & Allport, 1999). Yet, recent evidence has shown that next to the lexical-semantic level, manipulations related to other theoretical constructs, such as syntax and phonology, can also mediate language switching. Since the set-up of this dissertation allows for an investigation of the functional locus of language control, as will become clear later on, an overview of possible loci and/or influences found in language switching studies is provided here.

6.1 The lexical-semantic level

The assumption of the ICM, that language control occurs at the lexical-semantic level, was investigated by a recent study. Runnqvist, Strijkers, Alario, and Costa (2012) investigated whether language control occurs at the lexical-semantic level by means of a cumulative semantic interference task. The cumulative semantic interference variant employed in Runnqvist et al. (2012) consisted of alternating semantically-related items over trials. This means that trial n-2 and trial n were semantically related to each other, whereas trial n-1 was semantically-unrelated to the other two trials. In mixed language blocks, participants had to change language for every semantically-related item, whereas the semantically-unrelated items had to be produced in the same language as the last semantically-related item. In pure language blocks, on the other hand, participants had to respond in one of the two assigned languages (i.e., Catalan or Spanish) throughout the block. Similar to the findings of the cumulative semantic interference task in a monolingual setting (e.g., Navarrete, Mahon, & Caramazza, 2010; Oppenheim, Dell, & Schwartz, 2010), they observed longer response times with the production of every semantically-related item. However, the cumulative interference task did not interact with mixing costs. Since the cumulative interference task is assumed to
measure lexical competition through semantic influences (e.g., Alario & Moscoso del Prado Martín, 2010; Howard, Nickels, Coltheart & Cole-Virtue, 2006), it can be concluded that this finding indicates that there was no lexical-semantic influence on language switching.

A similar semantic context effect was implemented in a German-English language switching study (Declerck et al., 2012). This study employed semantic blocking, which also examines lexical competition (e.g., Damian, Vigliocco, & Levelt, 2001). In a semantic blocking task, items are presented either in a related context (i.e., the items prior and/or ensuing the current one belong to the same semantic category) or an unrelated context (i.e., the items prior and/or ensuing the current one belong to different semantic categories). The data typically reveals that items in a related context are named slower than items in an unrelated context (e.g., Belke, 2008; Damian et al., 2001; Declerck et al., 2012; Herrera & Macizo, 2011; Kroll & Stewart, 1994; for a review, see Rahman & Melinger, 2009).

Yet, Declerck et al. (2012) were mainly out to investigate the difference between digit naming and picture naming in language switching. Next to comparing digit naming with a standard language switching picture set, which contained no cognates and concepts that were not related, this study contrasted digit naming against two other sets of pictures. The first of these sets consisted of pictures of the same semantic group (i.e., related to the human body), whereas the second picture set consisted of pictures depicting cognates. Interestingly, digits elicited smaller switch costs than the standard language switching picture set. A similar switch costs difference was found between digit naming and naming pictures that were all part of the same semantic group. This finding lead to the conclusion that the switch cost difference between digit naming and picture naming in language switching is not due to digits being part of the same semantic group (i.e., semantic blocking) and thus does not provide evidence for a lexical-semantic influence on language switching.
In the same study, Declerck et al. (2012) did find a semantic influence on switch costs in a post-hoc analysis on the digit data. This re-analysis was focused on a specific marker of semantics, namely the numerical distance effect. This is a facilitation effect that occurs when two consecutive numbers have a small numerical distance, relative to when two consecutive numbers have a large numerical distance (e.g., Brysbaert, 1995). The results of Declerck et al. (2012) showed that a small numerical distance causes larger switch costs than when the numerical distance is large. Hence, priming of numerical semantic information can influence language switching and thus language control.

In sum, there is little evidence for a lexical-semantic influence on language switching, which undermines the claim that the lexical-semantic level is the locus of language control (e.g., Green, 1998). Yet, the fact that the numerical distance effect did interact with language switching seems to indicate that we should not disregard the idea all together. More research, preferably with different tasks, should give us a clearer view on whether and how language control operates in the lexical-semantic level.

6.2 Syntax

Whereas no models have assumed language control to be influenced by syntactic information, the examination of language switching in sentences is of special interest, since language switching in a natural setting (i.e., code-switching; e.g., Herredia & Altarriba, 2001; Joshi, 1983) usually occurs in a sentence or between sentences. Furthermore, because language control (e.g., Green, 1998) and bilingual syntactic information (e.g., Hartsuiker et al., 2004; Hartsuiker & Pickering, 2008; Hatzidaki et al., 2011) are both assumed to guide lemma selection, they should occur in close temporal distance of each other. Hence, this indicates that language control and bilingual syntactic information could be interconnected.

Recently two studies have investigated how language control operates in and between sentence sequences in a bilingual setting. Declerck and Philipp (2013a) contrasted language
switching in sentence sequences vs. in mixed, non-syntactic sequences. The data revealed smaller switch costs in sentence sequences that were syntactically correct in both German (L1) and English (L2) when the sentence is translated in a word-to-word fashion (e.g., my uncle loves fast cars/mein Onkel liebt schnelle Autos) than in a non-sentence sequence (e.g., fast loves uncle cars my/schnelle liebt Onkel Autos mein) and in sentence sequences in which the syntax was correct in just one of the two languages (e.g., today you can go shopping/heute du kannst gehen einkaufen). Another interesting result of this study was that several experiments showed no substantial switch costs in the sentence sequences that were syntactically correct in both languages when translating word-to-word (see also Gullifer, Kroll, & Dussias, 2013).

Tarlowski et al. (2012), on the other hand, investigated the influence of different sentence types by letting participants language switch between sentences instead of words. These authors let Polish-English bilinguals describe an action depicted in a drawing in either a present progressive or a present perfective phrase. Their study revealed that switch costs can still be obtained when Polish-English bilinguals switch languages between sentences. Furthermore, they found asymmetrical switch costs with progressive phrases and symmetrical switch costs with perfective phrases. The latter finding indicates that different syntactic structures can influence language switching differently.

Taken together, these results provide evidence that bilingual syntactic information can instigate differences in language switching and thus language control. The influence of syntax on language control has been interpreted as an indirect influence. More specifically, it is assumed that syntactic information affects the overall activation level of the lemmas and thereby influences language interference and language interference resolution.
6.3 Phonology

Next to lexical-semantic and syntactic influences, are influences from phonological characteristics on switch costs. It is interesting to note that in the task switching domain, several studies have provided evidence for the influence of “late” motor-related processes, like response execution, on switch costs (Koch & Philipp, 2005; Philipp, Jolicoeur, Falkenstein, & Koch, 2007; Philipp, Weidner, Koch, & Fink, 2012; Schuch & Koch, 2003; Verbruggen, Liefooghe, & Vandierendonck, 2006; for a review, see Kiesel et al., 2010). So, it appears likely that processes associated with response execution (e.g., phonology and articulation) also influence switch costs in a language switching setting.

Recent evidence has shown that motor-related processes play an important role during language switching. As mentioned earlier, a study by Declerck et al. (2012) found that language switch costs were smaller during digit naming than picture naming. An additional picture set with pictures depicting cognates, showed similar switch costs to those obtained in digit naming. This finding lead to the conclusion that the switch cost difference between digit naming and picture naming was due to a significant proportion of the digits being cognates.

Christoffels et al. (2007) also found an influence of cognate status on language switch costs. These authors investigated, among other effects, the influence of cognates on language switching by contrasting pictures that depict cognates vs. pictures that depict non-cognates. The results revealed that the cognate facilitation effect (e.g., Costa et al., 2000; Hoshino & Kroll, 2008), was substantially larger for repetition trials than for switch trials. Furthermore, they found that the cognate facilitation effect, which was faster for L2 (Dutch) than L1 (German) in pure language blocks, was faster for L1 than L2 in mixed language block. This pattern indicates an influence of phonology on mixing costs.

Using a similar set-up as Christoffels et al. (2007), but presenting written words instead of pictures to Italian-English bilinguals, Filippi, Karaminis, and Thomas (in press)
found larger switch costs for cognates relative to non-cognates (see also Thomas & Allport, 2000). This pattern is similar to that found in the numerical data of Christoffels et al. (2007; L1 switch costs for cognates: 51 ms; L1 switch costs for non-cognates: 33; L2 switch costs for cognates: 67 ms; L2 switch costs for non-cognates: 41). However, this pattern was not confirmed by statistical analysis in Christoffels et al. (2007). Yet, larger switch costs with cognates than with non-cognates is the opposite of what Declerck et al. (2012) found. Furthermore, Filippi et al. (in press) found larger switch costs with interlingual homographs and also found an influence of phonology on asymmetrical switch costs. More specifically, they observed a larger switch cost asymmetry with cognates, relative to non-cognate naming.

Whereas the previous studies manipulated phonological characteristics within words (i.e., cognate status and interlingual homographs), Declerck and Philipp (2013b) set out to investigate the influence of phonological characteristics across words and trials, by manipulating the phonological overlap between trials (Damian & Dumay, 2009; Sullivan & Riffel, 1999; Wheeldon, 2003). More specifically, they investigated words of which the first two phonemes were identical to those of the previously produced word (e.g., drill-dress) and contrasted this against words that did not have an overlap of these phonemes (e.g., cherry-bone) in a German-English language switching task. The results revealed that phonological overlap increases asymmetrical switch costs relative to trials without phonological overlap. Thus, similar to Filippi et al. (in press), this study also found an influence of phonology on asymmetrical switch costs.

Taken together, whereas some inconsistencies have been found across studies (Christoffels et al., 2007; Declerck et al., 2012; Filippi et al., in press), these results lead to the conclusion that phonology plays a considerable role during language switching and thus language control. Similar to syntax, the role of phonology during language control is assumed to be indirect. It has been proposed that the phonological influence might be due to feedback loops from phonological representations to their respective lemmas (e.g., Bernolet,
Hartsuiker, & Pickering, 2007; Declerck & Philipp, 2013b), which could influence the language interference between translation-equivalent lemmas and thus also language control (Declerck & Philipp, 2013b).

6.4 Theoretical relevance

Whereas Green (1998) assumed that language control operates on the lexical-semantic level, recent language switching studies have demonstrated that the scope of language control might go beyond that. Manipulations of the characteristics of different major theoretical constructs (i.e., lexical-semantic level, syntax and phonology) can, under the right conditions, influence mixing costs, switch costs and/or asymmetrical switch costs. Hence, it could be assumed that language control is, at the very least, influenced by representations of multiple theoretical levels and, at most, has multiple loci.
Another domain, next to the locus of language control, that has received little attention in the language switching literature are preparation processes. Preparation is a mental process that allows us to adjust for coming events and to change our mental state accordingly (for a review on preparation, see Jennings & van de Molen, 2005). Many variables can be altered by preparation, such as heart rate (Bohlin & Kjellberg, 1979; Graham & Clifton, 1966), pupil dilation (Beatty, 1982; Steinhauer & Hakerem, 1992) and skin conductance (Boucsein, 1992). Interesting for the current study is that reaction time and error rate are also susceptible to preparation (e.g., Logan & Bundesen, 2004; Meiran, 1996; Rogers & Monsell, 1995).

Preparation effects have also been observed in language switching (Costa & Santesteban, 2004; Macnamara et al., 1968; Philipp et al., 2007a; Verhoef et al., 2009). Yet, surprisingly few language switching studies have investigated preparatory processes, especially when compared against the large proportion of task switching studies that focused on preparatory processes (e.g., Altmann, 2004a, 2004b; Gotler, Meiran, & Tzelgov, 2003; Heuer, Schmidtke, & Kleinsorge, 2001; Hoffmann, Kiesel, & Sebald, 2003; Kiesel & Hoffmann, 2004; Koch, 2001; 2005; 2008; Logan & Bundesen, 2003; Lukas, Philipp, & Koch, 2010; Mayr & Kliegl, 2003; Meiran, 1996; Monsell & Mizon, 2006; Ruthruff, Remington, & Johnston, 2001; Schneider & Logan, 2007; Sohn & Carlson, 2000).

This lack of studies is even more surprising as some theoretical accounts assume that switch costs and mixing costs are mainly markers for interference (e.g., Allport et al., 1994). So, any difference in language switch costs or language mixing costs could solely refer to a difference in language interference. In contrast, language control is assumed to be a process of language interference resolution (e.g., Green, 1998). Hence, a more informative marker for endogenous language control are preparatory effects on switch costs or mixing costs, since
these allow for advanced (i.e., preparatory) interference resolution (e.g., Verhoef et al., 2009; for a review, see Kiesel et al., 2010).

Preparation can be examined in several different manners in a switching paradigm (for a review of preparation processes in a switching paradigm, see Kiesel et al., 2010). In the language switching literature, preparation has been investigated with either time-based preparation or predictability-based preparation. The results obtained with these two types of preparation will be discussed in the next sections, which will be followed by a discussion of how these results relate to models of control.

7.1 Time-based preparation

Several cued language switching studies have investigated the effect of preparation time on language switching (Costa & Santesteban, 2004; Macnamara et al., 1968; Philipp et al., 2007a; Verhoef et al., 2009). Preparation in these studies entails that more time is given in condition A than condition B, which can be used for active preparation. For example, by increasing the cue-to-stimulus interval (CSI; see Figure 4) additional time is provided until the actual response, which can be used to actively prepare the upcoming language to a larger extent. Costa and Santesteban (2004) used such a language preparation manipulation and found that language switch costs are smaller when language preparation time increases. Yet, this switch cost difference due to language preparation time was not observed by Philipp et al. (2007a). Furthermore, Macnamara et al. (1968) also did not find any time-based preparation effect on mixing costs, suggesting that language preparation effects are not very reliable in language switching.

A study by Verhoef et al. (2009) indicated that not just switch costs, but also the (a)symmetry of switch costs across languages might be influenced by language preparation time. Verhoef et al. (2009) found that switch costs were asymmetric with a short CSI, whereas with a long CSI they found symmetric switch costs. In contrast, Philipp et al. (2007a) did not
find any (a)symmetrical switch cost difference when comparing language switching with a short CSI and a long CSI. Declerck et al. (2012) assumed that this difference over studies was due to Philipp et al. (2007a) keeping the response-to-stimulus interval (RSI; see Figure 4) constant (1100 ms), which was not the case in Verhoef et al. (2009). In the short CSI condition of Verhoef et al. (2009) the RSI was 750 ms long, whereas in the long CSI condition the RSI was 1500 ms (plus a variable intertrial interval of 1500-2300 ms). This might indicate that asymmetrical switch costs are influenced by passive decay, since RSI is a marker for passive decay (for a review on decay in task switching, see Kiesel et al., 2010).

Note that Costa and Santesteban (2004) also found no (a)symmetrical switch cost difference when manipulating preparation time. However, the participants used by Costa and Santesteban (2004) were balanced bilinguals, who usually show symmetrical switch costs, even with a very short CSI (Costa & Santesteban, 2004; Costa et al., 2006).

Figure 4. Visual representation of a trial in a cued language switching task with the different interval types. The first interval consists of the cue-to-stimulus interval and is used as a marker for active preparation. The second interval entails the response-to-cue interval. This interval has been used as a marker for passive decay. The final interval, named response-to-cue interval, consists of both the cue-to-stimulus interval and the response-to-cue interval and is also a marker for passive decay.
7.2 Predictability-based preparation

Active preparation of languages in language switching is also possible when the language sequence is predictable, such as during voluntary language switching (Gollan & Ferreira, 2009) and during alternating language switching (e.g., Festman et al., 2010; Jackson et al., 2004), since the participants know which language will be used in the upcoming trial and thus can use this information for advanced preparation. Language switching studies using such a design demonstrate that switch costs appear even when the language can be prepared for due to a predictable language sequence. However, these studies did not specifically investigate the effect of language predictability on language switching.

A study by Macnamara et al. (1968) did investigate the effect of language predictability on language switching, next to time-based preparation effects. The data of Macnamara et al. (1968) revealed that a predictable language sequence reduces mixing costs compared to an unpredictable language sequence.

7.3 Theoretical relevance

The latter study (Macnamara et al., 1968) and Costa and Santesteban (2004) found a reduction of performance costs (i.e., mixing costs and switch costs respectively) due to language preparation. These findings indicate that language interference resolution has occurred on the basis of language information. This is in line with the reconfiguration model, which assumes that some reconfiguration can occur due to language information prior to stimulus presentation, and with the ICM, which assumes that some language interference resolution occurs between the language schemas. Yet, it needs to be taken into account that not all studies found a performance cost reduction due to language preparation (e.g., Philipp et al., 2007a). This inconsistent pattern across different studies (Costa & Santesteban, 2004; Macnamara et al., 1968; Philipp et al., 2007a) suggests that language preparation effects are
not highly robust and thus makes further examination of the role of language preparation in language switching essential.

**7.4 Gaps in the language switching literature related to preparation effects**

The previous sections demonstrated that several language switching studies have investigated language preparation effects. However, there are still some important areas that have not yet been examined.

One important hiatus concerns the influence of both language and concept preparation (i.e., response preparation) in language switching. Response preparation is an ecologically important characteristic, since natural language production typically consists of preplanning processes (e.g., Martin, Crowther, Knight, Tamborello, & Yang, 2010; Oppermann, Jescheniak, & Schriefers, 2010). So, investigating language control with response preparation is closer to natural bilingual language production. There are also theoretical aspects to consider: both the reconfiguration model and the ICM assume that control processes occur when both language and concept are known. Moreover, the reconfiguration model even assumes that no switch costs should be found when the response can be prepared.

Another gap is that no language switching studies have isolated the influence of concept preparation in a language switching setting. This line of research could be crucial, since it is assumed that concepts activate the target lemma and its translation-equivalent lemma (e.g., Green, 1998; Kroll & Stewart, 1994). Hence, some interference between lemmas could be resolved by concept preparation prior to knowing the target language. Yet, the reconfiguration model and the ICM assume no influence on language control solely due to concepts.

The aim of this dissertation was to address these gaps and try to gain some clarity on the language preparation effect in language switching.
7.5 Sequence-based language switching paradigm

To investigate response preparation in language switching, a novel language switching procedure was constructed (see last panel in Figure 2). Contrary to the cued language switching paradigm, in the SBLS paradigm, both the language sequence and concept sequence are endogenously triggered. This means that the concepts follow a fixed, memory-based sequence (e.g., weekdays). The language sequence is also fixed in that it changes after every second trial (e.g., L1-L1-L2-L2-L1 etc.; see e.g., Festman et al., 2010; Jackson et al., 2004). These fixed sequences allow participants to prepare for the upcoming trial in this paradigm. More specifically, the SBLS paradigm allows for predictability-based preparation. Furthermore, since both the concept sequence and language sequence are memory-based, no visual stimuli are needed in the SBLS paradigm. Accordingly, in the lower panel of Figure 2, which depicts a trial with the SBLS paradigm, there are no visual triggers (i.e., cue or stimulus) to produce a response. However, since no visual signal is given which instructs the participants to produce a response, an auditory response-signal is implemented that indicates that the next concept can be named in the correct language.

Next to the ability to investigate sequential predictability effects, the SBLS has several other advantages: by using a fixed sequence of responses (e.g., weekdays or numbers), it comes closer to natural speech production, because language is generally produced in a serial sequence (e.g., Acheson & MacDonald, 2009; Dell et al., 1997). Furthermore, by using no visual stimuli, the SBLS paradigm allows for the investigation of endogenous, memory-based response selection. This is important since during normal bilingual speech, response selection is for the most part endogenous, memory-based, whereas during typical language switching experiments, responses are exclusively exogenously triggered by visually presented pictures or digits (e.g., Costa & Santesteban, 2004; Declerck et al., 2012; Meuter & Allport, 1999).
8 Outline of the experiments

The previous chapter has shown that there are still gaps in our knowledge of preparation effects in language switching. To address these hiatuses, eight experiments were conducted, which are divided into two empirical parts.

The aim of the first empirical part consisted of investigating whether language switching with predictable responses would lead to switch costs. The reconfiguration model (e.g., Rogers & Monsell, 1995) assumes that being able to not just prepare for the upcoming concept but also for either a language repetition or language switch should abolish switch costs, given abundant time to prepare. This is because both the first reconfiguration stage (language) and the second (concept) could be executed in advance, so that even residual costs could be abolished. The proactive interference model and the ICM (Allport et al., 1994; Green, 1998), on the other hand, make no such claim. This entails that the proactive interference model and the ICM could account for switch costs with predictable responses.

Four experiments were conducted to examine language switching with predictable responses. More specifically, Experiment 1 consisted of a memory-based concept sequence (i.e., weekdays) and language sequence with long and short preparation times. Smaller switch costs with a long pacing-interval, which constitutes the time between the previous response onset and the current response-signal, than with a short pacing-interval would indicate that there was a preparation benefit on switch costs due to language predictability, concept predictability or both being predictable. This is because the participants had more time to prepare for the upcoming trial using the predictable information (i.e., concept and/or language) with a long pacing-interval.

Next to the predictable responses in Experiment 1, which allowed for preparation until response selection, a predictable response onset was added in Experiment 2 to investigate whether switch costs would arise when preparation was possible until response execution.
This experiment also examined whether, next to switch costs, mixing costs could be elicited by predictable responses and the effect of another semantic category (i.e., numbers).

Since the concept sequences in Experiments 1 and 2 were over-learned sequences (i.e., weekdays and numbers), the items of these sequences were scrambled into a new sequence in Experiment 3, which would further generalize the previous findings. The scrambled sequence, which was not over learned, was also contrasted against the over-learned standard sequence to investigate the effect of sequence novelty.

Finally, in Experiment 4, switch costs were measured with predictable responses that are not part of a pre-determined sequence but a sequence of unrelated words, since responses that can be produced in a pre-determined sequence contain semantic and phonological properties that are not common among all words.

The aim of the second empirical part was to systematically investigate sequential predictability of languages and/or concepts in language switching. According to the reconfiguration model and the ICM, smaller switch costs should be found when both the language and concept are known relative to when only one of these is known (Experiments 5 and 6). These two models also assume that smaller switch costs should be elicited when only the language sequence is predictable contrary to when the language sequence and the concept sequence are both unpredictable (Experiment 7). Finally, based on the reconfiguration model and the ICM, no switch cost difference should be found between language switching with a predictable concept sequence and language switching with an unpredictable language sequence and concept sequence (Experiment 8).
Experiment 5: The role of language predictability with knowledge of concepts

Experiment 6: The role of concept predictability with knowledge of languages

Experiment 7: The role of language predictability without knowledge of concepts

Experiment 8: The role of concept predictability without knowledge of languages

Note: Cloud-shape contours indicate a predictable (memorized) sequence; straight contours indicate an unpredictable sequence, with solely externally activated representations.

Figure 5. An overview of Experiments 5-8: the top panel shows the set-up of Experiment 5, with a predictable concept sequence in both conditions and either a predictable or unpredictable language sequence. The second panel shows the set-up of Experiment 6, with a predictable language sequence in both conditions and either a predictable or unpredictable concept sequence. The third panel shows the set-up of Experiment 7, with an unpredictable concept sequence in both conditions and either a predictable or unpredictable language sequence. The last panel shows the set-up of Experiment 8, with an unpredictable language sequence in both conditions and either a predictable or unpredictable concept sequence.

The effects of language predictability and/or concept predictability were investigated in four language switching experiments (see Figure 5 for an overview of the predictability manipulations of each experiment). More specifically, in Experiment 5, language switching with a predictable language sequence was contrasted with language switching with a random language sequence, while the concept sequence was predictable in both conditions. Hence,
this experiment should give us an idea on the role of languages when information about the concepts is also provided. In Experiment 6, a predictable sequence of concepts was contrasted with a random sequence of concepts, while the language sequence was predictable in both conditions. This experiment explored the role of concepts when information about the languages is also provided.

Experiment 7 contrasted a predictable language sequence with a random language sequence, while the concept sequence was unpredictable in both conditions. This experiment investigated the sole influence of languages without any information about the concepts. Finally, in Experiment 8, a predictable sequence of concepts was contrasted with a random sequence of concepts, while the language sequence was unpredictable in both conditions. This final experiment allowed us to investigate the sole influence of concepts without any information about the languages.
Part II

Empirical part
9 Experiments 1-4: Response predictability

9.1 Experiment 1

In Experiment 1, participants performed a sequential memory-based task with weekdays. The aim of the experiment was to examine whether language switch costs would be elicited by responses that are predictable and triggered from memory (instead of being unpredictable and visually triggered). Furthermore, the difference between long and short preparation time with predictable responses was investigated.

According to the reconfiguration model, no switch costs should be observed with predictable responses. This elimination of switch costs should surely occur when the preparation time is long, because longer preparation should decrease switch costs even more. This is not the case, or at least less so, with a short pacing-interval, due to reduced time to prepare for the upcoming response. The proactive interference model and the ICM, on the other hand, can account for switch costs with predictable responses. Yet, these models also assume that longer preparation time should lead to smaller switch costs.

9.1.1 Method

*Table 1.* Overview of demographic information of the participants of Experiments 1-4. The information consists of the average of English age of acquisition, the average years of formal English education, a self-rated score of spoken English from 1-7, with 1 being very bad and 7 being very good, and an average of known languages (not including the mother language).

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Age of acquisition</th>
<th>Formal English education</th>
<th>Self-rated score of spoken English</th>
<th>Known foreign languages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experiment 1</td>
<td>9.6</td>
<td>8.3</td>
<td>4.7</td>
<td>2.0</td>
</tr>
<tr>
<td>Experiment 2</td>
<td>10.0</td>
<td>8.9</td>
<td>5.3</td>
<td>2.2</td>
</tr>
<tr>
<td>Experiment 3</td>
<td>9.9</td>
<td>9.4</td>
<td>5.0</td>
<td>1.8</td>
</tr>
<tr>
<td>Experiment 4</td>
<td>9.1</td>
<td>9.2</td>
<td>4.7</td>
<td>2.3</td>
</tr>
</tbody>
</table>
Participants. 24 native German participants took part and spoke English as their second language (20 female, mean age = 22.5). Prior to the experiment they were asked to fill in a questionnaire about how old they were and when they started learning English, how many years of formal English education they had, how many other languages they know and how high they rated their own level of spoken English, with 1 being very bad and 7 being very good (see Table 1).

Apparatus and concepts. The to-be-produced concepts consisted of the seven weekdays, which the participants were required to produce from memory (i.e., no visual indication was given) in the appropriate serial order (Monday to Sunday; see appendix A for all responses).

The trials were presented and the responses recorded using E-prime. Speech onset of vocal responses was recorded with a voice-key and the entire experiment was recorded with a Zoom H2 Handy Portable Stereo Recorder. Errors were coded online by the experimenter in a subject file. The recorded speech files were consulted for accuracy.

Procedure. Prior to the experiment, the instructions were presented both orally and visually, with an emphasis on both speed and accuracy. This was followed by two practice blocks of 14 trials each and eight experimental blocks of 28 trials each. At the beginning of each block the participants were informed about the characteristics of the block (i.e., which language they should begin with and whether the pacing-interval would be long or short). This was followed by a fixation cross (+), presented in the center of the screen, which stayed visible throughout the entire block.

After hearing an auditory response-signal (50 ms), the participants had to produce one of the seven weekdays from memory. They were required to produce the weekdays in the correct serial order (Monday-Sunday), starting with the concept Monday, as well as in the correct language (German or English). The required language alternated after every second
trial (i.e., L1-L1-L2-L2-L1-L1 or L2-L2-L1-L1-L2-L2). Note that repeating the weekday sequence four times in each block and the languages requiring a language switch after every second trial results in perfect counterbalancing of language, language sequence and serial position. That is, each weekday was named equally often in each language and equally frequent on repetition trials and on switch trials in each block.

To measure the effect of preparation time, the pacing-interval, constituting the time between the previous response onset and the current response-signal, was varied blockwise. Additionally, a random jitter of 200 ms was used so that the participants could not automate responding based on fixed timing. This resulted in blockwise short pacing-intervals (mean of 1100 ms; 900, 1100 or 1300 ms) and blockwise long pacing-intervals (mean of 2000 ms; 1800, 2000 or 2200 ms). Overall, short pacing-intervals were used during half of the blocks, while long pacing-intervals were used during the other half. Also, half of the blocks started with German and half started with English. The starting language of each block was altered after every second block, whereas the pacing-interval altered from one block to the next. The sequence of blocks was counterbalanced across participants.

*Design.* The within-subjects independent variables were language (German vs. English), language transition (switch vs. repetition) and preparation time (long vs. short interval). The dependent variables were reaction time (RT) and error rate.

### 9.1.2 Results and Discussion

The first trial of each block and the error trials, which constituted the production of a wrong concept and/or production in the wrong language, were excluded from RT analyses, as were trials following an error trial. Furthermore, RTs in all trials were z-transformed and trials with a z-score of -2/+2 were discarded as outliers. Taking these three criteria into account, a total of 14% of the data was excluded.
An analysis of variance (ANOVA) of the RT data revealed a significant effect of language ($F(1, 23) = 6.64; p < .05; \eta_p^2 = .224$), with German responses (512 ms) being slower than English responses (500 ms, see Table 2), and of language transition ($F(1, 23) = 26.47; p < .001; \eta_p^2 = .535$), with switch trial responses (532 ms) being slower than repetition trial responses (480 ms), indicating language switch costs of 52 ms. These data showed that substantial switch costs arise using a sequential, memory-based concept sequence and language sequence, and thus predictable responses. This finding indicates that trial-to-trial language control processes, measured by switch costs, become necessary despite the possibility to prepare the upcoming responses. Hence, responses are not fully prepared, even though they are predictable. It also provides evidence that even when words are triggered from memory, instead of being visually triggered, switch costs arise.

Table 2. Overall RT in ms and percentage of errors (PE) of Experiment 1 (SD in parenthesis) as a function of language (German vs. English), language transition (switch vs. repetition), and preparation time (long vs. short interval).

<table>
<thead>
<tr>
<th>Language transition</th>
<th>German</th>
<th>English</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Long</td>
<td>Short</td>
</tr>
<tr>
<td>Switch R</td>
<td>514 (31)</td>
<td>564 (40)</td>
</tr>
<tr>
<td>Repetition R</td>
<td>473 (24)</td>
<td>496 (28)</td>
</tr>
<tr>
<td>Switch P</td>
<td>0.4 (0.1)</td>
<td>0.7 (0.2)</td>
</tr>
<tr>
<td>Repetition P</td>
<td>0.2 (0.1)</td>
<td>0.3 (0.1)</td>
</tr>
</tbody>
</table>

The main effect of preparation time was not significant ($F(1, 23) = 3.06; \text{ns.}; \eta_p^2 = .117$), even though the data showed a trend towards slower responses with a short interval (526 ms) than with a long interval (486 ms). However, the interaction between language transition and preparation time was significant ($F(1, 23) = 9.09; p < .01; \eta_p^2 = .283$), with larger switch costs for short intervals (76 ms) than for long intervals (37 ms, see Figure 6). Separate t-tests revealed that switch costs were significant with both the short interval ($t(23) = 4.34; p < .001$) and the long interval ($t(23) = 4.43; p < .001$). All other interactions were not
significant \((Fs < 1)\). The reduction of switch costs with a long interval supports the hypothesis that there was a preparation benefit for the upcoming responses, since during the long pacing-intervals the participants had more time to use the predictability information (i.e., concept and/or language) to prepare for the upcoming trial and thus could reduce language interference.

The error data revealed no significant main effects of language \((F(1, 23) = 0.34; \text{ns.}; \eta_p^2 = .015)\) and of preparation time \((F(1, 23) = 3.37; \text{ns.}; \eta_p^2 = .128)\). However, preparation time did reveal a trend with more errors during short intervals (0.6%) than during long intervals (0.4%). There was a main effect of language transition \((F(1, 23) = 11.40; p < .01; \eta_p^2 = .331)\), with switch trial responses (0.7%) being more erroneous than repetition trial responses (0.4%). The interaction between language transition and preparation time was not significant \((F(1, 23) = 1.40; \text{ns.}; \eta_p^2 = .058)\), nor any of the other interactions \((Fs < 1)\).

Figure 6. Switch costs (in ms) of Experiment 1 as a function of language (German vs. English) and preparation time (long vs. short interval).
**Summary.** The findings of this experiment indicate that responses cannot be prepared to the extent that switch costs would disappear. This entails that either the responses were not entirely prepared or that such preparation is not possible.

Furthermore, smaller switch costs were found with long preparation time than with short preparation time. Hence, it can be argued that some active preparation occurred which helped with the formulation of the upcoming response. Yet, due to the set-up of the current experiment, it is not possible to know whether switch costs were smaller in the long preparation time condition due to language preparation, concept preparation or response preparation.
9.2 Experiment 2

The results of Experiment 1 revealed that, even with long preparation time, switch costs could be elicited with predictable responses. However, preparation in Experiment 1 was only possible up to response selection, and not response execution, since the jitter prevented the participants from knowing when exactly to produce the next response. Since no hint was found of participants using automated strategies with respect to response onset in Experiment 1, no jitter was implemented in Experiment 2, which would allow the participants to prepare for response execution as well. Similar to Experiment 1, no switch costs should be obtained with this set-up according to the reconfiguration model, whereas substantial switch costs can be explained on the basis of the proactive interference model and the ICM.

Additionally, another marker of cognitive control was implemented, namely mixing costs, to investigate whether the effect of predictable responses with a predictable response onset elicits these performance costs. Mixing costs were chosen because previous studies have provided evidence that mixing costs measure a different aspect of language control than switch costs (Christoffels et al., 2007; Gollan & Ferreira, 2009; Wang et al., 2009).

Furthermore, in this experiment the participants performed a sequential memory-based task with either weekdays or numbers, in order to generalize the findings of Experiment 1 to other pre-determined sequences.

9.2.1 Method

Participants. 48 native German participants took part and spoke English as their second language (39 female, mean age = 22.8). A questionnaire, identical to that in Experiment 1, was given to the participants prior to the actual experiment (see Table 1).

Apparatus and concepts. The apparatus was identical to that used in Experiment 1. However, the to-be-produced concepts consisted either of the seven weekdays or numbers 1-7, which the participants were required to produce from memory in the appropriate serial
order (Monday to Sunday; 1 to 7; see appendix A for all responses). Half the participants had to produce weekdays, whereas the other half had to produce the numbers 1-7.

**Procedure.** The procedure was almost identical to that used in Experiment 1. Among the differences was the addition of pure language blocks, which lead to four different block types: pure English blocks, pure German blocks and mixed blocks with the first trial being either in German or in English. Secondly, there were four practice blocks, each presented prior to the first experimental block of the corresponding block type, instead of before all experimental blocks, which was the case in Experiment 1. Each condition was presented in two blocks during the experiment, excluding the practice blocks.

The sequence of blocks consisted of two pure language blocks, one English and one German, followed by four mixed blocks and then another German and English pure language block. The starting language of the four mixed blocks was altered from one block to the next. This was counterbalanced across participants, as was the sequence of pure language blocks. Finally, the pacing-interval was fixed at 1500 ms, without a jitter.

**Design.** Two non-orthogonal contrasts were defined. First, to investigate whether switch costs would occur with predictable responses, language switch trials were compared with language repetition trials (*switch-costs contrast*). Secondly, to examine whether mixing costs occur with predictable responses, language repetition trials from mixed language blocks were compared against trials in pure language blocks (*mixing-costs contrast*).

That is, the between-subject variable was semantic category (numbers vs. weekdays) and the within-subjects independent variables were language (German vs. English) and, in the switch-cost contrast, language transition (switch vs. repetition), whereas in the mixing-cost contrast this was type of block (pure vs. mixed language block). The dependent variables were RT and error rate.
9.2.2 Results and Discussion

Identical outlier criteria and error definitions were used as in Experiment 1, which resulted in the exclusion of 8% of the data. Furthermore, when analyzing mixing costs, only the repetition trials of the mixed language blocks were used, to have a clear distinction between switch costs and mixing costs.

Table 3. Overall RT in ms and percentage of errors (PE) of Experiment 2 (SD in parenthesis) as a function of language (German vs. English), trial type (switch vs. repetition vs. pure language trials), and semantic category (numbers vs. weekdays).

<table>
<thead>
<tr>
<th>Trial type</th>
<th>German</th>
<th>English</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Numbers</td>
<td>Weekdays</td>
</tr>
<tr>
<td>Switch</td>
<td>437 (26)</td>
<td>409 (26)</td>
</tr>
<tr>
<td>Repetition</td>
<td>419 (24)</td>
<td>364 (24)</td>
</tr>
<tr>
<td>Pure language</td>
<td>373 (23)</td>
<td>348 (23)</td>
</tr>
<tr>
<td>Switch</td>
<td>0.5 (0.2)</td>
<td>0.5 (0.2)</td>
</tr>
<tr>
<td>Repetition</td>
<td>0.2 (0.1)</td>
<td>0.2 (0.1)</td>
</tr>
<tr>
<td>Pure language</td>
<td>0.1 (0.0)</td>
<td>0.0 (0.0)</td>
</tr>
</tbody>
</table>

Switch-cost contrast: switch trials vs. repetition trials in mixed blocks. The corresponding ANOVA of the RT data revealed a significant main effect of language \(F(1, 46) = 11.13; p < .01; \eta^2_p = .195\), with German responses (407 ms) being slower than English responses (396 ms, see Table 3), whereas the main effect of semantic category \(F(1, 46) = 1.48; \text{ns.}; \eta^2_p = .031\) was not significant. Language transition was also significant \(F(1, 46) = 36.59; p < .001; \eta^2_p = .443\), with switch trial responses (414 ms) being slower than repetition trial responses (389 ms), indicating language switch costs of 25 ms. The switch costs suggest that substantial interference arises even when the response, language transitions and response onset are predictable, hence with predictable response execution.

The interaction between language and language transition was significant \(F(1, 46) = 6.71; p < .05; \eta^2_p = .127\), with larger switch costs for German responses (34 ms) than English
responses (17 ms). Likewise, the interaction between language transition and semantic category was significant \((F(1, 46) = 9.16; p < .01; \eta^2_p = .166)\), with larger switch costs for weekdays (37 ms) than numbers (12 ms, see Figure 7). Separate t-tests revealed that switch costs were significant for both the weekday data \((t(23) = 5.59; p < .001)\) and the number data \((t(23) = 2.59; p < .05)\). The interaction between language and semantic category and the three-way interaction were not significant \((Fs < 1)\). These findings show that asymmetrical switch costs can be found with predictable responses and that different stimulus categories can influence the size of switch costs. Furthermore, the data provided evidence that switch costs can be obtained with pre-determined sequences other than weekdays (i.e., numbers).

The error data revealed no significant main effect of language and semantic category \((Fs < 1)\). There was a significant main effect of language transition \((F(1, 46) = 15.42; p < .001; \eta^2_p = .251)\), with switch trial responses (0.5%) being more erroneous than repetition trial responses (0.2%). None of the interactions were significant \((Fs < 1)\).

![Figure 7. Switch costs (in ms) of Experiment 2 as a function of language (German vs. English) and semantic category (numbers vs. weekdays).](image)
Mixing-cost contrast: pure language blocks vs. repetitions in mixed language blocks.

An ANOVA of the RT data revealed no significant main effects of language \( (F(1, 46) = 2.68; \text{ns.}; \eta_p^2 = .055) \) and semantic category \( (F(1, 46) = 1.74; \text{ns.}; \eta_p^2 = .036) \). Type of block was significant \( (F(1, 46) = 12.69; p < .001; \eta_p^2 = .216) \), with responses in mixed language blocks (389 ms) being slower than in pure language blocks (357 ms), indicating language mixing costs of 32 ms. That is, mixing costs can be observed even when the responses, language transitions and response onset are predictable. The interaction between type of block and semantic category \( (F(1, 46) = 2.61; \text{ns.}; \eta_p^2 = .054) \) was not significant (see Figure 8). Similarly, all the other interactions \( (Fs < 1) \) were not significant.

The error data revealed no significant main effects of language, semantic category and type of block \( (Fs < 1) \). Also the interactions between type of block and language \( (F(1, 46) = 2.05; \text{ns.}; \eta_p^2 = .043) \), type of block and semantic category \( (F < 1) \), language and semantic category \( (F < 1) \), and the three-way interaction \( (F(1, 46) = 1.15; \text{ns.}; \eta_p^2 = .024) \) were not significant.

![Figure 8](image-url)  
*Figure 8.* Mixing costs (in ms) of Experiment 2 as a function of language (German vs. English) and semantic category (numbers vs. weekdays).
Next to the separate investigations of language switch costs and mixing costs, Experiment 2 also allows us to distinguish differences between these two measures. The data showed a difference on two accounts. The first one being that, similar to the results reported by Christoffels et al. (2007), Gollan and Ferreira (2009) and Wang et al. (2009), the current data reveals a difference in (a)symmetrical performance costs across languages, with asymmetrical switch costs (i.e., larger L1 performance costs than L2, see also Meuter & Allport, 1999) and symmetrical mixing costs. An explanation for the dissociation between switch costs and mixing costs across languages is presently difficult due to an unclear pattern of results across studies. Whereas Wang et al. (2009) found a similar pattern as the present study, with asymmetrical switch costs and symmetrical mixing costs, the data of Christoffels et al. (2007) and Gollan and Ferreira (2009) showed the opposite, with symmetrical switch costs and asymmetrical mixing costs. Yet, all four studies, including the present dissertation, provide evidence that switch costs and mixing costs are influenced differently by languages.

The data also revealed a difference between switch costs and mixing costs due to semantic category. Larger switch costs were elicited while producing weekdays than numbers. The numerical mixing cost data, on the other hand, showed that mixing costs were larger when producing numbers than during the production of weekdays (mixing costs weekday: 18 ms and numbers: 47 ms). This difference across performance costs could be due to the phonological difference between the two semantic categories (e.g., the phonological priming effect of weekdays from one trial to another, which is not present between numbers), since the data of Christoffels et al. (2007) also revealed a similar pattern between switch costs and mixing costs due to phonology (i.e., cognates vs. non-cognates).

**Summary.** The results of Experiment 2 have elaborated on the findings of Experiment 1 in several ways. One such additional finding is that next to switch costs, also mixing costs can be observed when responses are predictable. Furthermore, these performance costs could be elicited when not just the language sequence and concept sequence are predictably known,
but also when the response onset is predictable. Finally, the current experiment has indicated that the findings of Experiment 1 could be generalized to other over-learned sequences, such as numbers.
9.3 Experiment 3

So far only over-learned sequences (i.e., weekdays and numbers) have been implemented. In Experiment 3, this is expanded to a scrambled sequence (i.e., weekdays or numbers in a new order) to generalize the findings to new sequences. To explore the influence of sequence novelty, the difference between producing an over-learned sequence and a scrambled sequence was investigated.

9.3.1 Method

Participants. 24 native German participants took part and spoke English as their second language (13 female, mean age = 25.3). A questionnaire, identical to that in Experiment 1, was given to the participants prior to the actual experiment (see Table 1).

Apparatus and concepts. The apparatus was identical to those used in the previous experiments. However, the participants were instructed to produce the numbers 1-5 and weekdays Monday – Friday. Either one was used in the over-learned condition, while the other was used in the scrambled condition. This pairing of semantic category to sequence condition was counterbalanced across participants. In the over-learned condition, the normal sequential order was used, whereas in the scrambled condition a mixed sequence of the concepts was used (see appendix B for all response sequences).

Procedure. The procedure was identical to that used in Experiment 1, apart from some points. First, each block consisted of twenty trials and there were four experimental blocks for both the over-learned sequence and scrambled sequence condition. All four blocks, using the same sequence, were presented in succession. Secondly, there were two practice blocks, of 20 trials each, to practice each sequence, which were presented before the four experimental blocks that would use that particular sequence. During the first of these practice blocks the participants had the responses in written form, in both languages and in the correct order, in front of them. In the second practice block the participants had to perform the task without the
written responses. The order of the conditions, represented by four experimental blocks and two practice blocks, were counterbalanced across participants. Finally, the pacing-interval was fixed at 1500 ms, without a jitter.

**Design.** The within-subjects independent variables were language (German vs. English), language transition (switch vs. repetition) and sequence condition (over-learned vs. scrambled sequence). The dependent variables were RT and error rate.

### 9.3.2 Results and Discussion

Identical outlier criteria and error definitions were used as in Experiment 1, which resulted in the exclusion of 16% of the data.

<table>
<thead>
<tr>
<th></th>
<th>Language</th>
<th></th>
<th>Language</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>over-learned</td>
<td>scrambled</td>
<td>over-learned</td>
<td>scrambled</td>
</tr>
<tr>
<td>switch</td>
<td>588 (50)</td>
<td>689 (38)</td>
<td>559 (51)</td>
<td>697 (43)</td>
</tr>
<tr>
<td>repetition</td>
<td>547 (46)</td>
<td>619 (33)</td>
<td>538 (46)</td>
<td>628 (32)</td>
</tr>
<tr>
<td>switch</td>
<td>0.5 (0.2)</td>
<td>1.0 (0.2)</td>
<td>0.7 (0.2)</td>
<td>1.3 (0.4)</td>
</tr>
<tr>
<td>repetition</td>
<td>0.1 (0.1)</td>
<td>0.3 (0.1)</td>
<td>0.2 (0.1)</td>
<td>0.6 (0.3)</td>
</tr>
</tbody>
</table>

An ANOVA of the RT data revealed a significant effect of sequence condition ($F(1, 23) = 11.06; p < .01; \eta^2_p = .325$), with responses in the scrambled sequence (659 ms) being slower than in the over-learned sequence (558 ms, see Table 4), whereas language was not significant ($F < 1$). However, language transition was clearly significant ($F(1, 23) = 11.06; p < .01; \eta^2_p = .325$), with switch trial responses (634 ms) being slower than repetition trial responses (583 ms), indicating language switch costs of 51 ms.

The interactions between sequence condition and language ($F(1, 23) = 2.02; \text{ns.}; \eta^2_p = .081$), language and language transition ($F < 1$) and the three-way interaction ($F < 1$) were not
significant. Importantly, the interaction between sequence condition and language transition was significant \((F(1, 23) = 5.53; p < .05; \eta_p^2 = .194)\), with larger switch costs for responses in the scrambled sequence (69 ms) than in the over-learned sequence (32 ms, see Figure 9). Separate t-test revealed that both the scrambled sequence responses \((t(23) = 3.19; p < .01)\) and the over-learned sequence responses \((t(23) = 2.95; p < .01)\) revealed significant switch costs. This provides evidence that producing predictable responses elicits switch costs in both over-learned and scrambled sequences.

Presumably, the additional strain put on working memory (e.g., Barrouillet, Bernardin, & Camos, 2004; Barrouillet, Bernardin, Portrat, Vergauwe, & Camos, 2007; Portrat, Barrouillet & Camos, 2008) in the scrambled sequence caused the larger switch costs relative to the switch costs obtained with an over-learned sequence. Contrary to the over-learned condition, the scrambled sequences require the novel concept sequence to be maintained in working memory, whereas the concept sequence in the over-learned condition is part of the information retrieved from long-term memory. This would imply that more working memory load was implemented during scrambled sequences. Hence, it seems plausible that switch costs are influenced by working memory load, which is backed-up by recent task switching studies (e.g., Liefooghe, Barrouillet, Vandierendonck, & Camos, 2008).

The error data revealed a significant main effect of language transition \((F(1, 23) = 14.80; p < .001; \eta_p^2 = .392)\), with switch trials (0.9%) being more erroneous than repetition trials (0.3%), and of sequence condition \((F(1, 23) = 5.13; p < .05; \eta_p^2 = .182)\), with more errors generated in the scrambled sequence (0.8%) than in the over-learned sequence (0.4%), whereas the main effect of language \((F(1, 23) = 2.67; \text{ns.}; \eta_p^2 = .104)\) was not significant. The interaction between language transition and sequence condition \((F(1, 46) = 1.12; \text{ns.}; \eta_p^2 = .046)\) was not significant and neither were any of the other interactions \((Fs < 1)\).
Summary. Experiment 3 indicates that switch costs can be observed with both over-learned sequences and new, scrambled sequences. Yet, a switch cost difference was found between these two sequences, with smaller switch costs obtained with an over-learned sequence than with a scrambled sequence. This switch cost difference was attributed to a difference in working memory load.
9.4 Experiment 4

Since the responses used in over-learned sequences have semantic and phonological properties that are not applicable to all words, Experiment 4 set out to investigate language switching with predictable responses using unrelated concepts in a novel sequence. In Experiment 3, the scrambled sequence was also not over learned, but the responses in Experiment 3 were still part of pre-determined sequences. Thus, additional interference could have come into play because of sequential priming from the over-learned sequence (e.g., numerical distance priming when using numbers, Duyck, Depestel, Fias, & Reynvoet, 2008). This was excluded in Experiment 4, since the concepts were unrelated.

Using unrelated words also has the added benefit of not including semantic influences, like the words being part of one semantic category, and phonological influences, such as the high amount of cognates and phonological priming (every weekday in English ends with –day and almost every weekday in German ends with –tag) in the previously used sequences.

To further reduce the amount of phonological priming from one trial to the next, Experiment 4 contains sequences in which every word (both German and English responses) contains at least one language-specific phoneme, which are phonemes that do not appear in the other language. This is then contrasted against sequences that contain words without any language-specific phonemes.

9.4.1 Method

Participants. 24 native German participants took part and spoke English as their second language (16 female, mean age = 23.0). A questionnaire, identical to that in Experiment 1, was given to the participants prior to the actual experiment (see Table 1).

Apparatus and concepts. The apparatus was identical to those used in Experiments 1-3. With respect to the concepts, there were twenty concepts which had to be produced from memory in the correct serial order. Each of these concepts was used in one of four sequences,
two with a language-specific phonology word set and two with a language-unspecific phonology word set, each of which contained five concepts (see appendix C for the full sets). The four sequences were set up so that there was as little phonological overlap from one trial to the next, no semantic relationship between concepts, and as few cognates as possible.

Each concept in the two language-specific phonology sequences had at least one language-specific phoneme in the German response and English response. The German-specific phonemes were: /ʦ/ (e.g., Katze, meaning cat); /r/ (e.g., Rücken, meaning back); /χ/ (e.g., Tuch, meaning cloth) and /n/ (e.g., Rachen, meaning throat), whereas the English-specific phonemes were: /æ/ (e.g., cat); /ʌ/ (e.g., mushroom) and /θ/ (e.g., throat).

Furthermore, frequency (Baayen, Piepenbrock, & Gulikers, 1995) and the amount of syllables over sequences were controlled over the four sequences. The two language-specific phonology sequences were also controlled for the amount of language-specific German and English phonemes.

Procedure. The procedure was identical to that used in Experiment 1, apart from the following features: there were sixteen experimental blocks, four for each sequence. These four blocks that used the same sequence were always presented one after the other. To get acquainted with a new sequence there were two practice blocks of twenty trials each prior to the four experimental blocks. During the first practice block the participants would have a card in front of them with the written responses on it, in both languages and in the correct order, while during the second practice block they would have to respond without the card. Finally, the pacing-interval was fixed at 1500 ms, without a jitter.

Design. The within-subjects independent variables were language (German vs. English), language transition (switch vs. repetition) and phonology (language-specific vs. language-unspecific phonology). The dependent variables were RT and error rate.
9.4.2 Results and Discussion

Identical outlier criteria and error definitions were used as in Experiment 1, which resulted in the exclusion of 14% of the data.

Table 5. Overall RT in ms and percentage of errors (PE) of Experiment 4 (SD in parenthesis) as a function of language (German vs. English), language transition (repetition vs. switch), and phonology (language-specific vs. language-unspecific phonology).

<table>
<thead>
<tr>
<th>Language transition</th>
<th>German</th>
<th>English</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Language-specific</td>
<td>Language-unspecific</td>
</tr>
<tr>
<td>Switch</td>
<td>816 (81)</td>
<td>699 (59)</td>
</tr>
<tr>
<td>Repetition</td>
<td>741 (66)</td>
<td>623 (47)</td>
</tr>
<tr>
<td>Switch</td>
<td>0.6 (0.1)</td>
<td>0.8 (0.2)</td>
</tr>
<tr>
<td>Repetition</td>
<td>0.4 (0.1)</td>
<td>0.7 (0.1)</td>
</tr>
</tbody>
</table>

An ANOVA of the RT data revealed a significant main effect of language ($F$(1, 23) = 4.92; $p < .05$; $\eta^2_p = .176$), with German responses (720 ms) being slower than English responses (700 ms, see Table 5). Phonology ($F$(1, 23) = 10.80; $p < .01$; $\eta^2_p = .320$) was also significant, with responses in the language-specific phonology condition (754 ms) being slower than responses in the language-unspecific phonology condition (666 ms). The main effect of language transition was significant ($F$(1, 23) =14.09; $p < .001$; $\eta^2_p = .380$), with switch trial responses (745 ms) being slower than repetition trial responses (675 ms), indicating language switch costs of 70 ms. These switch costs show that even without the semantic factors, such as the influence of semantically-related words, without phonological factors, such as the high amount of cognates and the phonological priming from one trial to the next, and without sequential priming, that might have influenced Experiments 1-3, switch costs were elicited with predictable responses. Also, for the first time the effect is observed with a completely novel sequence with unrelated concepts. This finding is important for future experiments that want to investigate concepts different from those used in predetermined sequences.
All interactions had an $F$-value smaller than 1, apart from the significant two-way interaction between language and phonology ($F(1, 23) = 4.28; p < .05; \eta_p^2 = .157$), with the responses in the language-specific phonology condition eliciting faster responses in German than English (51 ms) and the responses in the language-unspecific phonology condition eliciting faster responses in English than German (11 ms). This could explain why the data in Experiments 1-3 revealed slower German responses than English responses: both weekdays and numbers consist of a large number of cognates, which are phonologically similar in both languages and thus have a small amount of language-specific phonemes.

An ANOVA of the error data revealed no significant main effects of language ($F < 1$) and phonology ($F(1, 23) = 1.67; \text{ns.; } \eta_p^2 = .068$). The data did show a significant main effect of language transition ($F(1, 23) = 7.65; p < .05; \eta_p^2 = .250$), with a higher occurrence of errors in switch trials (0.7%) than repetition trials (0.5%). All interactions had an $F$-value smaller than 1, apart from the two-way interaction between phonology and language ($F(1, 23) = 1.61; \text{ns.; } \eta_p^2 = .065$) and between phonology and language transition ($F(1, 23) = 2.68; \text{ns.; } \eta_p^2 = .104$), both of which were not significant.

![Switch costs (ms) of Experiment 4 as a function of language (German vs. English) and phonology (language-specific vs. language-unspecific phonology).](image)

Figure 10. Switch costs (in ms) of Experiment 4 as a function of language (German vs. English) and phonology (language-specific vs. language-unspecific phonology).
Summary. Experiment 4 revealed that switch costs are still observed, even when the concept sequence consists of unrelated words, which are not part of an over-learned sequence. Furthermore, the phonological manipulation, in which words with some language-specific phonemes are contrasted against words with just language-unspecific phonemes, indicates that no switch cost difference is obtained due to a difference in language specificity of phonology. However, note that a numerical difference is visible between these two conditions, but only in the English data (see Table 5 and Figure 10).
9.5 Overview of the main findings of Experiments 1-4

Experiments 1-4 examined language switching with predictable responses, using a novel paradigm, named the SBLS paradigm. The main finding is that switch costs were obtained in all four experiments, even though the responses could be prepared for. More specifically, switch costs were observed with over-learned sequences (i.e., weekdays or numbers; Experiments 1-3), new sequences (Experiments 3 and 4), with concepts of an over-learned sequence (i.e., weekday and numbers; Experiments 1-3) and with concepts which are not associated with an over-learned sequence (Experiment 4). Additionally, also mixing costs were found with this new paradigm (Experiment 2). Based on the pattern of results acquired in these four experiments, it appears that the novel language switching paradigm constitutes a viable tool to examine endogenous language switching.

Furthermore, the data of Experiment 1 showed that language switch costs were reduced with a long preparation time relative to a short preparation time. This finding indicates that predictable information, be it language predictability, concept predictability or a combination of both (i.e., response predictability), was used to prepare for the upcoming trial. Switch costs were also affected by the manipulations in Experiments 2 and 3. Smaller switch costs were observed with numbers than with weekdays in Experiment 2, and smaller switch costs were observed with over-learned sequences than with novel sequences in Experiment 3. Experiment 4, on the other hand, did not reveal a significant switch cost difference due to words with or without language-specific phonemes.

Since the results indicate that switch costs cannot be abolished by preparatory processes, there is an opportunity to further investigate language control with predictable responses. To this end, the aim of the second empirical part was to examine the differential effects of language predictability and/or concept predictability in four experiments (i.e., Experiments 5-8).
10 Experiments 5-8: Language predictability and/or concept predictability

10.1 Experiment 5

The goal of Experiment 5 was two-fold. The first goal was to investigate whether language switch costs would decrease by manipulating language predictability (i.e., cued random language sequence vs. cued alternating language sequence), while the concept sequence was predictable in all conditions (see top panel of Figure 5). With a cued alternating language sequence, the participants had to switch to another language after two trials with the same language. Since this language sequence was predictable, it should have enabled the participants to prepare for upcoming trials. During cued random language sequences, on the other hand, no such language preparation was possible. According to the reconfiguration model and the ICM, switch costs should be smaller when both language and concept are predictable than when only the concept is predictably known.

The second goal was to determine the influence of language cues on switch costs. Prior task switching research has shown that cue processing on its own can contribute to switch costs (for a recent review on the effect of cues in task switching, see Jost, De Baene, Koch, & Brass, 2013). The question remains whether this is also the case in language switching. To this end, the presence of visual language cues was manipulated during an alternating language sequence (see also Koch, 2003).

10.1.1 Method

Participants. 24 native German participants took part and spoke English as their second language (19 female, mean age = 22.5). Prior to the experiment, they were asked to fill in a questionnaire about how old they were and when they started learning English, how many years of formal English education they had, how many other languages they know and how
high they rated their own level of spoken English, with 1 being very bad and 7 being very good (see Table 6).

*Table 6. Overview of demographic information of the participants of Experiments 5-8. The information consists of the average of English age of acquisition, the average years of formal English education, a self-rated score of spoken English from 1-7, with 1 being very bad and 7 being very good, and an average of known languages (not including the mother language).*

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Age of acquisition</th>
<th>Formal English education</th>
<th>Self-rated score of spoken English</th>
<th>Known foreign languages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experiment 5</td>
<td>10.4</td>
<td>8.8</td>
<td>5.2</td>
<td>2.0</td>
</tr>
<tr>
<td>Experiment 6</td>
<td>9.8</td>
<td>9.1</td>
<td>4.5</td>
<td>2.3</td>
</tr>
<tr>
<td>Experiment 7</td>
<td>10.0</td>
<td>9.2</td>
<td>4.8</td>
<td>1.9</td>
</tr>
<tr>
<td>Experiment 8</td>
<td>10.5</td>
<td>8.8</td>
<td>5.1</td>
<td>1.9</td>
</tr>
</tbody>
</table>

**Apparatus and concepts.** The to-be-produced concepts consisted of the numbers 1-5. The participants were required to produce these five numbers, from memory (i.e., no visual indication of the numbers was presented), in the appropriate fixed order (see appendix D for all response sequences).

The trials were presented using E-prime. Speech onset of vocal responses was recorded with a voice-key and the entire experiment was recorded with a Zoom H2 Handy Portable Stereo Recorder. Errors were coded online by the experimenter in a subject file and the recorded speech files were consulted for accuracy.

**Procedure.** Prior to the experiment, the instructions were presented both orally and visually, with an emphasis on both speed and accuracy. These instructions were followed by one of three experimental conditions (with a counterbalanced order across participants). In the first condition, the alternating language sequence, participants were informed about which language they should begin with at the beginning of each block. This was followed by a fixation cross (+), presented in the center of the screen, which stayed visible throughout the entire block. After hearing an auditory response-signal (50 ms), the participants had to
produce one of the five numbers from memory. Once a response was registered, a pacing-interval of 1500 ms ensued. The responses had to be produced in the correct serial order, starting with the concept referring to “1”, as well as in the correct language (German or English). During this condition, the participants were required to alternate languages after every second trial (e.g., L1-L1-L2-L2-L1-L1 or L2-L2-L1-L1-L2-L2).

The second condition, the cued alternating language sequence, followed the same structure as the alternating language sequence, apart from the additional presentation of a visual language cue (color cue: green or blue rectangle; 160 × 106 pixels). The visual language cue was presented in the center of the screen simultaneous with the auditory response-signal, and remained on the screen until a response was registered.

In the third condition, the cued random language sequence, the language sequence was random, with only the language cues to indicate which language had to be used. The language cues also appeared simultaneously with the response-signal in this condition and remained on the screen until a response was registered.

Each condition consisted of four blocks of 20 trials each, which followed each other and were presented after two practice blocks, also consisting of 20 trials each. During the alternating language and cued alternating language sequence, half of the blocks started with English and half with German, and the sequence of blocks was counterbalanced across participants. In the cued random language sequence and cued alternating language sequence, the participants were aided by a card, indicating the color-cue to language assignment. The assignment of color-cue to language was held constant throughout the experiment and was counterbalanced across participants.

Note that, for the conditions using an alternating language sequence, repeating the concept sequence four times in each block and the language sequence requiring a language switch after every second trial results in perfect counterbalancing of language, language
sequence and serial position. That is, each number was named equally often in each language and equally frequent on switch trials and repetition trials in each block. Similar restrictions were put on the cued random language sequence.

**Design.** Two non-orthogonal contrasts were defined. First, to investigate the role of language in language switching with knowledge of the concepts, language switching with a cued random language sequence was compared with language switching with a predictable language sequence (i.e., cued random language sequence vs. cued alternating language sequence; *language predictability contrast*). Note that in both conditions the concept sequence was predictable, while the language predictability was varied.

Secondly, to examine the effect of visual language cues, language switching with visually presented language cues was compared against language switching without visually presented language cues (i.e., alternating language sequence vs. cued alternating language sequence; *visual language cue contrast*). Again an alternating language sequence was used and a fixed digit sequence, so that both languages and concepts were predictable, while only the presence vs. absence of the visual cue was varied.

That is, the within-subjects independent variables were language (German vs. English), language transition (switch vs. repetition), and in the *language predictability contrast*, language predictability (cued random language sequence vs. cued alternating language sequence), whereas in the *visual language cue contrast* this was language presentation (alternating language sequence vs. cued alternating language sequence). The dependent variables were RT and error rate.

10.1.2 **Results and Discussion**

The first trial of each block and the error trials, which constituted the production of a wrong concept and/or production in the wrong language, were excluded from RT analyses, as were trials following an error trial. Furthermore, RTs in all trials were z-transformed, and
trials with a z-score of -2/+2 were discarded as outliers. Taking these three criteria into account, a total of 13% of the RT data was excluded.

Table 7. Overall RT in ms and percentage of errors (PE) of Experiment 5 (SD in parenthesis) as a function of language (German vs. English), language transition (repetition vs. switch), and language predictability/presentation (cued random language sequence vs. cued alternating language sequence vs. alternating language sequence).

<table>
<thead>
<tr>
<th>Language transition</th>
<th>German</th>
<th></th>
<th></th>
<th>English</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cued random</td>
<td>Cued alternating</td>
<td>Alternating</td>
<td>Cued random</td>
<td>Cued alternating</td>
<td>Alternating</td>
</tr>
<tr>
<td>Switch</td>
<td>667 (26)</td>
<td>472 (50)</td>
<td>456 (27)</td>
<td>664 (29)</td>
<td>470 (42)</td>
<td>473 (27)</td>
</tr>
<tr>
<td>Repetition</td>
<td>572 (25)</td>
<td>437 (43)</td>
<td>437 (24)</td>
<td>600 (26)</td>
<td>451 (43)</td>
<td>440 (20)</td>
</tr>
<tr>
<td>Switch</td>
<td>0.3 (0.1)</td>
<td>0.2 (0.1)</td>
<td>0.3 (0.1)</td>
<td>0.2 (0.1)</td>
<td>0.1 (0.1)</td>
<td>0.2 (0.1)</td>
</tr>
<tr>
<td>Repetition</td>
<td>0.1 (0.1)</td>
<td>0.1 (0.0)</td>
<td>0.1 (0.0)</td>
<td>0.2 (0.1)</td>
<td>0.1 (0.0)</td>
<td>0.0 (0.0)</td>
</tr>
</tbody>
</table>

Language predictability contrast: cued random language sequence vs. cued alternating language sequence. An ANOVA of the RT data revealed a significant effect of language \((F(1, 23) = 5.29; p < .05; \eta_p^2 = .187)\), with English responses (546 ms) being slower than German responses (537 ms, see Table 7), and a significant effect of language transition \((F(1, 23) = 46.92; p < .001; \eta_p^2 = .671)\), with switch trial responses (568 ms) being slower than repetition trial responses (514 ms), indicating language switch costs of 54 ms. Furthermore, the main effect of language predictability was also significant \((F(1, 23) = 29.44; p < .001; \eta_p^2 = .561)\), with responses in the cued random language sequence (626 ms) being slower than in the cued alternating language sequence (458 ms). The latter effect shows that language predictability reduced RT and thus was used to prepare for the upcoming trial.

Importantly, the interaction between language predictability and language transition was significant \((F(1, 23) = 12.18; p < .01; \eta_p^2 = .346)\), with larger switch costs during the cued random language sequence (80 ms) than during the cued alternating language sequence (27 ms, see Figure 11). Separate t-tests revealed that switch costs were significant for both the cued random language sequence \((t(23) = 5.68; p < .001)\) and the cued alternating language sequence \((t(23) = 4.30; p < .001)\). The reduction in switch costs found in this analysis
suggests that knowing both language and concept reduces language switching interference, relative to only knowing the concept.

The interaction between language and language transition \( (F(1, 23) = 3.68; \text{ns.} ; \eta_p^2 = .138) \) was not significant, but there was a trend towards larger switch costs for German (65 ms) than English (41 ms), a phenomenon found in several other studies (e.g., Macizo et al., 2012; Meuter & Allport, 1999; Philipp et al., 2007a; for reviews on asymmetrical switch costs, see Bobb & Wodniecka, 2013; Koch et al., 2010) and Experiment 2. None of the other interactions \( (Fs < 1) \) were significant.

The error data revealed no significant main effect of language \( (F(1, 23) = 1.60; \text{ns.} ; \eta_p^2 = .065) \), language transition \( (F(1, 23) = 2.94; \text{ns.} ; \eta_p^2 = .113) \) or language predictability \( (F(1, 23) = 1.66; \text{ns.} ; \eta_p^2 = .067) \). The interaction between language and language transition \( (F(1, 23) = 2.62; \text{ns.} ; \eta_p^2 = .102) \) was not significant. The other interactions were also not significant \( (Fs < 1) \).

Figure 11. Switch costs (in ms) of Experiment 5 as a function of language (German vs. English) and language predictability (cued random language sequence vs. cued alternating language sequence).
Visual language cue contrast: alternating language sequence vs. cued alternating language sequence. An ANOVA of the RT data revealed no significant effect of language \((F(1, 23) = 3.22; \text{ns.} ; \eta_{p}^{2} = .123)\), but there was a trend towards English (459 ms) being slower than German (451 ms). The effect of language transition was significant \((F(1, 23) = 22.02; p < .001; \eta_{p}^{2} = .489)\), with switch trials (468 ms) being slower than repetition trials (441 ms), indicating language switch costs of 27 ms. Importantly, the main effect of language presentation was not significant \((F < 1)\).

None of the two-way interactions \((Fs < 1)\) or the three-way interaction \((F(1, 23) = 2.36; \text{ns.} ; \eta_{p}^{2} = .093)\) were significant. This means that, contrary to task switching studies (e.g., Koch, 2003; for a recent review, see Jost et al., 2013), the current study did not provide evidence for an influence of additional, redundant language cues on switch costs (see Figure 12). This might be because of a difference between task switching and language switching. Evidence for this claim can be found in Philipp and Koch (2009). This study examined N-2 repetition costs with a 2:1 cue-to-language mapping, which entails that there are two cues per language. The results indicated that cue repetitions increased the N-2 repetition costs, which is the opposite pattern that is generally found in the task switching literature (e.g., Gade & Koch, 2008; Mayr & Kliegl, 2003).

Alternatively, no effect of visual language cues on switch costs were found because of the predictable language sequence counteracting the influence of language cues. Since the cues were not necessary, due to the alternating language sequence, it is possible that they did not have a large impact and thus the manipulation might not have been pronounced enough to affect the switch costs.

The error data revealed a main effect of language \((F(1, 23) = 5.75; p < .05; \eta_{p}^{2} = .200)\), with more errors in English (0.2%) than German (0.1%), and of language transition \((F(1, 23) = 10.47; p < .01; \eta_{p}^{2} = .313)\), with more errors in switch trials (0.2%) than in repetition trials.
The effect of language presentation \((F < 1)\) was not significant. The interaction between language and language transition was also not significant \((F(1, 23) = 4.00; \text{ns.}; \eta^2_p = .148)\), but did reveal a trend towards larger switch costs during German trials (0.2\%) than during English trials (0.1\%). None of the other interactions were significant \((Fs < 1)\).

![Figure 12. Switch costs (in ms) of Experiment 5 as a function of language (German vs. English) and language presentation (alternating language sequence vs. cued alternating language sequence).](image)

**Summary.** No switch cost difference was found between language switching with or without visual language cues when both language sequence and concept sequence were predictable. Contrary to some studies in task switching (e.g., Koch, 2003), this indicates that language cues do not seem to contribute a great deal toward language switch costs.

On the other hand, a switch costs difference was observed in the first contrast. Smaller switch costs were found when the language sequence and concept sequence were predictable than when solely the concept sequence was predictable. This finding indicates that being able to prepare both language and concept (i.e., the response) reduces language interference to a higher extent relative to preparing just the concept.
10.2 Experiment 6

Experiment 6 also had two goals. The first goal was to investigate the role of concepts in language switching, while information about the languages was available (see second panel of Figure 5). To this end, the predictability of the concept sequence was manipulated in a language switching setting (i.e., random digit sequence vs. fixed digit sequence), while the language sequence was predictable in both conditions. In the fixed digit sequence, the participants knew which concept would have to be activated in the upcoming trial, giving them the ability to prepare the response of the upcoming trial. In the random digit sequence, no prior indication was given on which concept would be required. Hence, no preparation of concepts or responses was possible in the random digit sequence. According to the reconfiguration model and ICM, switch costs should be smaller when both language and concept are predictable, relative to when only language is predictable. Furthermore, this is of special interest since the reconfiguration model and the ICM assume that advanced (i.e., preparatory) interference resolution can occur in both conditions, whereas this was not the case in Experiment 5.

Similar to Experiment 5, where the influence of visual language cues on language switching was investigated, the second goal of Experiment 6 was to investigate whether a visual trigger of the concepts would influence language switching. Having the concepts visually presented in the form of a digit should have reduced working memory load. Hence, this experiment allowed for an investigation of working memory load on switch costs, which proved to have an influence on switch costs in Experiment 3.

10.2.1 Method

Participants. 24 native German participants took part and spoke English as their second language (18 female, mean age = 22.2). A questionnaire, identical to that in Experiment 5, was given to the participants prior to the actual experiment (see Table 6).
Apparatus and concepts. The apparatus was identical to those used in the previous experiment. Similar to Experiment 5, the participants were instructed to produce the numbers 1-5. However, these numbers had to be produced either in a random or in a fixed order (see appendix D for all responses).

Procedure. The procedure was similar to that used in Experiment 5. However, there were some differences with respect to the language sequence, concept sequence and the visibility of language cues and digits.

Similar to Experiment 5, there were three conditions. In the first of these conditions, the memory-based number sequence, the concepts followed a fixed sequence, which means that they were triggered from memory. In the fixed digit sequence, the concepts (i.e., numbers 1-5) also followed a fixed sequence, but a visual representation of these concepts (i.e., digits) was also presented simultaneous with the response signal. The visually presented digit remained on the screen until a response was registered. In the last condition, the random digit sequence, the numbers were presented in a random fashion, so that concepts were solely triggered by a visual digit.

The former two conditions, which both employed a fixed sequence of concepts, each used a different fixed sequence. The assignment of sequence to condition was counterbalanced across participants. Additionally, each digit appeared equally frequent in both languages and equally frequent in switch trials and repetition trials in each condition.

Furthermore, an alternating language sequence was implemented for each of the three conditions, which meant that no visual language cues were necessary. Half of the blocks started with English and half with German and the sequence of blocks was counterbalanced across participants.

Design. Two non-orthogonal contrasts were defined. First, to investigate the influence of concept predictability with knowledge of the languages, language switching with a
predictable concept sequence was compared against language switching with an unpredictable concept sequence (i.e., fixed digit sequence vs. random digit sequence; concept predictability contrast). Note that there was a predictable language sequence in both these conditions, while the concept predictability was varied.

In the second contrast, the influence of visual representations that activate concepts on language switching was investigated by contrasting language switching with and without visible digits (i.e., fixed digit sequence vs. memory-based number sequence; visual digit contrast). Again an alternating language sequence was used and a fixed digit sequence, so that both languages and concepts were predictable.

That is, the within-subjects independent variables were language (German vs. English), language transition (switch vs. repetition), and in the concept predictability contrast, concept predictability (random digit sequence vs. fixed digit sequence), whereas in the visual digit contrast this was concept presentation (memory-based number sequence vs. fixed digit sequence). The dependent variables were RT and error rate.

### 10.2.2 Results and Discussion

Identical outlier criteria and error definitions were used as in Experiment 5, which resulted in the exclusion of 14% of the RT data.

<table>
<thead>
<tr>
<th>Language transition</th>
<th>German</th>
<th></th>
<th></th>
<th></th>
<th>English</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Random digit</td>
<td>Fixed digit</td>
<td>Memory-based number</td>
<td>Random digit</td>
<td>Fixed digit</td>
<td>Memory-based number</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Switch</td>
<td>599 (27)</td>
<td>514 (28)</td>
<td>570 (44)</td>
<td>627 (26)</td>
<td>524 (26)</td>
<td>571 (45)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Repetition</td>
<td>521 (20)</td>
<td>464 (20)</td>
<td>491 (35)</td>
<td>573 (21)</td>
<td>505 (23)</td>
<td>529 (37)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Switch</td>
<td>2.7 (0.5)</td>
<td>1.4 (0.3)</td>
<td>1.6 (0.4)</td>
<td>0.8 (0.2)</td>
<td>1.6 (0.5)</td>
<td>0.7 (0.3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Repetition</td>
<td>0.5 (0.2)</td>
<td>0.5 (0.2)</td>
<td>0.4 (0.3)</td>
<td>0.3 (0.2)</td>
<td>0.3 (0.2)</td>
<td>0.5 (0.3)</td>
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</tbody>
</table>

Table 8. Overall RT in ms and percentage of errors (PE) of Experiment 6 (SD in parenthesis) as a function of language (German vs. English), language transition (repetition vs. switch), and concept predictability/presentation (random digit sequence vs. fixed digit sequence vs. memory-based number sequence).
Concept predictability contrast: random digit sequence vs. fixed digit sequence. An ANOVA of the RT data revealed a significant effect of language \((F(1, 23) = 18.00; p < .001; \eta_{p}^2 = .439)\), with English responses (557 ms) being slower than German responses (525 ms, see Table 8), and a significant effect of language transition \((F(1, 23) = 32.78; p < .001; \eta_{p}^2 = .588)\), with switch trial responses (566 ms) being slower than repetition trial responses (516 ms), indicating language switch costs of 50 ms. Furthermore, the main effect of concept predictability was also significant \((F(1, 23) = 20.70; p < .001; \eta_{p}^2 = .474)\), with responses in the random digit sequence (580 ms) being slower than those in the fixed digit sequence (502 ms). The latter effect indicates that concept predictability reduced RT and thus was used to prepare for the upcoming trial.

Importantly, the interaction between concept predictability and language transition was significant \((F(1, 23) = 6.44; p < .05; \eta_{p}^2 = .219)\), with larger switch costs during the random digit sequence (66 ms) than during the fixed digit sequence (35 ms, see Figure 13). Separate t-tests revealed that switch costs were significant for both the random digit sequence \((t(23) = 5.82; p < .001)\) and the fixed digit sequence \((t(23) = 3.47; p < .01)\). The reduction of switch costs with a predictable language and concept sequence, relative to when only the language sequence was predictable, provides evidence that knowing both the language and concept reduces language switching interference. This finding is in line with the results of Experiment 5.

Both the interaction between concept predictability and language and the three-way interaction \((Fs < 1)\) were not significant. The interaction between language and language transition was significant \((F(1, 23) = 9.10; p < .01; \eta_{p}^2 = .284)\), with larger switch costs for German (64 ms) than for English (39 ms).

The error data revealed a main effect of language \((F(1, 23) = 6.46; p < .05; \eta_{p}^2 = .219)\), with more errors elicited in German (1.3%) than in English (0.8%), which indicates a speed-
accuracy trade off (i.e., German responses were less accurate and faster than English responses). The main effect of language transition was also significant ($F(1, 23) = 20.31; p < .001; \eta_p^2 = .469$), with switch trials (1.6%) being more erroneous than repetition trials (0.4%). The main effect of concept predictability ($F(1, 23) = 1.00; \text{ns.}; \eta_p^2 = .042$) was not significant.

Figure 13. Switch costs (in ms) of Experiment 6 as a function of language (German vs. English) and concept predictability (random digit sequence vs. fixed digit sequence).

The interaction between language and language transition ($F(1, 23) = 3.00; \text{ns.}; \eta_p^2 = .115$) was not significant, but (like in the RT) there was a trend towards larger switch costs for German (1.5%) than for English (0.9%). The interaction between concept predictability and language transition ($F < 1$) was also not significant. However, the interaction between concept predictability and language was significant ($F(1, 23) = 6.46; p < .05; \eta_p^2 = .219$), with a higher number of errors in the random digit sequence (1.6%) than the fixed digit sequence in the German trials (0.9%), and a higher amount of errors in the fixed digit condition (0.9%) than the random digit sequence in the English trials (0.6%). The three-way interaction ($F(1, 23) = 8.85; p < .01; \eta_p^2 = .278$) was also significant, with larger switch costs in the random digit sequence (2.2%) than in the fixed digit sequence (0.9%) during German trials, whereas in the
English trials the fixed digit sequence (1.3%) had larger switch costs than the random digit sequence (0.5%). Separate t-test showed that there was a significant difference in switch costs between the fixed digit sequence and random digit sequence in the German trials ($t(23) = 2.25; p < .05$), but not in the English trials ($t(23) = 1.77; \text{ns.}$). The latter finding indicates that switch costs are even more reduced in L1 than L2 due to concept predictability. Possible explanations for this three-way interaction will be discussed in the General Discussion.

**Visual digit contrast: memory-based number sequence vs. fixed digit sequence.** An ANOVA of the RT data revealed a significant effect of language ($F(1, 23) = 5.45; p < .05; \eta^2_p = .192$), with English responses (532 ms) being slower than German responses (509 ms), and a significant effect of language transition ($F(1, 23) = 20.50; p < .001; \eta^2_p = .471$), with switch trials (545 ms) being slower than repetition trials (497 ms), indicating language switch costs of 48 ms. The main effect of concept presentation was not significant ($F(1, 23) = 1.76; \text{ns.}; \eta^2_p = .071$).

The interaction between concept presentation and language transition was significant ($F(1, 23) = 4.37; p < .05; \eta^2_p = .160$), with larger switch costs during the memory-based number sequence (60 ms) than during the fixed digit sequence (35 ms, see Figure 14). Separate t-tests revealed that switch costs were significant for both the memory-based number sequence ($t(23) = 4.36; p < .001$) and the fixed digit sequence ($t(23) = 3.47; p < .01$). Additionally, the interaction between language and language transition was significant ($F(1, 23) = 7.10; p < .05; \eta^2_p = .236$), with larger switch costs for German (65 ms) than for English (30 ms), whereas the interaction between concept presentation and language and the three-way interaction were not significant ($F$s $< 1$). The decrease in switch costs due to digit presentation suggests that working memory load plays a role during language switching. This is in line with the result of Experiment 3. Interesting in this respect are the study of Thompson-Schill and Botvinick (2006) and the WEAVER ++ model (Levelt et al., 1999; Roelofs, 2003), which put forward that lemma selection is influenced by both bottom-up
processes, such as spreading semantic activation, and by top-down processes, such as representation of the task. Since task representations must be held in working memory (Roelofs, 2003), it follows that an increase of working memory load should reduce top-down modulation. This would lead to a larger influence of bottom-up processes (see e.g., Belke, 2008). A similar effect was found in the current study, namely an increase of language switch costs due to an increase of working memory load. This finding suggests that language control is not just a top-down process, but is also influenced by bottom-up processes.

![Figure 14. Switch costs (in ms) of Experiment 6 as a function of language (German vs. English) and concept presentation (memory-based number sequence vs. fixed digit sequence).](image)

The ANOVA of the error data revealed a main effect of language transition \(F(1, 23) = 12.79; p < .01; \eta_p^2 = .357\), with switch trials (1.6%) being more erroneous than repetition trials (0.4%), whereas language and concept presentation \(F_s < 1\) were not significant, and neither was the interaction between concept presentation and language \(F(1, 23) = 1.04; \text{ns.}; \eta_p^2 = .043\) or any of the other two-way interactions \(F_s < 1\). The three-way interaction \(F(1, 23) = 3.68; \text{ns.}; \eta_p^2 = .138\) was not significant, but showed a trend towards larger switch costs in the memory-based number sequence (1.2%) than in the fixed digit sequence (0.9%) during
German trials, whereas in English trials the fixed digit sequence (1.3%) had larger switch costs than the memory-based number sequence (0.2%).

Summary. In the visual digit contrast, where the influence of redundant visual stimuli was investigated, smaller switch costs were observed when the concepts were visually presented than when they were not visually presented. A probable explanation for this finding is that language switching was influenced by the difference in working memory load between both these conditions.

The first contrast also showed a switch cost difference: smaller switch costs were observed with a predictable language and concept sequence when compared with language switching with solely a predictable language sequence. This indicates that being able to prepare both language and concept (i.e., the response) can reduce language interference to a higher extent relative to preparing just the language. Moreover, the results also indicate that L1 switch costs are reduced to a higher extent than L2 switch costs due to both language and concept sequence being predictable.
10.3 Experiment 7

In Experiment 7, the sole influence of language predictability on language switching was examined without any knowledge of the concepts. More specifically, predictability of the language sequence was manipulated (i.e., cued alternating language sequence vs. cued random language sequence), while the concept sequence was unpredictable in both conditions (see third panel of Figure 5). This is similar to the set-up of Experiment 5, except that in Experiment 5 the concept sequence was predictable in both conditions. According to the reconfiguration model and the ICM, smaller switch costs should be elicited due to this manipulation.

10.3.1 Method

Apparatus and concepts. The apparatus was identical to that of Experiments 5 and 6. Similar to the random digit sequence in Experiment 6, the participants were instructed to produce number words in a random order, as indicated by the visually presented digits (1-5).

Procedure. The procedure was similar to that used in Experiment 5. However, the concept sequence was random in the current experiment, and thus indicated by visually presented digits. Furthermore, only two conditions were implemented, namely the cued random language sequence and the cued alternating language sequence.

Design. The within-subjects independent variables were language (German vs. English), language transition (switch vs. repetition) and language predictability (cued alternating language sequence vs. cued random language sequence). The dependent variables were RT and error rate.

10.3.2 Results and Discussion

Identical outlier criteria and error definitions were used as in Experiment 5, which resulted in the exclusion of 11% of the RT data.
Table 9. Overall RT in ms and percentage of errors (PE) of Experiment 7 (SD in parenthesis) as a function of language (German vs. English), language transition (repetition vs. switch), and language predictability (cued random language sequence sequence vs. cued alternating language sequence).

<table>
<thead>
<tr>
<th>Language transition</th>
<th>German</th>
<th>English</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Cued random</td>
<td>Cued alternating</td>
</tr>
<tr>
<td>Switch</td>
<td>655 (15)</td>
<td>612 (23)</td>
</tr>
<tr>
<td>Repetition</td>
<td>572 (17)</td>
<td>531 (15)</td>
</tr>
<tr>
<td>Switch</td>
<td>0.9 (0.2)</td>
<td>0.8 (0.2)</td>
</tr>
<tr>
<td>Repetition</td>
<td>0.4 (0.1)</td>
<td>0.3 (0.2)</td>
</tr>
</tbody>
</table>

An ANOVA of the RT data revealed a significant effect of language ($F(1, 23) = 16.70; p < .001; \eta^2_p = .421$), with English responses (619 ms) being slower than German responses (592 ms, see Table 9), and a significant effect of language transition ($F(1, 23) = 75.72; p < .001; \eta^2_p = .767$), with switch trial responses (638 ms) being slower than repetition trials responses (573 ms), indicating language switch costs of 65 ms. Furthermore, the main effect of language predictability was also significant ($F(1, 23) = 20.88; p < .001; \eta^2_p = .476$), with responses produced in the cued random language sequence (627 ms) being slower than those produced in the cued alternating language sequence (584 ms). The latter result shows that the predictable language information reduced RT and thus was used to prepare for the upcoming trial.

The interaction between language and language transition was significant ($F(1, 23) = 8.17; p < .01; \eta^2_p = .262$), with larger German switch costs (81 ms) than English (49 ms), whereas the other two-way interactions ($Fs < 1$) and the three-way interaction ($F(1, 23) = 1.02; \text{ns.}; \eta^2_p = .043$) were not significant. This indicates that language predictability, without any knowledge of the concepts, does not influence language switch costs (switch costs of 61 ms in the cued random language sequence vs. 68 ms in the cued alternating language sequence, see Figure 15), which is not in line with the reconfiguration model or the ICM.
The error data revealed a main effect of language \((F(1, 23) = 10.62; p < .01; \eta_p^2 = .316)\), with more errors in German (0.6%) than in English (0.3%), which indicates a speed-accuracy trade off for the language effect. The main effect of language transition was also significant \((F(1, 23) = 4.60; p < .05; \eta_p^2 = .167)\), with more errors in switches (0.6%) than in repetitions (0.3%), whereas the main effect of language predictability \((F < 1)\) was not significant. The interaction between language and language transition was significant \((F(1, 23) = 6.15; p < .05; \eta_p^2 = .211)\), with larger switch costs in German (0.5%) than in English (0.1%). However, none of the other interactions were significant \((Fs < 1)\).

![Figure 15. Switch costs (in ms) of Experiment 7 as a function of language (German vs. English) and language predictability (cued random language sequence vs. cued alternating language sequence).](image)

**Summary.** Experiment 7 revealed no switch cost difference between language switching with solely a predictable language sequence when compared against language switching with both an unpredictable language and concept sequence. This indicates that being able to just prepare the upcoming language does not reduce language interference to a higher extent relative to not being able to prepare either language or concept.
10.4 **Experiment 8**

To investigate whether some interference resolution can occur on the basis of concept predictability, a comparison was drawn between a condition in which only the concept sequence was predictable (i.e., fixed digit sequence) and a condition where neither concept nor language were predictable (i.e., random digit sequence; see last panel of Figure 5). According to the ICM and the reconfiguration model, no difference in switch costs should be obtained due to this manipulation, because interference resolution does not occur until the target language is known.

10.4.1 **Method**

*Participants.* 24 native German participants took part and spoke English as their second language (15 female, mean age = 23.2). A questionnaire, identical to that in Experiment 5, was given to the participants prior to the actual experiment (see Table 6).

*Apparatus and concepts.* The apparatus and concepts were similar to those used in the random digit sequence and the fixed digit sequence of Experiment 6. Unlike Experiment 6, however, only one fixed concept sequence was implemented (see appendix D for all response sequences).

*Procedure.* The procedure was similar to that used in Experiment 6. Yet, in the current experiment, the languages followed an unpredictable sequence and thus were triggered solely by language cues. These were presented simultaneous with the response-signal. Furthermore, only two conditions were implemented, namely the fixed digit sequence and the random digit sequence.

*Design.* The within-subjects independent variables were language (German vs. English), language transition (switch vs. repetition) and concept predictability (random digit sequence vs. fixed digit sequence). The dependent variables were RT and error rate.
10.4.2 Results and Discussion

Identical outlier criteria and error definitions were used as in Experiment 5, which resulted in the exclusion of 13% of the RT data.

Table 10. Overall RT in ms and percentage of errors (PE) of Experiment 8 (SD in parenthesis) as a function of language (German vs. English), language transition (repetition vs. switch), and concept predictability (random digit sequence vs. fixed digit sequence).

<table>
<thead>
<tr>
<th>Language transition</th>
<th>German</th>
<th>English</th>
<th>German</th>
<th>English</th>
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<tbody>
<tr>
<td></td>
<td>Random digit</td>
<td>Fixed digit</td>
<td>Random digit</td>
<td>Fixed digit</td>
</tr>
<tr>
<td>R Switch</td>
<td>708 (21)</td>
<td>663 (22)</td>
<td>703 (21)</td>
<td>683 (23)</td>
</tr>
<tr>
<td>T Repetition</td>
<td>630 (20)</td>
<td>620 (23)</td>
<td>661 (20)</td>
<td>637 (18)</td>
</tr>
<tr>
<td>P Switch</td>
<td>1.2 (0.2)</td>
<td>1.0 (0.2)</td>
<td>0.5 (0.2)</td>
<td>0.4 (0.2)</td>
</tr>
<tr>
<td>E Repetition</td>
<td>0.3 (0.1)</td>
<td>0.8 (0.2)</td>
<td>0.3 (0.1)</td>
<td>0.3 (0.1)</td>
</tr>
</tbody>
</table>

An ANOVA of the RT data revealed a significant effect of language ($F(1, 23) = 5.53; p < .05; \eta^2_p = .194$), with higher RT for English responses (675 ms) than for German responses (651 ms, see Table 10), and a significant effect of language transition ($F(1, 23) = 140.13; p < .001; \eta^2_p = .859$), with slower switch trial responses (689 ms) than repetition trial responses (637 ms), indicating language switch costs of 52 ms. Furthermore, the main effect of concept predictability was not significant ($F(1, 23) = 4.23; \text{ns.}; \eta^2_p = .071$), even though there was a trend towards slower responses in the random digit sequence (671 ms) than in the fixed digit sequence (655 ms).

The interaction between language and language transition was not significant ($F(1, 23) = 1.64; \text{ns.}; \eta^2_p = .067$), as were the interactions between concept predictability and language transition ($F(1, 23) = 2.66; \text{ns.}; \eta^2_p = .104$) and between concept predictability and language ($F < 1$). However, the three-way interaction was significant ($F(1, 23) = 4.36; p < .05; \eta^2_p = .159$), with larger switch costs in the random digit sequence (78 ms) than in the fixed digit sequence (43 ms) during German trials, whereas there was only a small switch cost difference
between the random digit sequence (42 ms) and fixed digit sequence (46 ms, see Figure 16) during English trials. Separate t-tests revealed that the switch cost difference between the random digit sequence and the fixed digit sequence was significant for German trials ($t(23) = 2.55; p < .05$), but not for English trials ($t < 1$). Thus, whereas there is no overall influence of concept predictability, without a predictable language sequence, on switch costs, there is such an effect in L1. This is similar to the result found in Experiment 6, where a larger decrease in German switch costs was observed due to concept predictability. Possible explanations for this three-way interaction and the one found in Experiment 6 will be discussed in the General Discussion.

The error data revealed a main effect of language ($F(1, 23) = 5.84; p < .05; \eta^2 = .203$), with more errors in German responses (0.8%) than in English responses (0.4%), which indicates a speed-accuracy trade off for the effect of language. The main effect of language transition was also significant ($F(1, 23) = 8.46; p < .01; \eta^2 = .269$), with more errors in switch trials (0.8%) than in repetition trials (0.4%), whereas the main effect of concept predictability ($F < 1$) was not significant. The interactions between language and language transition ($F(1, 23) = 2.32; \text{ns.} ; \eta^2 = .091$), concept predictability and language transition ($F(1, 23) = 1.80; \text{ns.} ; \eta^2 = .073$), concept predictability and language ($F(1, 23) = 1.56; \text{ns.} ; \eta^2 = .064$), and the three-way interaction ($F(1, 23) = 1.81; \text{ns.} ; \eta^2 = .073$) were not significant.
Experiment 8 revealed overall similar switch costs when comparing language switching with a predictable concept sequence against language switching with both language sequence and concept sequence being unpredictable. Yet, the results do indicate that L1 switch costs are in fact significantly reduced due to a predictable concept sequence. The latter finding indicates that concept predictability does play some role during language control.

**Summary.** Experiment 8 revealed overall similar switch costs when comparing language switching with a predictable concept sequence against language switching with both language sequence and concept sequence being unpredictable. Yet, the results do indicate that L1 switch costs are in fact significantly reduced due to a predictable concept sequence. The latter finding indicates that concept predictability does play some role during language control.
10.5 Overview of the main findings of Experiments 5-8

The last four experiments investigated the influence of language and concept predictability on language switching, with hybrids of the cued language switching paradigm and the SBLS paradigm. The main finding of these experiments is that smaller switch costs were obtained when both the language and concept sequence were predictable, relative to when only the language sequence or concept sequence were predictable (Experiments 5-6). On the other hand, no overall switch cost difference was found when comparing language switching with solely a predictable language sequence (Experiment 7) or concept sequence (Experiment 8), relative to when both the language and concept sequence were unpredictable.

More specifically, Experiment 5 revealed smaller switch costs when both the language and concept sequences were predictable than when only the concept sequence was predictable. Similarly, Experiment 6 showed smaller switch costs when both the language and concept sequences were predictable than when only the language sequence was predictable. Furthermore, smaller L1 switch costs than L2 switch costs were observed in Experiment 6, due to the predictability manipulation.

Experiment 7 revealed no switch cost difference between language switching with a predictable language sequence and language switching with neither the language nor concept sequence being predictable. Similarly, in Experiment 8 there was no overall switch cost difference due to a predictable concept sequence, relative to neither the language or concept sequence being predictable. However, the data of Experiment 8 did reveal smaller L1 switch costs due to concept predictability.

These data, and those observed in the first four experiments, will be discussed in light of models of control to establish their theoretical relevance in the next segment.
Part III

Discussion
11 General discussion

This dissertation aimed to gain a deeper understanding of language control during bilingual production. To this end, an examination of sequential predictability in language switching was carried out, using a new paradigm (i.e., SBLS paradigm). This novel paradigm requires participants to produce a word after hearing a response-signal. There is no visual indication given to specify the target concept or language, and thus participants rely on a memorized language sequence and concept sequence to produce the correct response. More specifically, the concept sequence is either over learned (i.e., weekdays or numbers) or has to be learned prior to the experiment, whereas the languages follow an alternating language sequence.

Using this novel paradigm, or a variant of it, two aspects of predictability in language switching were investigated. The first aspect revolves around whether switch costs would be elicited by predictable responses (Experiments 1-4). The second aspect considers the influence of language predictability and/or concept predictability on language switching (Experiments 5-8).

Before delving into the theoretical significance of the findings, a short overview of the results is given.

11.1 Overview of the results

Since summaries of the results have already been provided after the first four experiments (see “Overview of the main findings of Experiments 1-4”) and the last four experiments (see “Overview of the main findings of Experiments 5-8”), an abridged version is provided here (see Table 11 and Table 12). This synopsis consists of the main findings of each experiment, with respect to the focus of this dissertation, and additional interesting findings that were observed.
Table 11. Summary of the main findings and additional findings of Experiments 1–4.

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Main findings</th>
<th>Additional findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experiment 1</td>
<td>- Switch costs emerged with predictable responses (weekdays)</td>
<td>- Smaller switch costs with a long than a short interval</td>
</tr>
<tr>
<td>Experiment 2</td>
<td>- Switch costs emerged with predictable responses (weekdays and numbers) and a predictable response onset</td>
<td>- Smaller L2 than L1 switch costs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Smaller switch costs with numbers than weekdays</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Mixing costs emerged with predictable responses (weekdays and numbers) and a predictable response onset</td>
</tr>
<tr>
<td>Experiment 3</td>
<td>- Switch costs emerged with predictable responses (over-learned and scrambled sequences of weekdays and numbers) and a predictable response onset</td>
<td>- Smaller switch costs in an over-learned sequence than in a scrambled sequence</td>
</tr>
<tr>
<td>Experiment 4</td>
<td>- Switch costs emerged with predictable responses (sequence of unrelated concepts) and a predictable response onset</td>
<td>- Similar switch costs with responses that consist of solely language-unspecific phonemes and responses that also contain language-specific phonemes</td>
</tr>
</tbody>
</table>
Table 12. Summary of the main findings and additional findings of Experiments 5-8.

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Main findings</th>
<th>Additional findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experiment 5</td>
<td>- Smaller switch costs when both language and concept sequence were predictable than when only the concept sequence was predictable</td>
<td>- Similar switch costs with visually presented language cues and visually not presented language cues</td>
</tr>
<tr>
<td>Experiment 6</td>
<td>- Smaller switch costs when both language and concept sequence were predictable than when only the language sequence was predictable</td>
<td>- Smaller L2 than L1 switch costs</td>
</tr>
<tr>
<td></td>
<td>- Larger influence of the predictability manipulation on L1 than L2 switch costs</td>
<td>- Smaller switch costs with a visually presented trigger for the concepts (digits) than without a visually presented trigger for the concepts</td>
</tr>
<tr>
<td>Experiment 7</td>
<td>- Similar switch costs when both language and concept sequence were unpredictable and when only the language sequence was predictable</td>
<td>- Smaller L2 than L1 switch costs</td>
</tr>
<tr>
<td>Experiment 8</td>
<td>- Similar switch costs when both language and concept sequence were unpredictable and when only the concept sequence was predictable</td>
<td>- Smaller L1 switch costs due to concept predictability</td>
</tr>
</tbody>
</table>
These results will be considered in a theoretical framework in the rest of this chapter, starting with a discussion about predictable responses in language switching. Following this section will be a discussion on the influence of different types of predictability on language switching, ensued by a description of a modified ICM, which can accommodate the observed findings. Finally, different strengths of the cued language switching paradigm, voluntary language switching paradigm, and the SBLS paradigm will be discussed, as will future avenues for language switching research in general and for the SBLS paradigm in specific.
11.2 Does response preparation abolish switch costs?

Based on the smaller switch costs due to increased preparation time in Experiment 1, it can be concluded that participants used the predictability information, being it either concept predictability, language predictability or the combination of both. The switch cost reduction due to response predictability in Experiments 5 and 6 provide further evidence that participants actively prepared upcoming trials based on the predictable information. Yet, even though participants used the predictability information to prepare for an upcoming response, switch costs were obtained.

Please note that in cued language switching, preparation time generally consists of the time between language cue and stimulus (e.g., Costa & Santesteban, 2004; Philipp et al., 2007a). That is, participants can prepare for the upcoming language, but not for a specific response. In contrast, in Experiment 1 preparation was possible up to response selection, because the concept sequence was also predictable. Further preparation was not possible due to the jitter, which prohibited the participants to know when the actual response production should take place. In Experiments 2-6, however, the task allowed response execution to be predictable, by introducing a predictable response onset. Still, substantial switch costs were observed in these experiments.

The observation of switch costs with predictable responses is of theoretical importance because it provides evidence that language switch costs cannot be completely counteracted by processing stages that occur prior to response preparation (e.g., lexical selection). Yet, one could argue that in the present experiments, preparation time was not long enough to prepare a response. However, preparation time in Experiment 1 (i.e., 1500, 1700 or 1900 ms between the end of a response and the next response-signal in the long preparation time condition, since the average response duration of the weekdays was 300 ms) was substantially higher than in other language switching studies that investigated preparation time (Costa &
Santesteban, 2004: 0, 800 or 1200 ms; Philipp et al., 2007a: 100 or 1000 ms; Verhoef et al., 2009: 750 or 1500 ms). Additionally, based on a meta-analysis on picture naming (Indefrey & Levelt, 2004), which provides a temporal structure of word production, phonological encoding is scheduled between 455 to 600 ms after picture onset. Thus, we are confident that the preparation time in the present experiments was long enough to prepare the responses at least up to the level of phonological encoding.

The present result pattern is also of theoretical importance since there are two influential cognitive control models, borrowed from task switching (for a review of models in task switching, see Kiesel et al., 2010; Vandierendonck et al., 2010), that have made predictions about switch costs with predictable responses. The first is the reconfiguration model (e.g., Rogers & Monsell, 1995), which assumes that during switch trials the task needs to be reconfigured on the level of the language and on the level of the actual stimulus (i.e., concept). Importantly, this model suggests that switch costs might be abolished, given ample preparation time and all the necessary information (i.e., language and concept). This means that in the current set-up switch costs should disappear, since the task meets both requirements. However, this was not the case in the current study. Switch costs were observed with predictability up to response selection and switch costs and mixing costs were found with predictability up to response execution. Thus, the data does not correspond with the assumption that switch costs can be abolished with substantial preparation time and both languages and concepts being predictable.

The second model is the proactive interference model (Allport et al., 1994; Green, 1998). In this model, activation of the previously used task persists and thus causes either interference with the current task (switch trials) or results in residual activation and thus facilitation (repetition trials). Different from the reconfiguration model, this model does not make any claims about abolishing switch costs due to predictable responses, which is in line

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3 This model also assumes inhibition of the non-target task on the previous trial to persist into the current trial.
with the current findings. The proactive interference model could account for switch costs with predictable responses by assuming that interference from the previous trial cannot be abolished completely by preparation, which would mean that on switch trials there would always be interference from the prior trial, which could be diminished, but not abolished (see also Koch & Allport, 2006).

The ICM, in essence, assumes a similar process to account for switch costs as the proactive interference account, with the specification that interference resolution mainly occurs due to an inhibitory process. Hence, a similar argumentation could be used to explain the data pattern with the ICM (Green, 1998), by assuming that the inhibitory process is not an all or nothing process, but a flexible process. Put differently, the target language is generally not free from inhibition and the non-target language is not completely inhibited in most cases (see also Costa et al., 2000; Gollan & Ferreira, 2009). The ICM, indirectly, assumes such a flexible inhibitory process. As mentioned before, the ICM can account for cross-language interference and for the selection of words of the non-target language (see “Cross-language influences” and “Selection of words from the non-target language”). These findings would be difficult to explain if this model relied on an all or nothing inhibition account.

If there is no all or nothing inhibition process, then the non-target language can continuously inhibit the target language to some extent. In turn, there would typically be some inhibition that interferes with production, even after substantial preparation. However, repetition trials could also suffer from inhibition of the non-target language according to this explanation. Even if this is the case, the amount of inhibition should still be larger for switch trials than repetition trials with predictable responses due to language priming of the target language in repetition trials, which should result in further inhibition of the non-target language. Hence, the non-target language will inhibit the target language to a lesser degree in

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4 This would be in line with an inhibitory account of mixing costs, since repetition trials in mixed blocks would suffer from inhibition, whereas this would be not the case, or at least less so, for trials in pure language blocks.
repetition trials than switch trials and thus could explain switch costs with predictable responses.

An alternative account for switch costs with predictable responses is based on the role of motor-related processes. Previous task switching studies have provided evidence that motor-related processes, such as response selection and response execution, influence switch costs (Koch & Philipp, 2005; Philipp et al., 2007b, 2012; Schuch & Koch, 2003; Verbruggen et al., 2006). Similar evidence was found in language switching studies (Christoffels et al., 2007; Declerck et al., 2012; Declerck & Philipp, 2013b; Filippi et al., in press). In a recent language switching study, for example, Declerck et al. (2012) found that language switch costs were smaller during digit naming than picture naming. By contrasting specific characteristics of digits against pictures, it was found that the difference between digit naming and picture naming was due to the large amount of cognates in the digit stimulus-set. Hence, this study provides evidence for a motor-related influence on language switch costs.

Thus, failing to fully prepare responses (i.e., concept and language) could be accounted for by motor-related processes, such as articulation. It was argued that the participants could prepare up until response execution in Experiments 2-6, yet it is feasible that solely the mental representations of sounds can be prepared for, whereas the actual motor movement of the mouth, vocal cords, and tongue are not, especially since both languages implement different motor movements (e.g., due to language-specific phonemes). Evidence for the influence of articulation can also be found in Experiment 4. The numerical data in Experiment 4 revealed larger L2 switch costs for responses that contained language-specific phonemes than for responses that only contained language-unspecific phonemes (see Table 5 and Figure 10). This result reflects an execution-related locus of language control. Hence, it could be that articulation is a locus of language control.
If articulation elicits language switch costs, then the reconfiguration model would fit the current data if the role of articulation would be taken into account. The model, as it is described by Rogers and Monsell (1995), would be able to account for preparation effects up to mental representations of sounds, which would be followed by a motor process. However, while the motor process also elicits switch costs, these switch costs would be unaffected by preparation.

The proactive interference model could also account for switch costs due to articulation by assuming that articulation is a level on which interference plays a role. However, this is not in line with the assumptions of the ICM, which assumes that the language control process occurs earlier in the language production process (i.e., lexical-semantic level).
11.3 The influence of language and/or concept predictability on language switching

Whereas it has been established that switch costs cannot be abolished by preparatory processes, preparation effects can still inform us about the role of language and concept during language control. While the proactive interference model (Allport et al., 1994) has made no specific assumptions about the separate role of language and/or concept during interference resolution, its bilingual variant, the ICM (Green, 1998), has. According to the ICM, language control starts between language schemas, which then influence language tags after lemmas have been activated by their corresponding concept. In turn, these language tags influence the target lemma and its translation-equivalent lemma, resolving any interference between the two translation-equivalent lemmas. Put differently, some language control processes can start when knowing which language to produce in (i.e., interference resolution between language schemas). Yet, language interference resolution between lemmas only starts after lemmas have been activated by their respective concepts.

The reconfiguration model also accounts for interference resolution in two separate stages. Prior to stimulus presentation, a reconfiguration to the parameters of the new task (i.e., language in the current study) occurs. Hence, interference resolution can partially be accounted for by merely knowing the upcoming target language. The second reconfiguration stage occurs when the stimulus has been presented (i.e., concept in the current study), which requires the task rules to be activated. This second stage should reduce language interference to an even larger extent when both the language and concept are known.

The results of Experiment 5 and 6 demonstrate that when both the language sequence and concept sequence are predictable, switch costs are reduced relative to when only the language sequence or concept sequence is predictable. This finding provides evidence that
language control benefits from the combined information about the upcoming language and concept (i.e., response), and thus is in line with the ICM and the reconfiguration model.

Similar evidence was found in Experiment 1 by manipulating preparation time with a predictable language and concept sequence, which led to a decrease in switch costs when preparation time was longer. However, Experiments 5 and 6 indicate that the decrease in switch costs, due to both a predictable language and concept sequence, was arguably not solely the result of language predictability or concept predictability but because of the combination. This distinction was not possible in Experiment 1, since the language sequence and concept sequence were not manipulated independently from each other. Furthermore, since more time elapsed in the long preparation time condition than in the short preparation time condition, the decrease of switch costs in Experiment 1 could also have been due to time-based decay processes (for a discussion of task decay, see Horoufchin, Philipp, & Koch, 2011; Rogers & Monsell, 1995) rather than based on active preparation. This could not have been the case in Experiments 5 and 6, since the time between response onset and the next trial was identical for both conditions in those experiments.

In Experiment 7, no language predictability effect on switch costs was found, without any knowledge of the concepts. This finding is contrary to the assumption postulated by the ICM, which constitutes that language control can start between the two language schemas prior to knowing the concept, and the reconfiguration model, which assumes that some language interference resolution should occur when reconfiguring to a new language (i.e., first reconfiguration stage). Yet, there was an overall RT reduction in the predictable condition, which indicates that the predictable language information was used to prepare the upcoming trial. The absence of a language predictability effect on switch costs is even more surprising since Macnamara et al. (1968) did find an effect of language predictability on mixing costs. However, this might be due to a difference between mixing costs and switch costs. The results of Experiment 2 and previous research has shown that an asymmetry in performance costs
across languages, for example, differ between mixing costs and switch costs (Christoffels et al., 2007; Gollan & Ferreira, 2009; Wang et al., 2009). Furthermore, in Experiment 2, different stimulus types (i.e., weekdays vs. numbers) also had a different impact on mixing costs and switch costs. Differences between these two markers have also been reported in the task switching literature (e.g., Goffaux, Phillips, Sinai, & Pushkar, 2006; Koch, Prinz, & Allport, 2005; Mayr, 2001). So, it could be that these two measures respond differently to predictability effects.

The inconsistent pattern of results across studies on language predictability resembles the inconsistency of the pattern of results found by studies that investigated the effect of language preparation time in language switching. For example, whereas the study of Costa and Santesteban (2004) revealed that longer language preparation time causes smaller switch costs, no such effect was found by Philipp et al. (2007a). Thus, it might be that knowing the target language is not a guarantee to start language interference resolution processes. Yet, the question remains why some language switching studies find an effect of language preparation on switch costs and others do not.

Note that Verhoef et al. (2009) also investigated time-based preparation on switch costs. These authors reported larger asymmetrical switch costs with a short than a long preparation time. Similar to the study of Costa and Santesteban (2004), Verhoef et al. (2009) also manipulated CSI, with the RSI being variable. Hence, regardless of the type of preparation effect (i.e., time-based or predictability-based), it could be deduced that the only two studies that found an influence of preparation on switch costs (Costa & Santesteban, 2004; Verhoef et al., 2009) implemented a variable RSI. In contrast, those studies that did not find smaller language switch costs due to preparation (Experiment 7; Philipp et al., 2007a) implemented a constant RSI. This leads us to believe that language control could be affected by processes associated with temporal variability across trials, such as hypothetical decay.
processes (e.g., Horoufchin et al., 2011; Rogers & Monsell, 1995; for a similar argument about asymmetrical switch costs, see Declerck et al., 2012).

In turn, this would mean that active language preparation does not have a large impact on switch costs. It could very well be that the previously activated language passively decays over time and thus leads to smaller switch costs in those studies that found a preparation effect (Costa & Santesteban, 2004; Verhoef et al., 2009). Since, there is no conclusive evidence for an active language preparation effect, it could be assumed that there is no interference resolution between language schemas in the framework of the ICM or no reconfiguration process solely between languages (i.e., first reconfiguration stage). So, interference resolution could mainly occur between language tags or lemmas in the ICM and during the second reconfiguration stage in the reconfiguration model (for a similar claim with respect to inhibition, see Guo, Ma, & Liu, 2013).

Similar to Experiment 7, Experiment 8 revealed no overall switch cost difference between language switching with a predictable concept sequence and an unpredictable language sequence and language switching with an unpredictable language and concept sequence. This finding is in line with the ICM and the reconfiguration model, which assume that information about the target language is needed to start language interference resolution. However, Experiment 8 did demonstrate that concept predictability, without knowledge of the upcoming language, can reduce switch costs, but only for L1. A similar result was found in Experiment 6, which revealed that concept predictability, with knowledge of the upcoming language, influences L1 switch costs more than L2 switch costs.

These two similar results could be explained by an idea proposed by Kroll and Stewart (1994), who assumed that concepts have a stronger connection to L1 lemmas than to L2 lemmas. This would mean that when a concept can be prepared (i.e., concept activation), the L1 lemma will receive a higher amount of activation than the translation-equivalent L2
lemma. Thus, switching languages with the concepts already activated should be easier from L2 to L1 than from L1 to L2, since the L1 lemmas are activated more, prior to the language control process, and thus should be easier to select.

An alternative explanation for the larger predictability-based reduction of L1 switch costs relative to L2 switch costs could be that the participants learned the concept sequence in their L1. The participants were not instructed to do so, but it seems plausible for them to learn the sequence in their L1. This would have a similar effect as proposed in the previous paragraph, with each predictable concept activating the respective L1 lemmas. When L2 production is required in the predictable condition, a translation process would be engaged. However, at least a slight reduction in switch costs should have been observed in the English trials as well, since a large number of practice trials were used, which contained both German and English trials. Yet, no such effect arose in the English trials of Experiment 8 (see Table 10). Furthermore, a recent study on semantic modulation during the production of memory-based words (Declerck, Stephan, & Philipp, 2013) suggests that not L1 or L2 responses are stored when working with memory-based responses in a bilingual setting, but a more abstract representation, which includes semantic information. Hence, it seems unlikely that storing the concepts as L1 words alone can account for the finding of more reduced L1 switch costs than L2 switch costs due to concept predictability.

The ICM and the reconfiguration model do not indicate that L1 switch costs should be affected more than L2 switch costs when concept predictability is manipulated and language is predictable in both conditions (Experiment 6). Furthermore, the ICM and the reconfiguration model do not assume that concept predictability, without any knowledge of languages (Experiment 8), should affect L1 switch costs more than L2 switch costs. Yet, both these results were found in the current study. However, the ICM does assume L1 lemmas to be more strongly activated, which has an effect on switch costs (cf. its interpretation on asymmetrical switch costs, Green, 1998), but this is not specified. For example, it could be
that L1 lemmas have a larger base activation than L2 lemmas. Identical to the previous idea, the results of Experiments 6 and 8 could be explained by a stronger connection between concepts and L1 lemmas than with L2 lemmas (Kroll & Stewart, 1994). In turn, the increased activation of the L1 lemmas would make it easier to select an L1 lemma after an L2 trial than an L2 lemma after an L1 trial. Thus, language control could function as the ICM assumes, but lemma selection is easier during L1 trials when the concept is predictable by increased L1 lemma activation.

If this is the case, we could talk about an L1-oriented language control process instigated by language-unspecific concepts. Whereas this idea would not critically change the ICM, it would require a differently weighed connection between the concept level and the translation-equivalent lemmas in this model.

With respect to the reconfiguration model, a similar explanation could be given. The concepts activate the words in the task set (i.e., task parameters of the target stimuli, responses and their S-R mappings) to a larger extent if it is an L1 word than an L2 word (Kroll & Stewart, 1994). Hence, using the same logic, smaller switch costs due to concept predictability should be observed when producing L2 words than L1 words.
11.4 Preparation effects in task switching vs. language switching

In the previous section it was assumed that language control is not instigated solely due to language information. This would mean that, in the context of the ICM, no interference resolution occurs between schemas. Interesting, with respect to schemas in the ICM, is that schemas can be task oriented or language oriented. Put differently, according to this model, task interference resolution and language interference resolution resemble each other partially, with the main overlap being the schemas. So, if we assume that language interference resolution does not occur between language schemas but on a later stage, then it follows that task control and language control rely on different processes within the ICM.

In contrast, several studies have assumed a close relationship between task control and language control (e.g., Prior & Gollan, 2011; Thomas & Allport, 2000; Von Studnitz & Green, 1997). This assumption could be tested quite easily by comparing task switching results to those obtained in language switching, since these two paradigms are very similar and measure task control and language control respectively. Correlation analyses have shown that the relationship between task switch costs and language switch costs are rather weak (Calabria et al., 2011, in press; Klecha, 2013; Prior & Gollan, 2013). These results seem to indicate that task switching and language switching do not necessarily measure the same processes (see also Weissberger et al., 2012).

So far, no correlation studies have been conducted between preparation effects of task switching and language switching. Yet, in what follows it will become clear that, similar to the correlation studies, there seems to be little overlap between task switching and language switching with respect to preparatory effects.

The manipulation of CSI and its effect on switch costs, for example, indicates that task switching and language switching might rely on different mechanisms. In task switching, many studies have reported reduced switch costs when CSI increases (e.g., Altmann, 2004a,
2004b; Hoffmann et al., 2003; Kiesel & Hoffmann, 2004; Koch, 2001; Logan & Bundesen, 2003; Mayr & Kliegl, 2003; Meiran, 1996; Monsell & Mizon, 2006; Schneider & Logan, 2007). Yet, in language switching only Costa and Santesteban (2004) reported such a decrease in switch costs, while Philipp et al. (2007a) did not find such an effect. What is more, Costa and Santesteban (2004) manipulated CSI across participants, whereas Philipp et al. (2007a) manipulated CSI within participants. In contrast, several task switching studies have shown that manipulating CSI between subjects usually does not cause a difference in switch costs, whereas manipulating CSI within subjects does (Altmann, 2004a, 2004b; Koch, 2001; Poljac, de Haan, & van Galen, 2006).

A similar discrepancy is found between task switching and language switching with regard to time-based preparation effects on mixing costs. Whereas preparation time is found to have no effect on language mixing costs (Macnamara et al, 1968), several task switching studies did find smaller mixing costs when preparation time increased (e.g., Lawo, Philipp, Schuch, & Koch, 2012; Rubin & Meiran, 2005). These time-based preparation effects on switch costs and mixing costs seem to indicate quite a difference between task switching and language switching.

On the other hand, when investigating the effect of task predictability, typically no effect on switch costs is found (e.g., Gotler et al., 2003; Heuer et al., 2001; Koch, 2001; 2005; 2008; Ruthruff et al., 2001; Sohn & Carlson, 2000). This is compatible with the result of Experiment 7, which showed no switch cost difference due to just language predictability. Thus, the language predictability effect on language switch costs is in line with the task predictability effect found in the task switching literature.

Taken together, there seems to be dissimilarity between task switching and language switching when investigating the effect of preparation time on switch costs. This difference goes even beyond quantitative differences, since the type of manipulation (i.e., between
subject or within subject) also seems to differ across switch costs found in task switching and language switching. In contrast, when it comes to investigating preparation on the basis of predictability, task switching and language switching both show no effect on switch costs, even though the overall reaction times decrease when the task/language sequence is predictable. However, not finding a predictability effect does not seem to be grounds to assume that similar processes are at play during task switching and language switching. Hence, similar to the correlation studies, the preparation studies show little evidence for a connection between task switching and language switching, which provides additional evidence that no interference resolution occurs between language schemas.
11.5 A modified inhibitory control model

These correlation studies and the overview of preparation effects in task switching and language switching (see “Preparation effects in task switching and language switching”) seem incompatible with some of the assumptions of the ICM. Similarly, several of the results of this dissertation were also not in line with the assumptions postulated by models of control. A modified model of control is proposed to account for the results of this dissertation and those found in other language switching studies. The focus fell on the ICM to modify it to fit the current data, since this model is specifically designed to account for language control, whereas the proactive interference model and the reconfiguration model were initially composed to explain task control.

Based on the findings of the current study and those observed in previous studies, several differences are postulated with regard to the ICM, while still trying to stay as close to the original ICM as possible (see Figure 17 for a visual representation of the modified ICM). First, the connection between the concepts and lemmas are weighed differently for each language, with a stronger connection between concepts and their L1 lemma than between the concepts and their L2 lemma (Kroll & Stewart, 1994). This is not contrary to the original ICM, since this issue was merely not specified. Yet, the considerable reduction of L1 switch costs relative to L2 switch costs due to concept predictability (Experiments 6 and 8) indicates that this is an important process that influences language control. Thus, the connection from the concepts to the L1 lemmas is stronger than to the L2 lemmas in Figure 17.

Furthermore, in the modified ICM it is assumed that little to no language interference resolution occurs between the language schemas. This assumption is based on the results found in Experiment 7 and Philipp et al. (2007a), where no effect of language preparation was

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5 It bears repeating that switch costs with predictable responses were previously explained with a flexible inhibitory process (see “Does response preparation abolish switch costs?”). No modification was necessary based on these results, since the original ICM could already account for it.
found on switch costs. Those studies that did find a language preparation effect on language switch costs (Costa & Santesteban, 2004; Verhoef et al., 2009) might be accounted for by passive decay, as was discussed previously (see “The influence of language and/or concept predictability on language switching”). Furthermore, if there was some language interference resolution between language schemas, then this should resemble that of task interference according to the ICM, since these are both partially resolved between schemas. Yet, correlation studies have found a poor relationship between task switch costs and language switch costs (Calabria et al., 2011, in press; Klecha, 2013; Prior & Gollan, 2013). Similarly, preparation effects found in task switching and language switching are not converging (for a review, see “Preparation effects in task switching vs. language switching”).

However, there are still language schemas in this modified model, which represent the mental devices to speak a specific language. The proposed modification simply entails that the schemas of both languages have little influence over the activation level of the other language schema. Interference resolution in the modified ICM now occurs between the language tags (see Figure 17), which then inhibit the corresponding lemmas. Since language tags do not come into play until the concepts have been activated, and thus when the entire response is known, language interference resolution between the language tags can account for switch costs to be unaffected by just language preparation (Experiment 7; Philipp et al., 2007a), while also being able to account for a switch cost reduction due to response preparation (Experiments 1, 5 and 6).

These modifications do not change the locus of language control suggested by the original ICM (i.e., lexical-semantic level). However, recent studies have indicated that processes that occur after lemma selection, such as phonological encoding, also influence language switching and thus language control (e.g., Christoffels et al., 2007; Declerck et al., 2012; Declerck & Philipp, 2013b; Filippi et al., in press). As of yet, it still remains an open question whether these processes merely influence lemma selection or whether language
control also occurs on those levels. Since this question remains unresolved, it was not yet included in the modified ICM.

Note: arrow head means activation; circle head means inhibition; lightning bolt means interference resolution; full line means larger activation than dotted line.

*Figure 17.* Visual representation of the modified inhibitory control model. Language control starts when both the language and concept are known in this model. Hence, no interference resolution occurs between the language schemas, which was the case in the original ICM. Similar to the original ICM, the language schemas activate their respective language tags. In turn, the language tags influence each other and then inhibit the lemmas of the other language, which makes it more likely that the correct lemma will be selected. However, prior to the language tags being activated, the concepts activate their respective lemmas, with L1 lemmas being activated to a higher extent than the L2 lemmas by their corresponding concepts.
11.6 The (possible) future of language switching

This dissertation has opened the door to some new and interesting research. Several of these opportunities will be highlighted in this section. More specifically, an overview will be given of the cued language switching paradigm, voluntary language switching paradigm and the novel SBLS paradigm, and possible future applications of the SBLS paradigm. Finally, some still remaining questions will be discussed.

11.6.1 The different strengths of cued language switching vs. voluntary language switching vs. sequence-based language switching

While the majority of language switching studies are cued language switching studies (e.g., Costa & Santesteban, 2004; Meuter & Allport, 1999), switch costs also appear when using the voluntary language switching paradigm (Gollan & Ferreira, 2009) or the new SBLS paradigm. This leaves future research with three options, depending on the different strengths of each paradigm, or an array of hybrid variations, such as an alternating language sequence with visually presented stimuli (e.g., Experiment 6; Festman et al., 2010).

Cued language switching, voluntary language switching, and sequence-based language switching, in their strictest set-up, differ on several levels. First, stimuli are visually triggered when using the cued and voluntary language switching paradigm, whereas the SBLS paradigm relies on a predictable concept sequence that is memory-based.

The second difference is on the language level. While languages are visually triggered in a random fashion during the cued language switching paradigm, they are endogenously triggered in the voluntary language switching and SBLS paradigms. However, both the voluntary language switching and SBLS paradigms use different types of endogenous language triggers. In the voluntary language switching paradigm, the participants have to choose which language to respond with during each trial. The SBLS paradigm relies, identical
to the concept level, on a predictable sequence that is memory-based (i.e., alternating
language sequence).

These differences lead to different strengths for each of the three paradigms. The cued
language switching paradigm, for one, is backed-up by an extensive amount of behavioral
studies (e.g., Costa & Santesteban, 2004; Meuter & Allport, 1999; Philipp et al., 2007a),
neuroimaging studies (e.g., Hernandez, Dapretto, Mazziotta, & Bookheimer, 2001;
Hernandez, Martinez, & Kohnert, 2000) and event-related potential studies (e.g., Christoffels
et al., 2007; Verhoef et al., 2010), which created an extensive amount of knowledge about the
effects and processes that are at play during cued language switching. This paradigm is also
interesting when investigating the effect of preparation time, since there are different types of
intervals (i.e., cue-to-stimulus interval and response-to-cue interval) that can be varied in cued
language switching, which cannot be modified as readily in the other two paradigms.

One of the strengths of voluntary language switching is that it is closely related to
actual language switching during natural speech (i.e., code-switching; e.g., Herredia &
Altarriba, 2001; Joshi, 1983). Consequently, this paradigm can be used to investigate this
process in an experimental set-up. Furthermore, when using voluntary language switching,
switch costs are not the only interesting phenomenon. Since participants can choose when to
switch languages or repeat the same language, it also serves as a measure for when bilinguals
switch to another language.

The SBLS paradigm also has several strengths. One of these strengths is its close
resemblance to natural speech, due to the endogenous language retrieval and concept retrieval
and the sequential nature of the task, since words are most often retrieved from memory and
produced in a certain sequence. Additionally, using novel sequences, all word categories (e.g.,
verbs, adjectives, etc.) can be investigated using this paradigm, instead of only words that can
be visually depicted as language-unspecific targets of naming responses. This could be
crucial, since Experiment 2 of the current study has demonstrated that responses from different semantic categories elicit a difference in language switch costs. As the SBLS paradigm does not rely on pictures, one could, theoretically, even use whole sentences (see Declerck & Philipp, 2013a). Finally, it has to be noted that using visual cues and voluntary language switching can also be implemented in the SBLS paradigm, resulting in hybrid paradigms. This will of course change the concept of this paradigm and its strengths and constraints.

11.6.2 Probable directions for the sequence-based language switching paradigm

Apart from research into how predictable and endogenous responses impact language control, there are a multitude of other potential applications for the SBLS paradigm. One of these applications would be the further investigation of working memory load on language switching. Whereas working memory could also be examined with other language switching paradigms, certain working memory aspects are already inherently present in the SBLS paradigm due to its memory-based nature. Working memory could for example be investigated in the SBLS paradigm by manipulating the amount of concepts in a sequence. This line of research could prove fruitful since the importance of working memory has been shown in a multitude of areas, such as bilingual sentence production (e.g., Declerck & Kormos, 2012) and both task switching (e.g., Liefooghe et al., 2008; for a discussion, see Vandierendonck et al., 2010) and language switching (see Experiments 3 and 6).

Another research topic would revolve around syntactic information. One strain of this research could encompass the influence of different word types in language switching. While picture-based language switching paradigms can solely investigate certain nouns and verbs, the SBLS paradigms could also investigate other word types, due to the memorized concept sequence. This would be of interest since it has been found that code-switching occurs more
often with certain word types (e.g., Prince & Pintzuk, 1984) and would provide further insight into the influence of syntactic information on language control.

Related to this line of research is the investigation of sentence-based research. Some language switching studies have investigated the influence of sentences, such as Declerck and Philipp (2013a), who used the SBLS paradigm to investigate whether a sentence sequence would affect switch costs differently than a non-sentence sequence. However, whereas some studies have looked into the influence of sentences, much more could be done in this interesting area. Furthermore, research of sentence-based language switching would not just be interesting on a theoretical level but also on an ecological level, since code-switching generally occurs in sentences or between sentences.

11.6.3 Open issues

While the current study addresses a number of important issues, some issues are still unresolved. Three important topics are discussed in this section, which future research should address.

One open question revolves around language preparation in language switching. Costa and Santesteban (2004) found a decrease of performance costs with longer language preparation time. However, this effect was not found in all studies that manipulated language preparation (Macnamara et al., 1968; Philipp et al., 2007a). Philipp et al. (2007a) even found that switch costs were increased due to a longer time to prepare the language, which is the opposite of what Costa and Santesteban (2004) found. Furthermore, the current study did not show an effect of language predictability on switch costs, without any knowledge of the concept, whereas Macnamara et al. (1968) did find such an effect on mixing costs. Finally, Verhoef et al. (2009) also found an effect of language preparation time on asymmetrical switch costs, which could not be replicated in the current study or that of Philipp et al. (2007a). Hence, the question remains when language preparation influences language
switching? In this study, and thus also in the modified ICM, it has been postulated that passive decay might play an important role. Yet, this remains to be examined.

Another important question revolves around the syntactic and phonological influences on language switching (Christoffels et al., 2007; Declerck et al., 2012; Declerck & Philipp, 2013a, 2013b; Filippi et al., in press). To what extent do these processes merely influence the lemma activation or are they possibly loci of language control as well? These important theoretical questions could help us understand language control on a different level, by recognizing that language control occurs within the scope of the entire bilingual language process, instead of in the isolation of the lexical-semantic level.

Finally, future research should also consider the differences between prominent markers of language control. The current study indicates that two markers of language control, namely switch costs and mixing costs, measure different aspects of language control. Hence, a deeper understanding of which aspects of language control these markers examine would be highly valuable to interpret data with different markers.
12 Conclusion

Exploring a new sequence-based language switching paradigm, a distinction of predictability effects was made at the language level and at the concept level, which jointly determine the overt vocal response. The results showed that a predictable response (i.e., the combination of language and concept) can reduce switch costs, whereas solely the language or concept being predicable has, at best, a minimal impact on switch costs. This lead to the conclusion that both language and concept are needed to resolve language interference.

Yet, whereas response preparation can reduce switch costs, switch costs cannot be abolished by preparation, which demonstrates that language switch costs are a very robust measure. The difficulty to fully prepare the upcoming response further indicates that language control is a pervasive process, which exerts its influence continuously throughout bilingual speech production.
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## Appendix

Appendix A.

Responses used in Experiments 1 and 2.

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<thead>
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<th>Languages</th>
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<td>sieben</td>
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Appendix B.

Responses used in Experiment 3.

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<th>Languages</th>
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<td>Friday</td>
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<td>zwei</td>
<td>two</td>
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Appendix C.

Responses used in Experiment 4.

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Appendix D.

Responses used in Experiments 5, 6 and 8.

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