

Processes and Mechanisms of Bilingual Control: Insights from Monolingual Task Performance Extended to Simultaneous Interpretation

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Abstract

A topical question in the study of bilingualism from a psycholinguistic perspective is how bilinguals manage to produce relatively pure monolingual language output when the communicative setting requires them to do so. Models that account for this behaviour assume subtle control processes that differentially activate and/or inhibit each of the two underlying language sub-systems and that inhibit — prior to articulation — output of the non-target language sub-system that might otherwise seep through. The control operations in simultaneous interpreting are likely to be even more complex due to the fact that this form of language behaviour demands that both of the interpreter's language sub-systems are activated, but possibly to a different extent. In this paper we will discuss a number of views on bilingual language control in “monolingual” tasks and, especially, in simultaneous interpreting, which presumably is the cognitively most demanding “bilingual” task. A monolingual task (as we define it) is one where, in theory, the (bilingual) participants only have to address one of their language sub-systems and where, ideally, pure output is produced. A bilingual task is one where task performance requires that both language sub-systems are implicated. A number of studies suggest that the control exerted by bilinguals in monolingual and bilingual language tasks is effectuated by a more general cognitive system that takes care of the control of action in

general. An attempt will be made to relate simultaneous interpreting to this more general theory of control.

1. Introduction

After decades of relative neglect, the question of how bilinguals control their two languages such that most of the time the output emerging from the system is in the “target” language — the language the bilingual “intended” to speak and that is appropriate given the specifics of the communicative setting — now features prominently on the research agenda of many researchers of bilingualism. Intrusions of the non-target language (“language switches”) *do* occur, but their incidence is typically low, especially in the speech of relatively fluent bilinguals (Poulish 1999) and in settings where code switching would hinder the conversation flow, such as when a bilingual speaker shares only one language with a monolingual interlocutor (Grosjean 1997a). How does the bilingual manage such relatively language-pure output? An answer to this question is of special interest to translators and interpreters, for whom it is a professional requirement that elements from the source language input intrude in the target language output as infrequently as possible. This paper provides insights gained from psycholinguistic research on the processes and mechanisms that prevent these unwanted language switches from occurring more frequently than they do.

1.1 Co-activation of the non-target language

The low incidence of language switches is especially surprising given the fact that a steadily increasing number of bilingual studies suggest that, both during the various stages of processing a language input (in comprehension) and during the various stages from a conceptual message to be verbalized to the actual language output (in production), not only elements belonging to the target language are activated in bilingual memory but also elements of the non-target language.¹ Pertinent evidence that points at activation of the non-target language in bilingual language *comprehension* comes from at least three types of bilingual studies: “interlexical neighbourhood” studies, “phonological activation” studies, and “interlexical homograph” studies (see De Groot, Delmaar, and Lupker 2000 for details). The interlexical neighbourhood studies have shown

that when bilinguals encounter a word in one of their two languages, not only (the mental representations of) words with similar forms (“neighbours”) in this language are initially co-activated with the target word’s representation, but also those with similar forms in their other language (e.g., Van Heuven, Dijkstra, and Grainger 1998). To illustrate, when the English word “hand” is presented to a Dutch-English bilingual, it gives rise to, among others, activation in the mental representations of English “hand”, “hang”, “hank”, and “hind”, but also in the representations of the Dutch words “hand” (meaning hand, as in English), “hond” (meaning dog), “pand” (meaning building), “land” (meaning land, as in English), and “mand” (meaning basket). The phonological activation studies have demonstrated that automatic phonological coding of an encountered word occurs in both of a bilingual’s languages simultaneously. In other words, the visual presentation of a word (written in an alphabetic script) activates the sets of grapheme-to-phoneme correspondence rules of both languages and both sets of rules are simultaneously applied to the word so that its phonological form in both languages is generated (e.g., Brysbaert, Van Dyck, and Van de Poel 1999). Finally, the interlexical homograph studies have shown that if a presented sequence of letters happens to be a word in both of a bilingual’s two languages, but with different meanings, the corresponding representations in both languages are initially activated (e.g., Dijkstra, Van Jaarsveld, and Ten Brinke 1998). This holds, for instance, when a French-English bilingual encounters the word “coin” in print (“coin” means corner in French).

Kroll, Bobb, and Wodniecka (2006) looked for evidence of non-target language activation in bilingual language *production*. From their review of the literature they concluded that such activation may occur in all stages of the language-production process beyond the initiation of the process at the conceptual level: the lemma level (e.g., Hermans, Bongaerts, De Bot, and Schreuder 1998), the phonological level (e.g., Kroll, Dijkstra, Janssen, and Schriefers 2000), and the articulation level (e.g., Jacobs, Gerfen and Kroll 2005), and that the absence of cross-language activation at any of the language-production levels is more the exception than the rule. Furthermore, they concluded that the participants’ proficiency in the second language (L2), the relative dominance of L1 and L2, the exact demands of the production task, and the degree of overall activation of L1 and L2, are all factors that determine how deep into the production process activation from the other language permeates.

1.2 Activation and selection

How then, if non-target language activation is ubiquitous in target-language comprehension and production, is an element of the target language ultimately selected (and output by the system) correctly most of the time? Posing this question is particularly imperative because in the study of cognition, including the study of bilingual cognitive processing, activation and selection are closely related concepts: In language comprehension, an input word will be recognised (selected) as the word corresponding to the representation that is ultimately the most highly activated. For instance, if the word *shower* is encountered in speech and the memory representation of the word *flower* ultimately reaches a higher level of activation than the memory representations of all other words, including the representation of *shower*, the input word will be recognised as the word *flower* rather than *shower*. Similarly in production, the word corresponding to the most highly activated memory representation (“lemma”) will be output by the system. This will occasionally produce a speech error, an error that in bilinguals may cross the language boundary, thus producing a language switch (but see Costa, Miozzo and Caramazza 1999, for a different view).

In the next section we present a number of views on how target language selection is effectuated in “monolingual” tasks, that is, tasks that, *in theory*, only require the involvement of one of the bilingual’s two language systems. Examples of such tasks are picture naming in L1 or in L2. Among the definition of a monolingual task we include Stroop-like tasks, where to-be-ignored distractors in either the target or the non-target language appear simultaneously or in close temporal proximity with the actual stimulus that requires responding to in one particular language. Similarly, language-switching tasks, where participants have to switch between their two languages over a series of trials, will be included, because *on every individual trial* a response in either L1 or in L2 is asked for. We will focus on control processes and ensuing selection in language *production*, but occasionally we will refer to comprehension studies as well. Most of the evidence for activation of the non-target language in language production dealt with versions of monolingual tasks as defined here. Rather than detailing the specifics of the pertinent studies we will focus on the central ideas that motivated these studies. We will start the section with a discussion of how language membership is represented in bilingual memory.

The third section deals with control in simultaneous interpretation, building on and extending the views on control in monolingual tasks. Unlike in monolingual tasks, in simultaneous interpretation it is not a theoretical option that only one of the language systems is implicated. In this sense it is a *bilingual* task *pur sang*. If both languages *must* be involved (and, thus, activated) at any moment in time, it may be even more surprising that, again, intrusions from the non-target language (the “source” language) are not more frequent than they are in actual interpreting output. Finally, the fourth section explains more explicitly about the control mechanisms involved.

The present paper is a follow-up on De Groot and Christoffels (2006). It attempts to sharpen some of the topics raised there and puts different accents on them. Topics explicitly raised there but not dealt with here (or only implicitly so) are the contrast between global and local control and between proactive and reactive inhibition of memory representations that compete with the element that is ultimately selected. Furthermore, an issue discussed by De Groot and Christoffels (2006) that will not be addressed here is how various types of bilingual aphasia can be accounted for in terms of control failure. An important focus of the present contribution is on the nature of the control mechanisms involved.

2. Control in Monolingual Tasks

If in speech production (as implemented experimentally in, for instance, picture naming or in word naming following the definition of the word’s meaning) the word corresponding to the most highly activated lexical element is ultimately selected and output by the system, how then can it be promoted that the *targeted* word, that is, the word that expresses the conceptualised content most faithfully *and* that is also a word in the intended language, is the word that is ultimately the most highly activated lexical element? What mechanisms and processes will see to it that the required differential activation of the targeted word representation and the representation of its translation equivalent may settle in the system?

2.1 A prerequisite for control: The representation of language membership

A prerequisite for the required differential activation of target-language words and non-target language words is that information about language

membership of individual lexical items is built in the system. The system must somehow specify which of the stored lexical elements belong to L1 and which ones belong to L2. One proposal (Dijkstra and Van Heuven 1998, 2002) is the existence of two “language nodes” in the underlying representational system, one for each language. The representations of all L1 words are connected to the L1 language node and the representations of all L2 words are connected to the L2 language node. Language membership is determined by these connections between the words’ representations on the one hand (the “word-nodes”) and the language-node representations on the other hand. A second proposal (De Bot 2000, Green 1998, La Heij 2005, Poulisie 1997, Poulisie and Bongaerts 1994) is that lexical representations or “lemmas”, as they are often called, each contain a “language tag”, a piece of information that specifies that a particular lemma belongs to L1 or L2. A third proposal is that the bilingual’s two vocabularies are represented in two separate memory networks of strongly associated elements, one for each language (De Bot 2000; Grosjean 1997a, 1997b; Paradis 1994). According to this account (the “subset” hypothesis), language membership of each word is determined by the position of the word’s representation in one of these networks.

2.2 Language nodes and control

The various ideas about how language control is exerted incorporate one or more of the above views on language membership. For instance, Dijkstra and Van Heuven (1998), presenting a model (the “Bilingual Interactive Activation”, BIA, model) that focuses on language *comprehension*, assumed that language nodes operate as a language filter (but not as an all-or-none language switch) that modulates activity in the word representations. The language nodes collect — through excitatory connections from the word representations to the corresponding language nodes — activation from all words from the corresponding lexicon. In addition, the activation of the language nodes is influenced by information external to the word-representation system, for instance, by non-linguistic contextual information. An activated language node, say the L1 node, suppresses the activation of the words in the other lexicon, in this case L2, through inhibitory connections from this L1 language node to the L2 word representations. As a result, the L2 word representations will subsequently be less activated generally than the L1 word representations and the presented stimulus will be recognised as an L1 word.

Dijkstra and Van Heuven (2002) presented a successor of the BIA model, BIA+, in which the language nodes no longer function as language filters that respond to experimental manipulations and to non-linguistic contextual information. Furthermore, in BIA+ the inhibitory connections from the language nodes to the word representations of the other language have been removed. The only remaining function of the language nodes is that of a language tag, but just one for all of the language's words instead of one attached to each single word representation. To account for the effects of non-linguistic contextual information and subject strategies, the original BIA word-identification system (but in adapted form) is augmented with a "task/decision" system. Dijkstra and Van Heuven adopted this latter component of the BIA+ model from Green (1986, 1998), who's views on bilingual control, expressed most explicitly in his "Inhibitory Control Model" (1998), will be discussed in the last section of this paper.

2.3 Language tags, a language cue and control

When language membership is implemented not by two language nodes but by means of a language tag for every individual word representation (or lemma) in the bilingual's lexicon, the language of output can be controlled through the differential activation of the lemmas in the bilingual's two languages enabled by these tags. La Heij (2005) presented a parsimonious view on how exactly this differential activation may come about, building on earlier work by Poulisse (1997) and Poulisse and Bongaerts (1994). Imagine that a Dutch-English bilingual speaker intends to express the concept for "boy" in English. Among the conceptual information in the "preverbal message" (Levelt 1989), La Heij assumes a "language cue", a piece of information that specifies the language the bilingual speaker intends to use (see also De Bot and Schreuder 1993). In the present case, the language cue *+English* is part of the conceptual information in the preverbal message. Lemmas are activated proportionally to the amount of information they share with the information in the preverbal message. Because of the language cue *+English* in the preverbal message, the lemma for "boy" (containing the language tag *+English*) will (other things being equal) be more highly activated than the lemma for "jongen", the Dutch translation of "boy" (containing the language tag *+Dutch* or *-English*). Consequently, the word "boy" rather than "jongen" will be output.

2.4 Language subsets and control

Finally, in a subset framework, where language membership is specified by the language network a word representation is embedded in, language control can be exerted by activating or inhibiting/deactivating a complete language subset independently of the other. Paradis (e.g., 1986, 1994, 2004) assumes that when a bilingual intends to speak in one of his two languages, the activation threshold of the non-target language subset is raised somehow. This raised state of the activation threshold then prevents interference from that language during production. According to Grosjean (1997a), the non-target language is never completely deactivated. He furthermore assumes that the relative degree of activation of the target- and the non-target languages depends on the specifics of the communicative setting such as the characteristics of the person spoken to, the topic of conversation, and the goal of the interaction. In Grosjean's terminology, depending on the prevailing communicative circumstances, a bilingual "chooses" a position on a "language mode continuum", shifting between a "monolingual mode" and a "bilingual mode". At the monolingual end of the continuum the target language (also called the "base" language or the "selected" language) is maximally activated and the non-target ("guest") language is deactivated as much as possible. Under these circumstances, few switches into the non-target language occur. At the bilingual end of the continuum target- and non-target languages are activated about equally and, consequently, relatively many switches occur.

Support for the view that a bilingual is indeed equipped with the means to activate and/or inhibit a whole language subset independently of the other comes from the language-switching task, where participants have to switch between languages within a series of trials, predictably or randomly (e.g., the picture-naming experiments of Costa and Santesteban 2004, and the number-naming experiment of Meuter and Allport 1999). Response times are longer on switch trials, where the response language of previous and current trial differs, than on non-switch trials, where previous and current trial require a response in the same language. The slowing-down effect on switch trials is particularly large when the participants have to switch from their weaker into their stronger language, a finding that may seem paradoxical at first sight. These results suggest that language production requires suppression of the non-target language system and that the stronger the non-target language, the more it has to be suppressed in order not to interfere with production of the target language. The more

suppressed the language, the larger the effort to reactivate it again on the next trial where the previously suppressed language becomes the target language (hence the above apparently paradoxical effect). Meuter and Allport argued that the suppression mechanism operating in the language-switching task is a general control mechanism that is operative in other tasks as well and that the asymmetrical switch cost occurs with all pairs of tasks where the one task (e.g., word reading; L1 word naming) is more dominant (because more practised) than a second task (e.g., colour naming; L2 word naming). We will become more explicit further on about the nature of the control mechanism involved.

The above discussion suggests that individual researchers adhere to one of the above views on the relation between, on the one hand, the specific implementation of language membership in the bilingual mind and, on the other hand, the way bilinguals exert control over their two languages, with the exclusion of the other views. Contrary to this suggestion, Green (1998) — and presumably others as well, but less explicitly so — presented a model of bilingual control, the Inhibitory Control Model mentioned earlier, that incorporates both language tags and the subset organisation of the bilingual system. As Meuter and Allport (1999) have assumed, the control mechanism at work is not specific to language processing but also operates in other situations that require the control of action. Some of the evidence for this position will be presented further on. But first we will present a number of views on how the control processes operative in monolingual tasks can be extended and accommodated so that they can account for control in simultaneous interpretation as well.

3. Control in Simultaneous Interpretation

3.1 Language subsets and control

The views on control in simultaneous interpretation are built on those presented above for monolingual tasks, i.e., assigning language subsets, language cues and language tags as central roles that have been chosen. For example, Paradis (1994) chooses a solution in terms of differential thresholds for the language subsets. Setting the threshold of one subset at a low level (which is functionally equivalent to activating the elements in that subset highly; cf. note 1) and setting the threshold of the other subset at a high level (functionally equivalent to deactivating (or inhibiting) the

elements in the subset) will not work, because in simultaneous interpretation source language comprehension and target language production take place simultaneously at least most of the time (Chernov 1994). Therefore, both the (elements in the) source-language system and the target-language system must be activated, and sufficiently so to enable both acceptable comprehension and acceptable production.

Equal activation (or threshold settings) of the source- and the target-language subsets would involve the risk of mixed output (unless a strict monitor would filter words from the source-language system prior to accidentally being output). Therefore, Paradis (1994) proposed a model of control where in simultaneous interpretation the threshold of the source language is set higher than the threshold of the target language, but not so high as to impede comprehension. Consequently, the output will be a series of words in the target language, maybe with an occasional code switch. Of course, to guarantee that at any moment in time the output is not just *any* word in the target language but the actually intended word — the word that expresses the current conceptual content — the system with the activation levels of source and target language thus set will have to be augmented with decoding and encoding processes. Decoding and encoding combined constitute one of the two translation strategies distinguished by Paradis (1994), namely “vertical” or “conceptually mediated” translation. This strategy involves the processing of the source-language input from the speech input “upward”, through the various levels of linguistic analyses (such as word recognition and syntactic analysis), until a deverbilised conceptual representation of the input has been formed. Subsequently, this conceptual representation is output in the target language as the result of a “downward” process, which passes through the various intermediate levels in the reverse order. (The second strategy, “horizontal” translation or “transcoding”, involves the direct replacement of source-language linguistic structures of various types [words, phrases, clauses etc.] by the corresponding structures in the target language.) The reader is referred to De Groot and Christoffels (2006) for a more detailed account of these two strategies (see also Paradis, Goldblum and Abidi 1982, De Groot 1997, Macizo and Bajo 2004).

3.2 Which language should serve as the target language?

According to Paradis (1994), this set-up with differential thresholds of the elements in the source- and target-language systems will generally not

involve the risk of sub-optimal comprehension, because under most circumstances language comprehension is easier than language production (see also Snodgrass, 1993), allowing a higher threshold for the source language. This difference between the demands posed by comprehension and production is the reason why many interpreters prefer to have their weaker language as the source (comprehension) language and their stronger language as the target (production) language. By assigning the stronger language to the production part of the task, the relative difficulty of the production process is at least partly compensated for. Recent brain imaging studies (Rinne et al. 2000, Tommola et al. 2000/2001) provided support for the experience of interpreters that simultaneous interpretation is harder from the stronger to the weaker language than vice versa. Employing the Positron Emission Technique (PET) these researchers observed more extensive brain activation when professional interpreters translated from their native and stronger language (Finnish) into their non-native and weaker language (English) than when translating from English L2 into Finnish L1. The fact that translating into the weaker language recruited more neural resources suggests that, indeed, this is the cognitively more demanding of the two interpreting conditions. However, the apparent higher load with English as the target language may, in theory, also be due to specific problems (regarding, e.g., syntax, vocabulary, or pragmatics) associated with English. Therefore, to be able to unequivocally attribute the observed directionality effect to a dominance difference between the two languages, the effect (relatively extensive brain activation with the weaker language as the target language) should also emerge in interpreters who have English as their stronger language and Finnish as their weaker language. To our knowledge, such an experiment has yet to be performed.

Interestingly, Tommola et al. (2000/2001) observed that the more demanding condition (translating into English, the weaker language) produced a higher propositional accuracy than the less demanding condition. Barik (1975), who tested interpreters at low proficiency levels, obtained a similar result. Tommola and colleagues explained this counterintuitive finding by pointing at the beneficial effects of good comprehension during interpreting: Good comprehension enables the interpreter to render more of the content “despite the fact that, qualitatively, the surface-level textual links between propositions, the lexical-syntactic formulation of output, and the fluency of delivery may not be at the level as in simultaneous interpreting into the dominant language”

(p. 159). In other words, with good comprehension, the interpreter has an optimal chance of at least rendering the content of the input faithfully in the output, albeit the surface form of the output may contain many flaws. When comprehension is poor, not only flawed output may emerge but also, and more serious, the output's content may deviate dramatically from that of the input. Therefore, under poor comprehension conditions, interpreting from the stronger language into the weaker may sometimes be advisable. Possible causes for poor source-language comprehension may be a relatively weak mastery of the language concerned, a noisy environment, high information density of the input message, and too fast the input rate (see e.g., Christoffels and De Groot 2005, Gerver 1976). This may be why several of the inexperienced interpreters that we have encountered in the past (typically unbalanced bilinguals asked to interpret because no professional interpreter was available) spontaneously reported to prefer their dominant language as the source language.

3.3 Subsets, input and output mechanisms, and control

The error data of Barik (1975) and Tommola et al. (2000/2001) suggest that control through differential threshold raising (differential activation) of the source and target languages involves a risk of occasional poor comprehension and ensuing breakdown. As pointed out above, equal activation levels of the two languages might result in mixed output and is, therefore, no satisfactory alternative. Grosjean (1997b, 2001) proposed another solution. He not only distinguished between source and target languages as two sub-systems (subsets) of a larger language system, but added an input mechanism (also called an "input component") and an output mechanism ("output component") to each of them. According to Grosjean, as the language sub-systems proper, these input and output mechanisms can be activated to different degrees.

Grosjean assumed that in simultaneous interpretation the source- and target-language sub-systems are activated equally (the interpreter is in a "bilingual mode"; see above). In addition, to allow for comprehension of the source language, this language's input component is activated. However, to prevent source-language elements emerging in the output, the output component of the source language is totally deactivated. Finally, both the input and the output component of the target language are activated, albeit possibly to different degrees. The output component of the target language must be activated to enable output in this language.

Activation of the target language's input component would account for the fact that interpreters appear to monitor their own speech (Gerver 1976, Isham 2000), just as speakers in monolingual settings do (Levelt 1989). Monitoring being a special form of language comprehension, not production, the activation level of the target language's input component does not have to be set as high as that of this language's output component (see above). Fabbro and Darò (1995) and Moser-Mercer et al. (2000) obtained experimental data (from so called "delayed-auditory-feedback studies) suggesting that interpreters can indeed control their level of monitoring. In Grosjean's model this would mean that they can set the level of activation of the target language's input component at a level that varies with the prevailing circumstances.

3.4 Sub-dividing the language subsets

A somewhat awkward aspect of Grosjean's (2001) solution is that it remains unspecified what exactly more there is to each of the separate language sub-systems than the combination of an input system for language comprehension and an output system for language production. Consequently, it is as if Grosjean's model incorporates *two* language systems for each language, the pertinent language sub-system and the combined input and output components for that language. To circumvent this problem of doubling, De Groot and Christoffels (2006; see Figure 22.2b in Christoffels and De Groot 2005 for an illustration) took the original notion of language subsets as a starting point and proposed a sub-division of each of the two language subsets in a sub-system specialised for (word) comprehension and one specialised for (word) production. The two sub-systems dedicated to comprehension together constituted an "input lexicon". The two sub-systems dedicated to production together constituted an "output lexicon". We hypothesised that these remaining four sub-systems of the bilingual language system can be independently activated. Because the source language must be comprehended and the target language produced, the source language's input lexicon and the target language's output lexicon must be highly activated. Furthermore, to allow for monitoring of the target language's output, the target language's input lexicon must be activated (but plausibly to a lesser degree than the source language's input lexicon; see above). Finally, to prevent words from the source language emerging in the output, the source language's output lexicon must be deactivated as highly as possible.

Comparing this view with Paradis' account of control in simultaneous interpretation, the only difference thus appears to be the splitting up of Paradis' source and target language systems (subsets) in a part that takes care of comprehension and one that subserves production. This difference is crucial, however, because it does not risk sub-optimal comprehension as a consequence of too low the activation level (or too high the threshold setting) of the source language's system in Paradis' account. In the present, adapted model, the activation of the source language's input lexicon can safely be set high (enabling good comprehension), without any risk of this language's intrusion in the output. The reason is that the elements in this system are specialised for comprehension and will, therefore, not interfere with production.

3.5 Language cues, language tags, and control

Finally, in case interpreting follows the conceptual route that was briefly described above, La Heij's (2005) views on bilingual control in monolingual production tasks can account for control in interpreting as it is. Recall that the conceptual interpreting route produces a deverbalised conceptual representation of the source input en route to the target-language output. Recall also that La Heij's theory assumes a language cue in a preverbal (and, thus, nonverbal) message and lemmas that contain a language tag. The deverbalised conceptual representation that constitutes a component in the interpreting process can plausibly be regarded the equivalent of the preverbal message as hypothesised in La Heij's theory (and the "production leg" of the complete interpreting process is plausibly the same as or similar to language production in monolingual production tasks). It is only the origin of the conceptual representation that differs between the interpreting setting and the monolingual language production task considered by La Heij: In interpreting, the conceptual representation is the end-product of the complete linguistic analysis of the source-language input, whereas in the monolingual production setting it comes "from within", representing the message the speaker intends to put into words.

If in interpreting, as in monolingual language production by bilinguals, the deverbalised conceptual representation specifies, by means of the language cue, the language of the targeted output, a lemma of the target language will generally be the ultimately most highly activated element in the language system. As explained before, this is the result of the fact that the lemmas of the target language (containing the appropriate language

tag) share more information with the content of the conceptual representation. As a consequence of the relatively high level of activation in the lemma of the target language, it is the word associated with this lemma (instead of its translation in the source language) that will be emitted by the system (see De Groot and Christoffels 2006 for more detail). An interesting qualification of this view to consider is that in unbalanced bilinguals the language cue only has to be included among the information elements in the preverbal message when these bilinguals intend to speak in their weaker language. When they intend to speak in their stronger language, the addition of the appropriate language cue to the preverbal message may be redundant because the baseline activation level of the words in this language are generally higher than those of the corresponding words in the weaker language. As a result, the chance that a word from the non-target weaker language is emitted is low. Similarly, if an interpreter's two languages differ considerably in strength, only translation to the weaker language may require a language cue to be added to the content of the conceptual representation.

To summarise, it appears that the views on bilingual control in monolingual tasks as set forth in the previous section can be extended so that they can account for bilingual control in simultaneous interpretation. Yet, up until now hardly anything has been said about the mechanisms of control, and the terminology we used was embarrassingly vague at times. For instance, when presenting Paradis' ideas on control we stated that "when a bilingual intends to speak in one of his two languages, the activation threshold of the non-target language subset is raised *somehow*" (italics now added), and discussing Grosjean's language-mode continuum we used the phrase "depending on the prevailing communicative circumstances, a bilingual 'chooses' a position on a 'language mode continuum'", the quotation marks around *chooses* signaling our awareness of the vagueness of the term. Furthermore, the reader may be left with the unsatisfactory feeling that simultaneous interpretation is too complex a task to be understood in terms of views on control derived from performance on relatively simple tasks such as picture naming in L1 or in L2. In the next section we will present Green's (1998) seminal attempt to identify the mechanisms involved as well as some of the emerging support for his approach. We will then argue that this approach may provide the means to make the connection between, on the one hand, control operations in these simple tasks used in the work on bilingual control and, on the other hand, simultaneous interpretation.

4. Mechanisms of Control

4.1 Language control and the control of action in general

In his Inhibitory Control Model, Green (1998; see Green 1986, 1993 for earlier versions) developed his view that language use is a form of action in general and that, therefore, the control of language and the control of other types of action are likely to have much in common. From Norman and Shallice's (1986) model of action he borrowed the central construct of a Supervisory Attentional System (SAS), a resource-limited control structure that is involved in the planning, regulation and verification of non-routine, voluntary actions and that is assumed to reside in the prefrontal regions of the brain. In Norman and Shallice's model, the SAS is a sub-system of a larger control system, where simple, well-learned actions are carried out automatically by ready-made memory structures that specify action sequences, called "schemas". The SAS supervises the routine running of the schemas and intervenes when necessary (e.g., to prevent action slips). It does so by altering the activation levels of the running schemas, thereby biasing their selection. Unlike Norman and Shallice, Green not only applies the term "schema" to these ready-made structures in long-term memory but also to "mental devices or networks that individuals may construct or adapt on the spot in order to achieve a specific task" (p. 69). In his view, this process of schema construction and adaptation is commanded by the SAS.

According to Green (1998; see there for more details), when the goal is to perform a particular task, the SAS installs the relevant "task schema". This schema then controls behaviour (regulates the output of the system) in two ways: by altering the activation levels of representations within the bilingual lexico-semantic system and by inhibiting output from that system. For instance, when a bilingual is asked to name pictures in L2, the relevant schema is activated and enables task performance by increasing the activation level of L2 lexical items in the lexico-semantic system, decreasing the activation of L1 items in the system, and by inhibiting imminent outputs from the system that correspond to L1 words. When the task is translating L1 words into L2, the SAS installs a schema that specifies L1 as the input language, inhibits the schema for naming the input in L1, and activates a schema for producing L2 as the output.

4.2 Language control and the brain

The view that language control is a special case of the control of action in general and that the same mechanisms are involved, is held by other researchers as well and is supported by both behavioural and brain data. As already pointed out above (see the section on control in monolingual tasks), Meuter and Allport (1999) likened the performance of their bilingual participants in a language-switching task to that of participants in other pairs of tasks (including non-language tasks) where one task is more dominant than the other (e.g., word reading vs. colour naming). Bialystok et al. (2004), comparing bilingual adults with middle-aged and older monolinguals on the “Simon task” (which assesses the participants’ ability to ignore irrelevant spatial information), showed that the bilinguals outperformed the monolinguals. Importantly, the Simon task is not a language task. The finding thus suggested that bilinguals are better in inhibitory control *in general*. Bialystok et al. attributed this to the fact that (early) bilinguals have a life-long experience with inhibiting their one or other language and have thus become experts in inhibitory control. In a further study, Bialystok et al. (2005) searched for neural correlates of this difference between monolinguals and bilinguals, employing the Magneto-Encephalography (MEG) technology (see Tammola et al. 2000/2001, for a brief explanation). In bilinguals, but not in monolinguals, fast responding was associated with relatively large involvement of areas in the left prefrontal cortex (PFC) and the anterior cingulate cortex (ACC). From these findings the authors concluded that the requirement of bilinguals to control their language output has led to systematic changes in frontal cognitive functions.

When trying to gain a better understanding of language control and the processes involved, it is tempting to turn to a set of studies that attempted to determine the exact roles of the two specific brain areas in cognitive control (e.g., Carter et al. 2000, Kerns et al. 2004, MacDonald et al. 2000). These studies are likely to be informative on bilingual language control because the participants in these studies performed the standard Stroop task, where they had to switch between reading words and naming the colour they were printed in. This is the same combination of a weaker and more dominant task that Meuter and Allport (1999) likened to their language-switching task and assumed to be sub-served by the same control system. Earlier studies had pointed at two frontal regions involved in cognitive control, the dorsolateral prefrontal cortex (DLPFC) and the

anterior cingulate cortex (ACC), but the exact division of labour between these two areas could not be deduced from these studies. MacDonald et al. (2000; see also Carter et al. 2000 and Kerns et al. 2004) assumed that the DLPFC is especially involved in representing the task at hand and maintaining control over it and that the ACC is specialised in evaluative, monitoring processes such as error detection and noticing response conflict. This combined set of functions seems very similar to (if not the same as) the functions Norman and Shallice (1986) assigned to the SAS and that Green (1998) applied to bilingual control. Note also that these brain areas are similar to those that Bialystok et al. (2005) showed to be differentially activated in monolinguals and bilinguals performing the Simon task.

MacDonald et al. (2000) tested their views by instructing their participants before each trial whether to read the word to be presented next or to name its colour and by registering the participants' brain activity both during instruction and during responding by means of functional magnetic resonance imaging (fMRI; see Tammola et al. 2000/2001, for an explanation of this technique). Importantly, there was a delay between instruction and response. This way, the task separated instruction-related strategic processes, including those for representing and maintaining the attentional demands of the task to be performed, from response-related processes such as evaluating the response.

Instruction-related brain activity was observed within the DLPFC when the task to be performed next was colour naming, the weaker task, but not when word reading, the stronger task, was anticipated. This finding is consistent with the requirement of attentional top-down control in colour naming, but not in word reading (a routine task that can come about automatically). The ACC did not show any instruction-related activity. Analysing the *response*-related brain activity, the ACC turned out to be more highly activated when the word's name and the colour it was printed in were incongruent (e.g., the word "blue" printed in red) than when they were congruent (the word "blue" printed in blue). This supports the hypothesised conflict-monitoring (evaluating) role of ACC (see also Carter et al. 2000 and Kerns et al. 2004). DLPFC did not show differential activity in the incongruent and congruent conditions. As concluded by the authors, the observed "double dissociation" provides strong support for complementary roles of the two prefrontal systems, DLPFC and ACC, in the attentional control of action. They suggested that the ACC, the monitoring device, signals to the DLPFC when control must be more

strongly engaged, as in the case of conflict (here incongruence between colour and word name).

The existence of such a feedback loop between the ACC and the DLPFC gains additional support from a recent study by Egner and Hirsch (2005). Furthermore, these authors (using a different conflict task: face recognition with incongruent or congruent names superimposed over the faces) obtained data to suggest that the DLPFC resolves the conflict situation signaled by the ACC by boosting the activation level of task-relevant information rather than inhibiting task-irrelevant information. All in all, these brain imaging studies suggest that a biological basis exists for Norman and Shallice's (1986) theoretical construct of a limited-capacity supervisory attentional system involved in the control of action (as well as for the various functions Norman and Shallice assigned to this system), and evidence is beginning to accumulate that such a system plays a crucial role in the more specific case of bilingual control.

5. Conclusion

There is obviously more to control in simultaneous interpretation than merely seeing to it that the output language differs from the input language, which was the focus of most of the above discussion. Skilled simultaneous interpretation requires that attention is dynamically assigned to the different attention-demanding components of the task. Gile (1995, 1997) distinguished four of them: comprehension, production, memory, and coordination. In the present framework, the last component is the most relevant. Its role is to oversee the operations of the other components and to allocate resources to each of them proportionally to the demands it poses at any moment in time, demands that vary with the ever-changing external environment and internal state of the interpreter's mind. These are the types of functions that, in terms of Norman and Shallice's (1986) model, are taken care of by the SAS. The other components of the task — comprehension, production, and memory — are also unlikely to proceed automatically in all stages of processing. For instance, both language comprehension and language production require attention-demanding conceptual processes at some point during processing as well as attention-demanding word retrieval processes the moment that automatic word access fails. They may also require supervision of the operations of the part-components they themselves consist of. Therefore, each of them individually plausibly appeals to the SAS as well. It thus appears that the

SAS and, more generally, the broader study of the control of action it relates to, provides a theoretical framework that carries the promise to get to grips with these other, broader, aspects of control in simultaneous interpretation.

Finally, we anticipate (and hope to avert) the confusion that may arise when the reader attempts to relate the work on cognitive control discussed above to a research line that tries to understand simultaneous-interpreting performance in terms of working-memory capacity (e.g., Christoffels et al. 2006, Padilla et al. 1995), a research line that is inspired by Baddeley's theory of working memory (e.g., Baddeley 1986, Baddeley and Hitch 1974). From the different terminology that is used it may appear that the latter entails an approach to bilingual control totally different from the present one. But in fact, the constructs of SAS and working memory, especially the central-executive part of the latter system, are very similar. Indeed, Baddeley (1996) remarks that when beginning to specify the central executive in more detail in his 1986 book on working memory, he relied heavily on Norman and Shallice's (1986) SAS, and elsewhere (Baddeley 1990) he wonders whether the SAS may be equivalent to the working-memory model's central executive. Results that point at the involvement in simultaneous interpretation of SAS on the one hand or the central executive on the other hand may thus converge, both plausibly pointing at a role for the resource-limited control mechanisms presented above.

Note

1. Activation is a central concept in psycholinguistics (and cognitive psychology in general). It is assumed that the memory units that represent words in the mental lexicon (often called "logogens") all have a certain baseline level of activation. This baseline level depends on various factors, such as how often the word is used (the more frequently it is used, the higher the level) and when it was used for the last time (a higher level when it was used recently than when previous use was further back in time). A word is recognised (in comprehension) or produced (in production) when the corresponding logogen's level of activation exceeds a preset activation threshold, the same threshold for all logogens. According to a different, but functionally equivalent, account, the baseline level of activation is the same for all logogens but the activation threshold differs between logogens (e.g., high frequency words have relatively low activation thresholds). Activation is added to the baseline level whenever the logogen receives "appropriate" input, input that

matches the specifications in the logogen. (In some models inhibition occurs as well: Input that mismatches a logogen's specifications lowers its level of activation.) According to some models of word recognition, only input coming from the external word stimulus affects the activation level. According to other models, contextual information (or more precisely, the mental representation of the prior context) can also contribute to the logogen's activation so that, other things being equal, the activation in a targeted word's logogen reaches threshold faster when the word is presented in a semantically appropriate context than when it is presented in isolation. Not only the activation level of the targeted logogen, the one corresponding to the word to be recognised or produced (if all goes well), but also the activation of other logogens, namely those with specifications that partly match the input (external and/or internal), is affected by the input. In other words, there is competition within the mental lexicon and the logogen that reaches threshold first is the one that determines which word is recognised or produced. In the majority of cases — but not always — this will be the “intended” word.

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