| RESEARCH ARTICLE

A Review on Language Control of Bilingual Speech Production in Language Switching

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| ABSTRACT

As bilinguals have increased in number these years, bilingual speech production (BSP) has become a hot topic in psycholinguistic research. The exploration of BSP can not only reveal the psychological mechanism of language processing but also help to understand the general mechanism of information selection in the human cognitive process. Language-switching has currently emerged as one of the primary research paradigms for studying multilingual speech production. Therefore, this paper summarizes several experimental designs of the language-switching paradigm, analyzes observations found in the experiments, summarizes the four theoretical models proposed in the previous literature, and finally puts forward possible future orientations on the basis of current research.

1. Introduction

In daily life, bilinguals refer to individuals who can master two languages. With the continuous development of internationalization, "bilingualism" has become a common phenomenon in modern society, and speech production has also been widely concerned by researchers, which has become a new hot spot in psycholinguistics research. The mechanism of processing, storage, extraction, and conversion of bilingual information in bilinguals' brains has become the focus of behavioral research and cognitive neuroscience research. However, due to the complexity of the human brain, the mechanism of bilingual processing is still unclear. Bilinguals can successfully separate the two languages in the process of language processing and effectively select and extract target words from the mental lexicon. In particular, some bilinguals with high proficiency in the second language, although they may have traces of their L1 when expressing in the second language L2, seldom find that they will be interfered with by the L1 vocabulary. Therefore, the ability of bilinguals to eliminate interference has aroused the research interest of many psycholinguists and has become the focus of cognitive psychology and psycholinguistics in recent years.

The core issue of bilingual speech production is language control (e.g., Declerck et al., 2015), which is not only the symbolic feature of bilingual production but also the concrete embodiment of human general cognitive control in language use. As an important cognitive function of the brain, the inhibition mechanism also serves as an essential regulating mechanism in many facets of speech production, ensuring that human beings can use limited brain resources to process unlimited information. Currently, one of the primary goals of research into language control systems is the language-switching paradigm. Therefore, the purpose of this essay is to discuss how bilinguals manage their two languages in the language-switching paradigm. The following four sections make up the paper's structure: The first part focused on the language-switching paradigm and introduced four different designs used in previous studies. The second part summarized four kinds of language control models in previous studies. In the third part, experimental findings in the language-switching paradigm were summarized. Finally, a conclusion about bilingual speech production was made, and some ideas for further investigation were also pointed out.

2. Review of language switching paradigm
At present, the language-switching paradigm (e.g., Declerck *et al.*, 2012; Declerck *et al.*, 2017; Zheng *et al.*, 2018; Zheng *et al.*, 2020), picture-word interference task (e.g., Hermans *et al.*, 1998; Costa *et al.*, 2000; Boukadi *et al.* 2016; Klaus & Lemhöfer, 2018) and read aloud task (e.g., Gollan *et al.*, 2014; Gollan *et al.*, 2014; Li & Gollan, 2018; Schotter *et al.*, 2019) are mainly used in the behavioral study of bilingual language production. In this section, an explanatory introduction and comment will be made to illustrate the language-switching paradigm.

Over time, various diverse language-switching paradigms that differ in how they implement particular concepts or languages have been established. To examine language control in language switching, paradigms can be utilized, each with its own advantages and disadvantages. All of the paradigms share the premise that they enable researchers to investigate how language control functions and which processes are essential for language switching.

2.1 Cued language switching
The paradigm used most frequently in language switching is cued language-switching. This paradigm's defining element is the use of visual numbers or visuals to represent topics that participants must name. Given that the paradigm uses many languages, visual language cues are used to indicate which language concepts must be produced. Since two languages are used inside a block, bilinguals either repeat the same language from the previous trial (repeat trial) or switch to a different language (switch trial).

The cued language-switching paradigm can benefit from extensive research on language switching in language production tasks, including both theoretical and empirical studies. Therefore, we are well-versed in the impacts and mechanisms. Another advantage of the cued language switching paradigm is the modification of many time-based intervals, such as the cue-to-stimulus interval, which is supposed to measure active language preparation, and the response-to-cue interval, which is thought to indicate passive decay (e.g., Kiesel *et al.*, 2010). Controlling these time-based intervals is more challenging when using the other language-switching paradigms.

2.2 Alternating language switching
In the alternating language-switching paradigm, bilinguals must typically switch languages after every second trial. For instance, Jackson *et al.* (2001) reported switch costs when fluent English speakers identified numbers in either L1 or L2. Every second trial's language was different, and there was an additional visual cue.

The alternate language switching paradigm permits language preplanning since the bilingual knows when to switch to another language, which is similar to preplanning during spontaneous language production. He or she might be prepared for the following language as a result of employing the predictable order.

2.3 Voluntary language switching
Under this paradigm, bilinguals have the freedom to decide when to switch. Gollan and Ferreira (2009) particularly requested that bilinguals in English and Spanish name the photographs in either language they choose. The findings demonstrated that switch costs might be seen when bilinguals were given the freedom to produce in any language they wanted. However, no switch costs were found when bilinguals were specifically instructed to use both languages in 50% of the trials. Additionally, there was a tendency toward a switch benefit in this situation.

Due to its reliance on internal language cues rather than exogenous language signals, which also allows for language preplanning, the voluntary language-switching paradigm is even more similar to natural language switching. Moreover, such as the frequency and timing of language switches made by bilinguals are also possible with the paradigm of voluntary language switching. By taking these additional metrics, we may be able to comprehend the language control mechanism during language changeover better.

3. Review of language control models
A significant corpus of evidence suggests that the lexical representations of the two languages used by bilinguals are kept separately in memory; they share the same semantic representation system. Hermans *et al.* (1998) demonstrated that bilinguals' semantic and lexical systems interact rather than function separately. In other words, bilinguals can continue encoding the activated words of the two languages since both languages' lexical systems are active at the same time when they produce speech. So how do bilinguals ultimately decide which language to use in the situation? Bilinguals have a specific cognitive mechanism to govern the two languages in time, which is closely related to inhibition and control. There are four models that can be used to summarize earlier research on this mechanism: The Inhibition Control model, the Language-specific model, the Concept Selection model, and the Specific Language Selection Threshold model.

3.1 The Inhibitory Control model

The Inhibitory Control model (ICM for short) is proposed by Green (1998). It is about the three-level control mechanism used throughout the entire process, from verifying the target to encoding and processing bilingual vocabulary's semantic system in particular activities. The Supervisory Attentional System, which oversees the entire speech production process, Language Task Schema, which oversees the control of the unrelated task schema; and Inhibition, which primarily deals with the inhibition of the unrelated lexical representation, are listed from top to bottom. According to the model, when producing bilingual speech, both L1 and L2 words that are semantically relevant are simultaneously active. To identify the language, these words have tags. In order to ensure that the target word is processed, the Language Task schema will suppress the extraneous candidates in accordance with the present task. In this strategy, the words chosen are determined by the triggered words rather than the bilingual language. It is also known as the Language Non-Specific model for this reason.

Switch costs are usually explained by the ICM with the concept of persistent inhibition. The non-target language will be suppressed when, on a trial (try n-1), a particular language must be produced. Therefore, the inhibition applied on trial n-1 will persist until trial n, and it must be removed when the previously inhibited language is required for production on the subsequent trial (trial n; i.e., switch trial). This is not the case for trials n-1 and n when generating in the same language (i.e., repetition trial). Because switching needs to get over chronic inhibition, switching should be more challenging than repeating the same language.

3.2 The language Specific Selection model

The Language Specific Selection model is proposed by Costa et al. (1999), which takes into account the simultaneous activation of comparable terms in both languages but excludes non-target phrases from the process of choosing target words. When the semantic system activates words in both languages, the language control mechanisms only consider the active words in the target language and leave the activated words in the non-target language out of the candidate set. Since this lexical selection mechanism is language-specific, bilinguals ignore the activation of non-target language.

According to this model, despite the semantically relevant words of the non-target language being activated to a certain extent, they have no effect on how easily the target words can be accessed; hence there is no need to inhibit them. This model can more adequately account for the experimental findings of the "picture-word interference paradigm," which contradicts the IC model. A well-known finding of this experiment is that when the distractor is the target name of the picture, the response time of the speaker is significantly shortened. That is to say, when the concept activates both the target word and the translation word at the same time, it promotes the processing of the target word instead of bringing great interference, and this facilitation phenomenon is termed as translation facilitation effect or cross-language/between-language identity facilitation effect.

3.3 The Conceptual Selection model

The Conceptual Selection model, which is "complex access, easy selection," was proposed by La Heij (2005) after summarizing the previous two models as "easy access, complex selection." The fundamental idea of the concept is that no additional mechanism is required and that language control in the selection of bilingual productive terms is simple to obtain. Based on the differences in the activation degree, the words with the highest activation can be selected. Due to the fact that the upfront information already has the required information to separate the candidate words, the selection is made so that bilinguals may govern their language and choose terms with ease. Specifically, foreword information includes not only the conceptual information, register features and pragmatic information that the speaker intends to express but also the provisions of the target language. The differences in foreword information in these aspects directly affect the activation of candidate words. The unique feature of the Conceptual Selection model is that it emphasizes the important role of target language stipulation as a clue of vocabulary access in vocabulary selection.

3.4 The Language-Specific Selection Threshold model

The Language-Specific Selection Threshold model is a comprehensive model, which is a compromise between the IC model and Language-Specific Selection Model. Costa and Santesteban (2004) believe that proficient bilinguals will use a completely different language control mechanism from unbalanced bilinguals; that is, bilinguals' proficiency in two languages is closed related to the processing of the non-target language, showing different control mechanisms in different learning stages. Then they further pointed out that in the initial stage of second language learning, bilinguals tend to have an inhibition mechanism in speech production, while when the second language reaches a high level, that is, when the proficient bilinguals reach the threshold of specific language selection, they are more focused on the information processing of a language, that is, specific language selection. At this time, although both languages are activated, word selection will only be carried out in the target language, and non-target language will not be considered. Therefore, non-target language will not interfere with the selection of the target word, and no inhibition mechanism is needed. In other words, when the proficiency level reaches a certain point, the high-level bilinguals are likely to no longer suppress the other language. Therefore, primary L2 learners need to consciously focus their attention on L2

target information in L2 production. When the level of L2 information activation is relatively low, they need to strongly inhibit the influence of L1, while at the advanced stage, when the familiarity of the L2 is close to that of the L1, the selection and inhibition will become an automatic process, without consuming too much control resources.

4. Findings
4.1 Switch cost
As noted above, the language-switching paradigm is usually conducted with a mix of repeat trials and switch trials. The slower performance in switch trials compared to performance in repetition trials has been observed in a large number of studies (e.g., Costa & Santesteban, 2004; Christoffels *et al.*, 2007; Philipp et al., 2007; Verhoef et al., 2009) and this slower performance has been referred to as "switch cost".

4.2 Asymmetry switch costs
When switching into L1 versus L2, there are higher switch costs, which are referred to as asymmetry switch costs (e.g., Meuter & Allport, 1999; Costa et al., 2006; Gollan et al., 2014). Given that we tend to be more familiar with L1, we may expect that switching to L1 is easier and faster, but the results seem to be paradoxical. The Inhibitory Control model (Green, 1998), which posits reactive, lasting inhibition occurs during language control, is the most often used theory to explain this phenomenon. The cost of the asymmetry switch is frequently used as an indicator of inhibition.

4.3 Reversed dominant effect
An additional reflection of the asymmetry brought on by unequal inhibition or augmentation is the so-called "reversed dominance effect". Bilingual speakers typically take longer in their dominant language than in their non-dominant language while participating in language-switching experiments (e.g., Costa & Santesteban, 2004; Christoffels *et al.*, 2007; Verhoef *et al.*, 2009). Additionally, speakers more frequently switch out words from the dominant language for those from the non-dominant language than the other way around (e.g., Gollan *et al.*, 2014; Gollan & Goldrick, 2016).

5. Conclusions
The research on the mechanism of inhibition in bilingual speech production has begun to take shape. Different views and evidence are emerging, and the differences mainly focus on "does inhibition work in the process of bilingual speech production?" Yet, there are still some questions that need to be answered. To better understand how activation and other potential mechanisms may affect language control, more research is required. The following part of this paper puts forward several directions for future research.

5.1 Experimental paradigm
We have mentioned four models above. These models can be further classed under such three headings as the Group of Inhibitory Control, the Group of Non-inhibitory Control and the Group of Compromise, which are mainly supported by two paradigms, language switching paradigm and picture-word interference task. The two paradigms contain very different psychological processing mechanisms, which are not comparable. The separation of the research paradigm is not conducive to further comparison and evaluation, thus making the exploration of bilinguals even more difficult. Therefore, in terms of research methods, scholars need to find a new paradigm that can test the two opposing views at the same time.

5.2 Context
None of the three groups gives due consideration to the context of language production. Green (1998) theoretically explains the importance of context and points out that it is unscientific to explore bilingual language production without considering the influence of context. Besides L2 proficiency, context is the most important factor in bilingual research. It not only affects the parallel activation of two languages but also further affects language control through the influence of the activation. Only by clarifying the similarities and differences between language control and inhibition in different production contexts can people further grasp the inhibition control in bilingual speech production. Fortunately, scholars have paid more attention to the context of language production. For example, many academics have undertaken studies using the language model theory (e.g., Grosjean, 1982; Grosjean, 2010), which postulates that the competence levels of all the speakers in a context can influence the levels of language activation in bilinguals' memories (e.g. Duyck *et al.*, 2008; Blanco-Elorrieta and Pylkkanen, 2015). Alsaigh and Kennison (2017) look into the potential that the setting in which bilinguals use their L1 could affect the level of L2 interference they encounter. The impact of the production environment on the inhibitory control of bilingual speech production can thus be further explored through research.

5.3 The limitation of language

The existing studies mainly involve alphabetic writing, such as in Indo-European languages, while there are few studies on ideographic writings. Therefore, future research should cover as many types of language as possible, especially bilingual language which are far away from each other in typology and has great differences in language characteristics.

5.4 Naming latency and language selection error

Speaking more frequently in the L2 instead of the L1 results in more language selection mistakes in the L1, which is another component of the reverse dominating effect. However, today's research tends to place more emphasis on name latencies and less emphasis on language selection errors. A possible reason is that bilingual participants hardly make any errors in experiments. Several studies applied time pressure to elicit higher error rates for statistical analysis (e.g. Zheng & Roelofs, 2018; Zheng & Roelofs, 2020), which offered a feasible solution for further study. Therefore, we can pay more attention to errors and try to conduct more empirical studies to enrich the reverse dominant effect.

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