Regulating the bilingual lexico-semantic system

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This paper aims to foster discussion of the means by which bilinguals control their two language systems. It proposes an inhibitory control (IC) model that embodies the principle that there are multiple levels of control. In the model a language task schema (modulated by a higher level of control) "reactively" inhibits potential competitors for production at the lemma level by virtue of their language tags. The IC model is used to expand the explanation of the effect of category blocking in translation proposed by Kroll and Stewart (1994) and predictions of the model are tested against other data. Its relationship to other proposals and models is considered and future directions proposed.

Introduction

There has been progress in understanding the nature and organization of processes underlying the performance of specific tasks (e.g., single word production, Levelt, Roelofs and Meyer, in press) but much less evident is an understanding of how various component processes are linked to perform one task rather than another or to switch between tasks (Monsell, 1996). Hearing a word a person could retrieve its meaning, write it down, repeat it (again and again), free associate to it, count the number of letters or syllables in it , or translate it into another language. Given one task to perform rather than another, how do individuals configure the various modules required and ensure that other tasks are not performed instead?

Typically, experimental research requires individuals to perform just one task (e.g., lexical decision, picture naming) and so this aspect of the potential competition between different tasks afforded by a stimulus goes unrecognized. Bilingual research poses the problem of the competition between tasks and the competition between responses quite directly. To exemplify: consider the task of translating a visually presented word. Is this task not also a kind of Stroop task? Bilinguals have to avoid naming the printed word and, instead, produce a translation equivalent as a response. In other circumstances, such as naming a picture, a bilingual speaker is also potentially faced with the problem of selecting between alternative responses.

This selection problem might seem to be directly connected to the problem of how words are represented in the minds of bilingual speakers. There are a number of proposals about the nature of the bilingual lexico-semantic system (Votaw, 1992) but these proposals have not always addressed the question of how to achieve a desired output. Ervin and Osgood (1954), for instance, did not specify how individuals acquiring their two languages (L1 and L2) in the same environment and so creating a compound system, in their terms, could ever produce a word in L1 when its meaning can also be expressed by its translation equivalent in L2 (see Green, 1993 for an extended critique). Potter, So, Von Eckhardt and Feldman (1984) contrasted this view of the relationship between corresponding words in two languages (which they termed the concept mediation hypothesis) with another possibility. Following Weinreich (1953), they supposed that bilinguals may construct a direct lexical link from a word in L2 to its translation equivalent in L1. The result of such a system is that access to the meaning of an L2 word or the route to the production of an L2 word is via the representation of its translation equivalent word in L1. If this is so, how do individuals ever manage to avoid producing a word in L1 when they wish to produce its translation equivalent in L2? Potter et al. concluded on the basis of their experimental evidence in favour of the concept mediation hypothesis but Kroll and colleagues have provided evidence for a more subtle view.

Kroll and Stewart (1994) in their revised hierarchical model proposed that translation equivalents are connected both through concept-mediation and through direct associative links. However, the strengths of these links differ as a function of language. But this model also leaves open questions such as how a person translating from one language to another avoids naming the word to be translated.

Bilinguals, of course, do succeed in speaking one language rather than another and they can also code-switch and can, with varying degrees of success, translate between their languages. And, indeed, the field is not without proposals, some very developed (e.g., Dijkstra & van Heuven, 1997), as to how specific tasks may be performed. Recent years have seen a marked shift in the nature of these proposals. Penfield and Roberts (1959) supposed that in order to speak one language rather than another a bilingual must throw the equivalent of a mental switch. Macnamara and Kushnir (1971) further distinguished between an input switch and output switch so that, for example, a person translating from one language (L1) to a second language (L2) could still comprehend the input in L1. The underlying assumption in both cases was that a language system (or subsystem) is either on or off. However, such an assumption did not go unchallenged either theoretically (Paradis, 1981) or empirically. Later empirical work demonstrates that individuals can be influenced by the nature of a non-selected language (i.e. one that is apparently switched off, though see Grosjean, 1997a, 1997b, for cautions) and so more recent proposals assume that language systems can be at different levels of activation and that in order to speak one language rather than another its activation level must exceed that of the other language (e.g., Paradis, 1984; Grosjean, 1988, 1997a, 1997b). A comparable view has also been adopted by individuals researching visual word recognition in bilingual speakers (Grainger, 1993; Dijkstra & Van Heuven, 1997).

The purpose of this paper is to stimulate debate and exploration of the mechanisms of language control in bilinguals. The paper is structured as follows: First, mental control in language processing is likened to the control of action. This thought leads to the notion that there are, in fact, multiple levels of control. A proposal is described based on this notion and justified by reference to both experimental and neuropsychological data. A specific inhibitory control model, the IC model, is then proposed for the control of language processing in bilinguals. There are three separable aspects of this model: first, one level of control involves language task schemas that compete to control output; second, the locus of word selection is the lemma level in Levelt et al.'s terms and selection involves the use of language tags; third, control at the lemma level is inhibitory and reactive. The following section applies this model to amplify the account of translation proposed by Kroll and Stewart (1994) and to interpret a crucial finding of these researchers. The IC model generates other predictions, some of which can be assessed against existing data in the area of language task switching, Stroop interference and competitor priming. The final two sections of the paper draw parallels with other accounts and consider future directions.

The regulation of the bilingual lexico-semantic system: multiple levels of control

Grosjean (1985, 1997a, 1997b) argued that bilinguals can be in different language modes: they may speak one language to the exclusion of the other or, in suitable contexts, they may mix their languages. Such regulation requires sensitivity to external input and the capacity for internal direction. The present proposal meets these requirements for both external (bottom-up/exogenous) and internal (top-down/endogenous) control. It is based on an earlier view (Green, 1986, 1993, 1995, 1997) derived from a model of action proposed by Norman and Shallice (1986; also Shallice, 1988).

A basic presumption is that the regulation of language processes and the control of action have much in common: language is a form of communicative action. In non-verbal actions, for instance, individuals must specify which object is to be the goal or the specific argument of an action such as grasping. In speech individuals must specify what role within the syntax of an utterance a particular entity will play. This presumption of communality commands support (e.g., Macnamara, Krauthammer & Bolgar, 1968; Paradis, 1980). A further notion is that regulation is achieved through the modification of levels of activation of language networks, or items within those networks, rather than via a simple switch mechanism (see also De Bot & Schreuder, 1993; Grainger & Dijkstra, 1992; Grosjean, 1988; Meuter, 1994; Paradis, 1981).

The Norman and Shallice model posited distinct systems for controlling routine and non-routine behaviour. The system responsible for a routine behaviour such as driving has direct control over behaviour. This system involved a process termed contention scheduling in which schemas (networks detailing action sequences), triggered by perceptual or cognitive cues, compete to control behaviour by altering their levels of activation. Human action can be analyzed at various levels of detail. At a mid-level are well-learned actions such as making breakfast or getting dressed. At this level the question is which sub-action to carry out and this is subject to voluntary control. Deciding to make coffee, for instance, will elicit various component schemas such as filling a kettle. Likewise, such a schema will in turn activate other sub-schemas involved in making precise reaching or grasping movements. At a much higher level are schemas for controlling activities such as going to a restaurant (Schank, 1982).

The term schema as used here refers to mental devices or networks that individuals may construct or adapt on the spot in order to achieve a specific task and not simply to structures in long-term memory. Where a task has been previously performed then the relevant schema can be retrieved and adapted from memory. Such existing schemas underlie the automatic performance of certain skills. Where automatic control is insufficient, as in novel tasks, contention scheduling is modulated by a supervisory attentional system (the SAS).
As Shallice and Burgess (1996) discuss, SAS must command a variety of processes, including the construction or modification of existing schemas and the monitoring of their performance with respect to task goals.

Simulations of the contention scheduling system (Cooper, Shallice & Farringdon, 1995; Cooper & Shallice, 1997) based on an interactive activation network (McClelland &

Rumelhart, 1981) have shown that when the system is "lesioned" it produces outcomes reminiscent of the behaviour of certain frontal lobe patients where the mere sight of an object may trigger actions that use it (e.g., Lhermitte, 1983). Such a result provides indirect computational support for the role of the SAS in modulating the activity of task schemas. Slips of action in everyday life are also consistent with the modulatory role of SAS since these can occur when a person is distracted (Reason, 1984).

The present proposal draws a parallel between experimental tasks such as word translation and lexical decision and schemas at an intermediate level of action. Detailed specification of the actions required to name a word (i.e. the articulation of a word form) are the province of low level schemas. Schemas for business meetings, letter writing, and conversational exchanges are higher level schemas.

Evidence for the role of frontal lobes in regulating language tasks in unilingual speakers comes from the poorer performance of frontal lobe patients on Stroop tests (Perret, 1974) and from their poorer performance on sentence completion tasks, especially ones that require them to inhibit prepotent responses (Burgess & Shallice, 1996). Figure 1 depicts the proposal.

Please insert Figure 1 about here

A conceptualiser (C) builds conceptual representations (based on information in long-term memory), driven by a goal (G) to achieve some effect through language. This communicative and planning intention is mediated by the SAS together with components of the language system, viz:- the lexico-semantic system and a set of language task schemas. Language task schemas (e.g., translation schemas or word production schemas) compete to control output from the lexico-semantic system. Willful selection of a word for production requires specification of the required language to be transmitted by SAS to the task schemas. It also requires conceptual information to be transmitted to the lexico-semantic system from the conceptualiser.

Once specified, a schema can be retrieved from memory and, if necessary, adapted to the demands of the task. In order for a schema to regulate behaviour, individuals must maintain the task as a goal. Otherwise, other schemas elicited by the stimulus may produce task-irrelevant behaviour.

A language task schema regulates the outputs from the lexico-semantic system by altering the activation levels of representations within that system and by inhibiting outputs from the system. It remains active until either 1) its goal is achieved in which case it inhibits its own activity or 2) it is actively inhibited by another schema or 3) SAS has changed the goal. SAS achieves a goal only indirectly then by altering the activation levels of a selected schema. It also acts indirectly to configure existing schemas or to construct a schema to perform novel tasks such as lexical decision. In the case of repeated tasks such as the translation of a series of words, the overall task goal maintains the activity of the schema but once a particular word is translated (for instance), it must not be repeated endlessly, unless that is the task goal. So, task schemas must be specified so as to produce a word on input, output its translation and reset themselves.

An inhibitory control (IC) model

The first part of this section proposes that language task schemas are separable and can be organized into "functional control circuits". The second part overviews the structure of the lexico-semantic system and describes the locus of word selection based on Levelt et al. (in press) and the concept of a language tag. The third part proposes a selection mechanism based on inhibition.

Functional control circuits

Since a given stimulus can evoke different actions on the part of a speaker, different tasks are potentially in competition to control output. In some cases, such task-irrelevant schemas appear to be automatically elicited by the stimulus. So, for instance, when individuals are asked to name the hue in which a symbol string is written, the more word-like the symbol string the greater the interference with colour naming (see Monsell, 1996) suggesting that a reading task schema may be elicited by inputs similar to those that normally trigger it. In consequence, part of the basis of Stroop interference may derive from competition between task schemas. Additional interference arises, of course, if the letter string is an incongruent colour word (Stroop, 1935).

Evidence in favour competitive processes between tasks also derives from experimental studies of task-switching. Rogers and Monsell (1995) required individuals to switch between a task of deciding whether or not a displayed numeral is odd or even to a task of deciding whether or not a displayed letter is a consonant or a vowel. Each trial comprised a display of two characters only one of which was a letter or a digit. Trials of one type alternated with trials of another type in an alternating runs paradigm (e.g., digit task, digit task, letter task, letter task etc.) yielding both switch and non-switch trials. An external cue provided participants with the means to keep track of the task required. Rogers and Monsell showed that a cost in switching between tasks existed even when the time interval between trials involving a task switch was much greater than the time needed to complete the task switch. The switch cost cannot then solely reflect the duration of an internal (top-down) control operation (cf. Meiran, 1996). In addition, they showed that such a reduction in cost only occurred when the interval between task switches was both sufficiently long and predictable. The reduction in time cannot therefore reflect the passive decay of an active schema since this should occur even when this interval is unpredictable (cf. Allport, Styles & Hsieh, 1994). There must be a process of active suppression which is initiated when individuals know that the interval is predictable.

Neuropsychological case reports also provide evidence for the separation, competition and coordination of language task schemas. There are bilingual aphasics with a tendency to translate what they produce (e.g., Perecman, 1984; Lebrun, 1991) suggesting that such activity may normally be held in check. Most intriguing are cases of paradoxical translation in which a person can translate into a language that they cannot use spontaneously but cannot translate into the language that they can use spontaneously. Paradis, Goldblum and Abidi (1982) described two bilingual aphasic patients who showed paradoxical translation combined with alternate antagonism (e.g., speaking just one of their two language spontaneously on one day but being unable to speak it spontaneously the next day, instead being able to speak the language that they could not use spontaneously the day before). Consider the case of A.D. On day 18 after a moped accident, A.D. could speak Arabic (call this L1) but could not translate into it. In contrast, she could translate into French (call this L2) even though her spontaneous use of French was poor. The following day she showed the converse pattern: she could speak L2 but not translate into it whereas she could translate into L1 but could not speak it. Comprehension in L1 and L2 was good.

Such a pattern of recovery indicates that speaking a language spontaneously and translating a language are functionally distinct activities. The pattern is also consistent with a problem in controlling a relatively intact lexico-semantic system since destruction of the functional subsystems underlying behaviour cannot yield such transient changes in performance. Consider the pattern of performance on day 18. Minimally, it suggests a functional control circuit in which a translation schema (L1=>L2) can call and boost the activity of a word production schema (i.e. that for L2) which can then suppress outputs in L1 and so permit translation into a language which cannot be used spontaneously. However, the fact that A.D. could not translate into a language (L1) that she could use spontaneously suggests that a translation schema cannot always capture the relevant word production schema. Conceivably this is because on the day in question, the L2=>L1 translation schema could not dominate the other currently active (L1=>L2) translation schema, though we will not pursue this speculation. [Note 1 discusses the possibility that the pattern of performance reflects variations in the strength of pathways within the lexical system.] In order for language schemas to exert control over the lexico-semantic system there must be a locus for word selection, a means by which to select and a mechanism of selection.

The locus and means of selection

We have already proposed a conceptualiser that is independent of language. We will not address the question of the mapping of thought into language here but will follow Levelt (1989; and, in particular, Levelt et al., in press) in supposing that each lexical concept is associated with a lemma that specifies its syntactic properties, vital for its use in sentences. The selection of a lemma in production leads to the activation of an associated word form. In the Levelt et al. model the input representation of word forms is distinguished from their output representations but it is assumed that a lemma for a lexical concept such as "chair" is activated in both perception and production.

In order to produce a word in a specific language the intention to do so must be part of the conceptual representation and this conceptual representation must contact the relevant lemmas. We suppose that lemmas are specified in terms of a language tag (see Albert & Obler, 1978 for earlier usage; also Green, 1986, 1993; Monsell, Matthews & Miller, 1992) and that tag specification is also part of the conceptual representation. Each lemma has an associated tag either for L1 or for L2 and tag specification is one factor affecting the activation of a lemma: it is a condition shared with all other lemmas in the language. A further motivation for believing that the locus of selection is the lemma level is that translation equivalents can differ in their syntactic properties such as gender (der Mond vs. la lune) and such information (e.g., about "moon") is only available at the lemma level (Jescheniak & Levelt, 1994).

The mechanisms of selection

Given a specific language task, such as producing a word in L1, how does the system establish that the right lemma is associated with right lexical concept? This binding problem may be solved by seeking to ensure that the intended lexical item is the most active at the critical moment (e.g., Dell et al., 1993). Alternatively, as Roelofs (1992) and Levelt et al. (in press) suppose, it may be solved by using a checking procedure that establishes whether or not a lemma node when activated is linked to the appropriate active lexical concept node. Levelt et al. note that this binding-by-checking solution, explains why it is that individuals when naming a picture and simultaneously hearing a distractor word rarely produce either semantic errors or phonological errors such as blends of the picture name and the distractor word. We adopt this proposal for present purposes though we note that under certain circumstances such as speeded picture naming (e.g., Vitkovitch, Humphreys & Lloyd-Jones, 1993) individuals may substitute the names of semantically related pictures named 1-15 minutes earlier. This result shows that responses can be triggered by incomplete conceptual matching and indicates that further refinement of this procedure is needed.

But is this the only checking procedure we need? We follow Jescheniak and Levelt (1994) in supposing, at least in the case of an L2 lemma (e.g., the lemma for "chaise" for a native English speaker) that it will point to the L1 lemma for the translation equivalent ("chair").

It follows that in this case, there is a checking procedure that establishes that an activated L1 lemma is linked to an active L2 lemma.

Given that a language tag is just one feature, how do we ensure that the correct response controls speech output? The IC model supposes that this is ensured ultimately by suppressing lemmas with incorrect tags. This process of inhibitory control through tag suppression occurs after lemmas linked to active concepts have been activated. It is perfectly possible for a lexical concept in L2 to activate a lemma in L1 to the extent that it shares properties with a concept in L1. Even the correspondence between so-called translation equivalents may be partial. As Paradis (1997) notes the English word "ball" and the French word "balle" are not co-extensive (see also De Groot, 1992). In addition, and this was one motivation for the proposal, if there is a route for translation which is not via lexical concepts, then in order for an activated L2 lemma to excite its associated L1 lemma, it must remain active until it has done so and until the checking procedure is completed. Of course at this point it must be inhibited or else it may capture speech production. Inhibition is assumed to be reactive though previous episodes of suppression may exert their effects since it takes time for the effects of prior inhibition to be overcome.

In short, the IC model supposes that the intention to perform a specific language task is expressed by means of the SAS affecting the activation of language task schemas that themselves compete to control output. These schemas coordinate into "functional circuits" and exert control by activating and inhibiting tags at the lemma level. According to the model, a language task schema can be readied in advance, but because the mechanism of inhibition is reactive, the activation of specific lemmas requires input either from external source (hearing words or reading them) or from the conceptual system. The next section considers a specific application of the model to the findings of Kroll and Stewart (1994) and proposes a number of predictions that are tested against existing data.

The IC model applications and tests

Amplifying the revised hierarchical model

Kroll and Stewart (1994) distinguished independent levels of representation for word form and meaning. There are lexical connections between words that are translation equivalents and separate connections between each of these words and the representation of their meaning. Please see Figure 2 where the relative size of the box indicates size of vocabulary.

Please insert Figure 2 about here

In terms of the connections between word forms, there is a weak link from L1 (the person's native language) to L2 (the person's second language) but a strong link from L2 to L1. In addition, the connections between L2 word forms and meaning are weaker than those between L1 word forms and meaning (Note 2, Note 3). Arguably, it is which language is currently dominant that is decisive in terms of the relative strengths of these different paths (see Heredia, 1997). For most bilinguals what is their native language and what is their dominant language will coincide but this will not invariably be the case.

By way of justification of the model, consider the case in which L2 words are acquired by learning their translation equivalents in L1. A native English speaker learns the French word "maison" by pairing it with its English translation equivalent "house". A word-form to word-form link by itself does not capture the state of the system as the person acquires the meaning of this L2 word. The meaning of a word in L2 is not the word form <house> but its meaning: [man-made] living space. The semantic representation of the word in L1 must therefore be activated at the same time (cf. Keatley, Spinks & De Gelder, 1994). The model captures this differential access to meaning and suggests that even relatively fluent bilinguals may continue to show an asymmetry in accessing meaning in their two languages. However, some reformulation is needed in order for the representation to be compatible with the demands of speech production. Indeed, Kroll and De Groot (1997, pp. 189-193) have begun to address this point. As above then, we will follow Jescheniak and Levelt (1994, p. 836) in supposing that word-association links involve links between lemmas that are perhaps in addition too, rather than instead of, direct links between word forms.

The revised hierarchical model has generated much productive research (see De Groot, 1995; Kroll & De Groot, 1997 for comprehensive reviews). Converging evidence is consistent with the view that the semantic route is more heavily involved in translating words into L2 from L1 at least in single word contexts (e.g. De Groot & Comijs, 1995) though recent research (see Kroll & De Groot, 1997) also points to a range of factors that moderate this conclusion. Precisely what weight is attached to the semantic route may be a product of the experimental context (e.g., presentation of pictures as in La Heij, Hooglander, Kerling &Van der Velden, 1996) and/or the product of acquisition history (see Kroll & De Groot,1997; MacWhinney, 1997). We concentrate here on the most direct test of the model.

On a strong version of the revised hierarchical model, translating a single word from L1=>L2 (forward translation) is achieved through conceptual mediation. It should therefore be affected by semantic factors. In contrast, translating a word from L2=>L1 (backward translation) is achieved by non-conceptual links between the word forms (via lemmas) and so should not be so affected. In a test of this prediction, Kroll and Stewart (1994) asked individuals to translate words that were either blocked by category or were randomly selected from various categories. For forward translation, but not for backward translation, individuals took longer to translate words when they were blocked by category compared to when they were presented in a randomised order. In forward translation blocking words by category leads to "conceptual activation in a specific semantic field" and "creates difficulty in selecting a single lexical entry for production" (Kroll & Stewart, 1994, p. 168), i.e. there is an increase in the time needed to resolve competition among activated lemmas in **L2**.

A critical control issue is apparent: how does a person avoid naming the target word in L1 when translating from L1=>L2 or avoid naming the target word in L2 when translating from L2=>L1? No mechanism is provided. Yet one other possible reason why there is an effect of category blocking in forward translation is that individuals have difficulty regulating the competition amongst lemmas in **L1** that become activated via the semantic route just as they do when they are naming category-blocked pictures in L1. In backward translation, the connections between L2 lemmas and meaning are weaker and competition is more readily suppressed. Hence the absence of any effect of category blocking in backward translation.

Given Kroll and Stewart's interpretation of their data (Kroll & Stewart, 1994), their model must be amplified in order to specify how the lexico-semantic system is controlled. Let us consider how this might be achieved. Consider L1=>L2 translation. One requirement is to avoid naming the word to be translated. An input word form in L1 must access its lexical concept via its associated lemma. Since the L1 lemmas are active, they will enter the competition for lemma selection for the production of words in L2. However, the competition for the selection can be weighted against L1 lemmas. According to the IC model, at the start of a block of trials, the L1=>L2 translation schema calls the production schema for L2. At the stage of selection for output, this schema actively suppresses those lemmas with an L1 tag. Competition then on trial N+1 is primarily among activated L2 lemmas since any L1 lemmas active on the previous trial (N) have been inhibited. In contrast, L2 lemmas active on trial N remain at a relatively high level of activation on trial N+1 since their tags match those of the schema. In consequence, they enter the competition for selection on trial N+1. In the case of translation from L2=>L1, given that this is mediated via an L2=>L1 lemma link, an L2 lemma transmits activation to its associated L1 lemma. Once again the process of lexical selection must be biased against lemmas with an inappropriate tag. Here, this is achieved by the production schema in L1 that reactively inhibits any activated lemma with an L2 tag. Hence, on this argument the two translation schemas involve the same mechanism of control and a comparable locus of inhibition. The actual outcome of the experiment reflects the relative strength of the connections in the lexico-semantic system just as the Kroll and Stewart model claims.

Predictions and tests of the IC model

Language switching in reception

Language switching may take time a) because it involves a change in language schema for a given task and b) because any change of language involves overcoming the inhibition of the previous language tags. I know of no direct tests of the costs of switching between different language tasks such as naming and translation but the IC model predicts that there will be such costs. However, there have been studies of language switching on specific tasks (both receptive and productive) and these confirm that such costs do exist.

Consider a lexical decision task in which bilinguals have to decide whether or not a presented letter string is a word in L1 or a word in L2 using the alternating runs paradigm, i.e. there is predictable switching between languages. We will describe the study by Von Studnitz and Green (1997; see also Thomas & Allport, 1995) in which the participants were German-English bilingual speakers. The presence of an external cue (the colour of the background on which the letter string is presented) informed participants of the required language for decision. Figure 3 portrays the relationship between this cue and two lexical decision-schemas in reciprocal inhibition, and the bilingual lexico-semantic system.

please insert Figure 3 about here

These schemas are established by SAS and relate an output of the bilingual lexico-semantic system (e.g., L1 tag present) to a response (press right key if L1 word). Once established, this control device is driven bottom-up though its performance is monitored by SAS to ensure appropriate performance. In order to respond on a switch trial, the new schema must be triggered by the external cue and suppress the previously active schema. In addition, an input in a different language must overcome the inhibition on its language tags occasioned by the previous trial. In other words, two loci of inhibition are supposed: schema level inhibition and tag inhibition in the bilingual lexico-semantic system. Inhibiting a previously active schema and overcoming the inhibition of the previously irrelevant language will take time and so a switch cost is predicted. For present purposes, we assume that responding to a word in particular language requires activation of its associated lemma and tag. But we note, as Grainger and Jacobs (1996) suppose, that lexical decision can be based on read-outs from different parts of the system (including word forms, and meaning). We also note (and there is evidence within the study for this claim, that stimuli contact representations in both languages regardless of the target language on that trial (see Smith, 1997 for a review of the evidence on non-selective access in visual word recognition including the role of language-specific cues; Grosjean, 1988, 1997a for relevant research in speech perception). In the case of a non-word response absence of such a signal by some deadline, triggers a "no" response.

Von Studnitz and Green (1997, Experiment 1) found an average switch cost of 118 ms (see Grainger & Beauvillain, 1987 for switching costs in a different design). A second experiment examined the effect of language switching when individuals were simply required to decide whether or not the letter string is a word or not. In this case, only one lexical decision schema is needed and this can trigger a response as soon as any language tag becomes active. Accordingly, any switch cost will primarily reflect effects within the bilingual lexico-semantic system itself. A significant switch cost was still obtained (averaging just 17 ms overall) but one that was markedly less than that obtained for the specific lexical decision task.

Language switching in production

The IC model also predicts a cost in switching between two language tasks in production: different language schema are involved and in order to achieve output, the new schema must dominate the previous one. There will also be a cost in overcoming inhibition within the system. Since both language are potentially active and competing to control output, successful selection requires the inhibition of active lemmas with non-target tags. Also because inhibition is reactive more active lemmas will be more inhibited. Because overcoming prior inhibition will be a function of the prior amount of suppression, it can predicted that the cost of switching will be asymmetric. It will take longer to switch into a language which was more suppressed - for unbalanced bilinguals this will be L1, their dominant language.

Meuter (1994; also Meuter & Allport, 1997) examined switching costs in a numeral naming task in which the required language of response was signalled by a colour-background and each trial comprised the presentation of one single-digit number. She found that switching language did yield a switching cost. She also obtained the predicted asymmetry: individuals took longer to switch into their dominant language.

Unpredictable switching should on average induce greater costs compared to predictable switching because in the unpredictable case correct performance may sometimes require the intervention of SAS as individuals temporarily overlook the language cue. Trial by trial data are not available for this contrast but Macnamara, Krauthammer and Bolgar (1968) found that estimated average switch costs in numeral naming were less for regular predictable alternations compared to unpredictable ones (210 ms per switch compared to 390 ms per switch, respectively).

What might be predicted under conditions where there are constraints on SAS? Given that schema level activity is monitored by SAS we should expect impaired performance when there is damage to the frontal lobes. Given language asymmetry, frontal lobe damage should induce incorrect switches into L1 from L2 and the occasional failure to switch on cue, especially from L1 into L2. In a pioneering study, Meuter and Humphreys (1997) report the case of an English-Urdu bilingual (FK) who showed this pattern of errors on Meuter's numeral naming task.

Stroop interference

The IC model supposes that individuals can establish language tasks and the relationship between them in advance. In principle, then we should find effects of knowing the nature of the interfering stimuli in a Stroop colour naming task. The data of Tzelgov, Henik and Leisser (1990, Experiment 1) supports this possibility: the Stroop effect was smaller in the expected language condition for those proficient in the language suggesting that such individuals were able to control their reading of the colour words. The IC model locates this increase in control at the level of language task schemas: in the expected condition individuals can suppress the word reading schema in their L1 (i.e. more speedily inhibit lemmas activated from that source).

In a unilingual study, Tzelgov, Henik and Berger (1992) showed that reaction times to incongruent Stroop stimuli were faster when participants expected a high proportion of such trials compared to neutral or congruent trials. However, congruent trials showed equal facilitation. The IC model supposes that when individuals know that there is a high proportion of incongruent trials that the colour naming schema dominates the word reading schema. The effect of this relative dominance of the colour naming schema is that a check of an activated lemma and the lexical concept for the hue is prioritised and so can elicit inhibition of a competing alternative more rapidly and so yield faster response. In the case of congruent stimuli the same lexical concept and lemma is activated and so prioritisation exerts no effect since there is no direct competitor: hence, there is no effect of expectancy on congruent trials.

Cross-language competitor priming

Where individuals are consistently translating from one direction to another then the controlling schema is in place and can indirectly (via the word production schema in the target language) reactively inhibit competitors in the non-target language. However, if there is a change of language then any lemmas in the previously active language will become inhibited. In certain circumstances, this should lead to the abolition of both cross-language and within-language competitor priming.

Wheeldon and Monsell (1994) showed that a word produced in response to a priming definition such as " falls in large white flakes from the sky" (snow) interfered with the naming of a subsequently presented probe picture that was semantically related to the concept evoked by the definition (rain). Such competitor interference should also exist across-languages: saying "snow" in response to a definition in English should interfere with naming a semantically related probe picture in French (pluie). However, it will not do so, according to the IC model, if a switch of language intervenes before the probe trial and suppresses lemmas with English tags. Such a switch should also abolish within-language competitor interference.

Lee (1997; Experiment 1) showed just such effects for a group of English-French bilingual speakers. Responses to the critical definitions were in English but probe pictures were named either in English or in French as stipulated 1300 ms in advance by a language cue. Within-language competitor interference averaged 68 ms and cross-language competitor interference averaged 85 ms. Both kinds of interference were eliminated when there was a change of language before the probe trial. For instance, cross-language competitor interference was eliminated when an intervening trial required individuals to name a semantically unrelated picture in French - a language different from that of the (prime) definition trial. According to the IC model, switching to French suppressed currently active English lemmas and so eliminated, in advance, the English lemma associated with the lexical concept evoked by the definition, from the competition for selection in naming the probe picture in French.

This section has proposed and examined a number of predictions from the IC model. A critical feature is that a dominant language will play an active role in determining reaction time and that selection of an appropriate response will reflect the state of activation of competitors. The claim that control is exerted through task schemas is a claim about how intention is expressed and how attention is achieved. A number of questions have been left open and additional predictions from the model will be discussed in the final section. The next section considers the relationship of the IC model to other proposals.

The relationship of the inhibitory control model to other models and proposals on the mechanisms of control

The IC model shares features in common with other accounts of the control of the bilingual lexico-semantic system. The distinction in the IC model between a non-linguistic conceptual system and the system of lexical concepts and word forms relates directly to the three-store model of Paradis (1980, 1997). In addition, the model assumes that the two or more languages of an individual are subsets of the language system as a whole (Paradis, 1989) and this notion is shared by models for both speech perception (Grosjean, 1997a), visual word recognition (Dijkstra & Van Heuven, 1997) and speech production (De Bot & Schreuder, 1993; Poulisse & Bongaerts, 1994).

All current accounts suppose regulation by activation though details and mechanisms vary. Paradis (1984, 1997) articulated the basic form of this conjecture in terms of the activation threshold hypothesis. The intention to speak one language rather than another leads to the raising of the activation threshold of the other language system but not to its total inhibition. Conversely, speaking one language reduces the activation threshold of components in the system. Activating and deactivating language systems allows bilinguals to achieve different language modes (Grosjean, 1985, 1997a). In the unilingual (monolingual) mode, one language is the base language and the other is deactivated at least partially. In contrast, in the bilingual mode, when individuals are speaking with others with whom they can code-switch or mix languages, bilinguals adopt one language as the base or matrix language and bring in the other language when required as a "guest" language. In consequence, both languages are relatively active but the base language is more strongly activated. On the IC model, code-switching would involve a co-operative rather than a competitive relationship between the word production schemas.

Models aimed at accounting for speech production in bilinguals adopt the production model of Levelt (1989; Levelt et al., in press) and suppose that lexical selection is achieved through competition between lemmas. In contrast, to the IC model though, and to the proposals of Paradis (1984, 1997), models based directly on Levelt's production model (De Bot & Schreuder, 1993; Poulisse & Bongaerts, 1995) assume no inhibitory mechanisms but rely instead on the notion that the state of activation in non-target lemmas affects the latency to select the target lemma according to a mathematical rule.

Production models differ in the locus of selection. De Bot and Schreuder (1993) presume that the selection of words in a given language is achieved by specifying a language cue which can activate one subset and de-activate another subset. Similar to the IC model, Poulisse and Bongaerts (1994) adopt the notion that lemmas are tagged with a language label and that it is the activation of this tag together with the conceptual information that leads to the selection of a given lemma. Intentional use of L1 during L2 speech, for instance, reflects the increased activation of an L1 lemma and its associated lexical concept. Grosjean (1997a) develops the point that in the case of code-switching, both topic and the addressee affect the activation of the guest language. The selection of a relevant lemma is also determined by the conceptual and pragmatic content to be expressed (see also Myers-Scotton & Jake, 1995). In such circumstances where code-switching is not an option, the problem of lexical selection is compounded and such a constraint does indeed induce more hesitation pauses and dysfluencies.

All current proposals, including the IC model, assume that the state of activation of input word forms is a function, in part, of external input. Grosjean and colleagues (see Grosjean, 1997a for a synopsis) have established for the perception of mixed speech some of the relevant factors and constructed a computational model. For instance, increased code-switching prior to a target guest word speeds a target word's recognition. Words marked phonotactically as belonging to the guest language are recognized more readily than those that are not (a phenomenon also shown in visual lexical decision tasks, Grainger & Beauvillain, 1987). BIMOLA (**B**ilingual **Mo**del of **L**exical **A**ccess) can account for these effects in terms of the bottom-up flow of activation between levels together within inhibition between competing candidates within a level.

In contrast to Grosjean's model (Grosjean, 1997a) but like the IC model, Dijkstra and van Heuven (1997) have proposed a model for word recognition in bilinguals (BIA, the **B**ilingual **I**nteractive **A**ctivation model) in which the resolution of competition between word candidates in both languages can be differentially inhibited top-down on the basis of language. Novel to the BIA model is the use of language nodes. Each node collects activation from its respective lexicon and suppresses all words in the other lexicon. This device allows the asymmetric inhibition of words in the two languages. Word forms in L1, for instance can be more inhibited than word forms in L2. These language nodes can be pre-activated reflecting a particular task. The model captures a wide range of data on visual lexical decision tasks and other tasks and it shows that responses are a function of the task situation, the nature of stimulus material, as well as the expertise of the bilingual (see, for example, van Heuven & Dijkstra, 1997).

In terms of the IC model, the language nodes achieve two functions. First, they are functionally equivalent to language tags (since they identify representations that are to be subject to control). However, currently the locus of control is directly on orthographic input forms, whereas in the IC model, the locus is the lemma level and input word forms are not directly inhibited. Moreover, in this sense, the IC model involves reactive inhibition whereas the BIA model does not. Language nodes are analogous to a control schema in that they are external to the system under regulation, are governed by a higher-order system (not currently modelled in BIA) that sets their starting values, and modulate the activity of units within the system top-down. Language nodes differ from the language task schema in the IC model in that they do not directly connect system outputs to responses (responses are read from the activation of units) and unlike the IC model they are not in a relationship of reciprocal inhibition for tasks such as language-specific lexical decision. In this sense, the locus of any switch cost is solely within the bilingual lexico-semantic system and not in the regulating schema.

These models, computationally more or less developed, account for a range of data within a particular task domain (speech perception, visual word recognition, speech production) but they do not currently address the range of tasks that the bilingual lexico-semantic system is required to fulfill. In that sense, they lack the relevant control structure to allow them to model different tasks. The IC model differs by attempting to specify the mechanisms of control (language task schemas and the SAS) and in the means of control (reactive inhibition of specified tags on lemmas). The BIA model is one computational model that is perhaps most amenable to the kind of control structure proposed here since it uses the idea of top-down inhibition to achieve effects but the principle of such structure seems widely applicable.

Future directions and implications

Top-down control

In the IC model, the supervisory attentional system (SAS), plays a number of roles. How these roles are performed needs to be specified. In the first instance, it would be helpful to gain more evidence on its role in regulating task performance. The IC model proposes that once established a language task schema can be triggered bottom-up but needs to be monitored to ensure appropriate levels of performance. Language switching within the same task will be affected when the SAS is required to carry out other control operations concurrently such as monitoring the completion of other goals. Switching between languages tasks, where the same input (e.g. an English word) can evoke either task (e.g., naming versus translating), should be compromised as well. Additional load to SAS should also increase dysfluencies and involuntary code-switching when bilingual speakers who routinely use both their languages are required to speak just one of them as in the experimental situation described by Grosjean (1997a).

The IC model supposes that individuals can prepare to perform a given task but that since inhibition operates reactively, when speaking L2, alternative competitors will become available in L1. Resolving such competition consumes time and so should be evident in production tasks. It follows that even though speech may be planned on a clause by clause basis that there will be traces of such competition in the speech stream at the time of lexical selection. Where individuals have elected to code-switch because, for instance, a particular idea can be lexicalized directly in one language but not in the other then dysfluency will be eliminated precisely because there is no competitor. Resolution of the mechanism of intentional code-switching requires spelling out how conceptual representations are mapped onto to linguistic representations. Crucial here will be an exploration of the role of attention (and the SAS) in organizing and maintaining non-linguistic representations for mapping.

Tag inhibition

The selection mechanism operates on language tags associated with lemmas. An open question is whether lemmas might possess two tags: one for reception and one for production. A further question concerns how fluency in a language alters the inhibitory mechanism. Undoubtedly we will need to consider both the link between concept and lemma and the link between lemma and word form.

Capacity-effects

A language task schema prioritises the processing of stimulus (it is a means of directing and allocating attention, see Van Der Heijden, 1996 for task control in visual attention). Consider a situation such as word translation. La Heij et al. (1990) showed interference in translation when a semantically related distractor, presented after the onset of the word, was in the language into which the word was to be translated. The IC model also predicts interference from a distractor when it is in the same language as the target. Consider forward translation. Given the activation of an L1=>L2 translation schema, the distractor will capture the translation schema too since its tag matches its perceptual conditions. In consequence, individuals must verify that they are translating the right item if they are to avoid error. Miller (1997) found that individuals do sometimes translate a distractor word when it is in the language of the target but never when it is not. They also occasionally name the distractor but only when it is in the language required for production.

However the effects of a distractor on translation time and on subsequent responses will depend on whether or not it is actually processed. Like other models (e.g., MacWhinney, 1997), the IC model presumes that functional subsystems are capacity constrained. It follows that if processing of the target demands the capacity of the system, distracting information will not be processed within the time interval for response and so will not interfere with processing and be subject to reactive inhibition (see Lavie & Fox, submitted, for a pertinent unilingual experiment).

Functional control circuits and neuroanatomical systems

The IC model envisages that bilingual individuals perform as they do by selecting and coordinating language task schemas into functional control circuits that in turn modulate the mental representations of word meanings and word forms. It follows that it should be possible to examine these circuits (or rather their effects) using functional imaging methods and so advance the cognitive neuroscience of bilingualism. We have been begun an exploration of these circuits using positron emission tomography, PET (Green, Von Studnitz & Price, 1997). German-English bilinguals were scanned whilst reading or translating unrelated, visually presented words. We found a) that forward translation relative to backward translation increased activation in some parts of the region mediating the semantic processing words consistent with the revised hierarchical model b) that relative to reading, translation increased activation in the anterior cingulate which is an area activated in Stroop tasks and associated with the inhibition of prepotent responses (Posner & DiGirolamo, in press) and c) that alternately switching between forward and backward translation relative to translating consistently in one direction induced increased subcortical activation consistent with the involvement of these regions in implementing the actions specified by language task schemas.

Conclusion

This paper has addressed the question of how bilingual individuals control the use of their lexico-semantic system. The IC model shares commonalities with existing proposals but amplifies them by specifying the locus, the means and the mechanism of selection so that bilinguals can perform a range of different language tasks.

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Note 1

Could the pattern of performance reflect variations in the strength of the pathways connecting the various modules in the system? Consider task performance on day 18. Good comprehension with poor production in L1 could reflect a temporary decrease in the strength of the output connection between lexical concepts and lemmas (or between lemmas and word forms.) Given such a weakening, translation into L1 might be possible because of activation spreading from the L2 lemma to the L1 lemma and so boosting the output pathway for L1 word forms. Can we explain why A.D. could not translate into the language (L2) that she could use spontaneously? Words in L1 are understood so there is access to lexical concepts. And since A.D. could speak L2 spontaneously, output connections from lexical concepts to lemmas and so to word forms in L2 are intact. A representational account seems to provide no ready explanation here since there is an intact set of pathways to allow word production. One remaining possibility is that the performance of this pathway is disrupted. Suppose there are also lemma-links between L1 and L2. If the pathway connecting L1 and L2 lemmas is disrupted then it is possible that it could block the selection of the correct L2 lemma even though the mapping between the lexical concept and the relevant L2 lemma is intact. The extent to which this account is really different from a cognitive control account depends on the locus of this interference. If it is a consequence of the failure to suppress the L1 lemma then cognitive control remains a viable account. The advantage of the control account is that it provides an account of why there might be problems.

Note 2

The representation of the model is incomplete in the sense that input representations of word forms need to be distinguished from their output representation (see, for example, Morton, 1996; Levelt et al. , in press). However, although this issue profoundly affects the predictions that can be made in the tasks used by Potter et al. (1984; see Green, 1997) it does not directly affect the argument here since it is supposed that the word association hypothesis is consistent with mediation at the lemma level.

Note 3

Monsell (e.g., 1987) contrasted declarative accounts of the representations of words in the mental lexicon which suppose that words are mentally represented independent of the operations to which they contribute, with a procedural account which supposes that words may not be represented separately from what is done to them. Monsell comments that he is aware of no data that could distinguish these alternatives but the contrast cautions against simply assuming that any task requiring auditory word identification, for instance, necessarily activates the same subsystem.

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Figure captions

Figure 1 The regulation of the bilingual lexico-semantic system displaying multiple levels of control.

Figure 2 The revised hierarchical model of Kroll and Stewart, 1994.

Figure 3 Regulatory processing in a lexical decision task involving language switching (self- inhibitory links on schemas are not depicted). The L1 task schema is shown to be suppressing the L2 task schema and inhibiting L2 lemmas in the bilingual lexico-semantic system.

Retroactive or proactive control of the bilingual system.

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The schema concept has had a long and varied history in psychology. It was introduced by Bartlett (1932), who observed that subjects' reproductions of a story showed systematic deviations from the original. Elements in the original story that were uncommon or strange were lost or changed and elaborated such that they became more common, made more sense to the subjects, and infrequent words and concepts were replaced by more common ones. Bartlett explained this normalization behavior by assuming that humans adapt incoming information to existing knowledge structures in long term memory and that they understand new information in terms of these structures. These knowledge structures were called schemas. Schemas may represent our knowledge of stereotypical events such as doing the laundry or cooking a meal (these schema structures are usually called scripts; Schank & Abelson, 1977), of objects and natural categories (see Anderson, 1985, for a discussion), and the knowledge underlying routine behavior (Norman, 1981).They provide a basis for explaining many different phenomena of information processing and memory functioning, such as inferencing, elaborating, stereotyping, reconstruction, false memorization, and the occurrence of slips in task performance. When, for instance, a reader encounters the word forest in a text, he is not surprised to see the noun phrase the trees, with the definite article, in the next sentence even though no trees were explicitly introduced before. The reason is that the word forest activates the relevant memory structure, the forest schema, and from that moment all the information contained by this structure, including the knowledge that forests are made up of trees, is available for processing.

More recently the term schema (or script) has not only been used to refer to permanent structures in memory, but also to memory structures that are created on the spot from higher-level structures while performing a particular task. For example, no dentist script exists in memory as one precompiled chunk, but this script is dynamically constructed from other memory units the moment it is needed (Schank, 1985). This same idea features in the work of Barsalou (e.g., Barsalou, 1987) who poses the view that concepts are not retrieved as wholes from memory but constructed in working memory on the spot, the precise information incorporated in the concept depending upon the particulars of the context and recent experiences. A central component of Green’s present model of language control in bilinguals is reminiscent of this view of schemas as structures that are built in working memory when performing a particular task, but it seems to differ from it as well. Whereas the more common view of schema construction is that previously present elements in memory are assembled into the schema, many if not all of the building blocks of Green’s ‘language task schemas’ seem to be provided by the instructions presented to the subjects prior to the experiment. The task schemas appear to be the equivalent of an understanding of the task instructions in them as schemas, the already extremely wide use of this term (too wide, according to many) is broadened even more. And in this expanded use of the term, the core of the original notion of a schema -- pre-existing knowledge that is accessed and used during the understanding process (but that is not equivalent to the end product of the understanding process itself) -- seems to be lost. Of course, an understanding of the task's goals (whether correct or incorrect) underlies all task performance, whatever the performance model. What then is the unique feature of Green's model of bilingual language control?

Unique in Green's model seems to be the assumption that the language task schemas, constructed and controlled by the 'supervisory attentional system', operate retroactively rather than proactively upon the level of activation of the units in the bilingual lexico-semantic system proper. For instance, if the subjects' task is to translate L1 words into L2, activated L1 lemmas must be inhibited if their names are not to pop out inadvertently as responses. The task schema dominant under the prevailing circumstances, the L2 production schema, takes care of this by reactively suppressing the level of activation of the lemmas with an L1 language tag and enhancing the level of activation of the lemmas with an L2 tag. If, on the other hand, the subjects must name pictures in L1, an L1 production schema must, again reactively, suppress the elements with an L2 language tag and enhance those with an L1 tag.

Green's model thus shares with other models the notion that control is effectuated by relative changes in the activation levels of sets of elements in the bilingual's lexico-semantic system. The elements of the output language must be activated more than those of the other language. A difference, however, is that these other models typically assume, albeit often only implicitly, that an understanding of the task goal is translated proactively into specific levels of activation of the relevant L1 and L2 elements. For instance, a bilingual may adapt to the task of naming pictures in L1 by boosting the activation level of the L1 elements and suppressing the activation of the L2 elements as much as possible, preferably to zero. She may do so immediately upon receiving the task instructions, and prior to the presentation of the first stimulus. When instead her task is to name pictures in L2, the opposite state of affairs is effectuated. And when L1 words have to be translated in L2, she may adapt to this task by setting the activation level of the L1 units clearly above zero, but lower than the activation level of the L2 elements. Both languages must be activated to some extent because translation involves both of them, but the output language should be activated more than the input language because language production requires a higher level of activation than does language comprehension (Paradis, 1994). In the Bilingual Interactive Activation model developed by Grainger and Dijkstra (1992), an understanding of the task goal may be translated into a change in the relative levels of activation of the two language nodes in the bilingual system, which in turn would affect the relative levels of activation of the L1 and L2 word nodes in a second layer in the system. In Poulisse and Bongaert's (see Poulisse, 1997) adaptation of Levelt's language production model to the bilingual case, the goal to produce one language and not the other is reached by installing a language cue as one of the conceptual features in the conceptual representation. As in Green's model, a language cue is attached to each lemma. What lemma will be selected for output (because activated most) is determined by the degree of overlap between the information specified in the lemma and the set of activated conceptual features, that includes the language cue. This set-up guarantees that most of the time the lemma of the contextually appropriate language will be activated more than the corresponding lemma of the contextually inappropriate language (whose language cue mismatches with the language cue in the conceptual representation). As a consequence the former lemma is the one eventually assigned a phonological form and output in that form. The presently important common point of the BIA model, Poulisse and Bongaert's model, and indeed most models that can account for language control one way or the other, is that according to them the activation levels of the relevant L1 and L2 memory nodes are proactively adapted to the task.

Proactive task adaptation seems more efficient than the retroactive regulation, by language task schemas, of the output of the bilingual lexico-semantic system suggested by Green. When the activation levels of the memory nodes in the bilingual system are proactively adapted to the specific goal of the subjects (that is, prior to the onset of task performance), the representational elements that belong to the contextually inappropriate language may generally not be activated enough to become available in the first place, and no mental energy will thus have to be wasted to prevent that they will be produced as output. In contrast, in a retroactive system both the contextually appropriate and the contextually inappropriate memory nodes will often be available, requiring active suppression of the latter, a process that is likely to consume mental energy. Before we trade a model that assumes efficient processing for one that assumes more laborious processing, we should know exactly what it is that forces us to do so. The pertinent question to be answered then is why we would need the present concept of language task schemas at all, including its assumptions about the locus of control in the bilingual system. I found myself unable to answer this question. Presumably the presently stretched notion of a schema -- a notion that is hard to distinguish from a mental representation of the instructions or from a set goal -- is to a large extent responsible for my failure to embrace the proposed model without reservations. But whatever the ultimate answer, Green's present contribution is important as it is. It fosters the awareness that models of bilingual processing are incomplete if they do not specify the mechanisms that support bilingual control.

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From tag to task: Coming to grips with bilingual control issues.

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The recent trend in psycholinguistics from autonomous, rule oriented models with symbolic representations, towards more interactive, regularity oriented, and subsymbolic models reflects an increasing awareness that the finer aspects of cognitive processing may be sensitive to "contextual factors". Apparently, there is systematic variability in the data that depends on task demands and stimulus list composition, and their effect on the strategies and decision criteria maintained by the experimental subject. However, most current (computational) models at best embody a task-independent stimulus identification process with a simple decision process operating in the same rigid manner across different tasks (Dijkstra & De Smedt, 1996).

Theoretical frameworks are needed that relate and integrate notions on stimulus identification with task demands, subject strategies, and resource use. It is here that the Inhibitory Control (IC) model and the model of action and cognition that inspired it (e.g., Norman & Shallice, 1986) are of great interest. The IC model focuses on language control issues in bilinguals, but, of course, for the model to be valid for bilinguals, it must be applicable to control issues in the monolingual lexico-semantic system as well.

The IC model is inspiring first of all because it provides interesting reinterpretations of available experimental data. As an example, consider the model's solution to the following paradox on the relation between automaticity of processing and cognitive control. The more often bilinguals process words from a second language, the more their word recognition or production process will become "automatic", i.e. it can be executed faster and with less demand on working memory capacity. At the same time, a higher L2 proficiency may entail more control over the relative contribution of the mother tongue and second language in a particular experimental situation (e.g., Dijkstra & Van Heuven, 1998). Thus, paradoxically, word processing in a high-proficiency bilingual is more automatized but also under more cognitive control than in a low-proficiency bilingual. The IC model provides an elegant solution to this paradox, because cognitive flexibility in terms of the SAS can be distinguished from automaticity in terms of the lexico-semantic system.

Currently, many of the new predictions by the IC model are qualitative in nature. In contrast, the computer-implemented BIA model (Grainger & Dijkstra, 1992; Dijkstra & Van Heuven, 1998) also makes more quantitative predictions. The latter model has concentrated on how the bilingual lexico-semantic system processes interlingual homographs and items differing in their neighborhood characteristics in a limited number of paradigms. As noted by Green, the two approaches, the one perhaps a bit more "top-down" and the other a bit more "bottom-up", are to a remarkable extent consistent and complementary.

Consider, for instance, the notion of a task schema. In the BIA model, "functional overlap" of task schemas is acknowledged by assuming that different tasks may involve the same processing architecture and share many (core) parameter settings. Differences in task schemas are implemented as differences in other (non-core) parameter settings, in response read-out from different information sources, and in language node pre-activation. For bilingual lexical decision, progressive demasking, and language decision, rather detailed suggestions are available on what the task schemas might look like (e.g., Dijkstra & Van Heuven, 1998; Dijkstra, Van Jaarsveld, & Ten Brinke, 1998). These proposals, which are extensions of empirically-tested ideas from the monolingual domain (Grainger & Jacobs, 1996) can in principle be incorporated directly in the IC model.

The language nodes in the BIA model are not control schemas in themselves, but can be considered as delivering output activation (or rather inhibition) allocated by the SAS to the bilingual’s lexica. As such, language nodes implement the IC model’s notion that top-down aspects can modulate the degree of language activation involved in a particular task situation. However, the language nodes currently do "double duty", because they also propagate language activation effects across trials. Green’s paper clarifies that future work should separate activation originating from the lexico-semantic system itself and from higher levels (e.g., the regulating task schema). Introducing the concepts of SAS and task schema into the BIA-model provides a structured way to develop the model beyond isolated word recognition.

Language nodes fulfill the same function as tags, but the two notions are not identical. Because a language node collects activation from all words in a lexicon, its speed of activation does not only depend on target item characteristics, but also on activated competitors (e.g., neighbors) from L1 and L2, and indirectly even on the activation of the other language node. The distinction is amenable to empirical tests.

With respect to the IC model, specifying the characteristics of the SAS, task schemas, and their interaction with the lexico-semantic system seems to be the most urgent. Very little is said about the SAS. How does the SAS relate to (individual differences in) working memory and the monitor notion proposed in language production studies? How is it assumed to regulate the language mode of a subject in relation to stimulus list composition (mixed/pure, frequency of items in sequence, etc.)? What is the role played by "attention" or "consciousness" in bilingual experiments? These terms have been used in many different senses (Allport, 1989). What are the dynamic, on-line effects of SAS control on task execution, given that many tasks assume "automatic" processing of input stimuli followed by a conscious decision on the products of such processing in order to produce a response (Dupoux & Mehler, 1992)?

Specifying task schemas will not be easy. Some bilingual studies may involve what Monsell (1996) calls multi-step tasks, for which it is difficult to determine the precise cognitive processing steps involved. Questions also arise at the level of whole schemas. For instance, suppose automatic reading of a color name in the Stroop task calls forth an irrelevant task schema interfering with uttering the color's name. To which extent will the schema for word naming compete with other task schemas as well, for instance, for lexical decision? Which factors (overlap, automaticity, etc.)

determine the degree of competition between different schemas and can they be quantified somehow?

Green suggests that changing the target language from one trial to the next in a switching task may lead to inhibition of both schemas and tags in the lexico-semantic system (what about remaining activation of word forms presented on earlier trials?). However, it would seem that changing the task from English to German lexical decision implies merely a change in parameter settings (tag used) of similarly structured language schemas, while changing the task from naming to lexical decision evokes really different schemas. Could the observed difference in switch costs between specific and general lexical decision be explained by a different use of tags rather than by inhibition between task schemas?

Relevant here is a recent study on interlingual homograph recognition by Dijkstra, Van Jaarsveld, and Ten Brinke (1998), who examined the effects of task demands (schemas) and target language(s) (tags) in relation to activation in the bilingual system. In an English lexical decision task, reaction times to interlingual homographs and exclusively English words did not differ (Experiment 1), but mixing in Dutch items, requiring a "no"-response, resulted in strong inhibition effects for the homographs (Experiment 2). This remarkable shift in data patterns is most easily interpreted as the consequence of a change in the relative activation of the English and Dutch lexica on the basis of stimulus input, rather than as an effect of schema change. In a third experiment, Dijkstra et al. varied the way in which the language tags for interlingual homographs could be used by instructing subjects to respond with "yes" to both English and Dutch items. In this situation, reaction times to homographs were facilitated relative to control items. Thus, while in Experiment 1 the language tag of the non-target reading of the homograph could be either ignored or used, it was to be excluded in Experiment 2 and could be advantageously used in Experiment 3.

Future research will need to clarify the precise contribution of task schemas and the lexico-semantic system to empirical results such as these. But, clearly, such issues are not just problems to be solved by the IC-model but are relevant to all models of bilingual processing. The value of a theoretical framework such as the IC-model is that it helps us to think in a structured way about control and task issues, and to formulate fresh questions. Indeed, the heuristic value of the IC-model may be even more important than whether the model proves to be right on particular points or wrong on others.

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Not by words alone: Comments on a proposal for the control of access to bilingual language representations

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Green makes the critical observation that models of lexical and semantic representation in bilingual memory fail to specify a mechanism that would enable the bilingual speaker to act. Under the conditions typical of most experimental research, bilinguals are asked to perform a well-defined task, such as word or picture naming, lexical decision, or translation. The question Green raises is how is it that the bilingual effectively performs one of these tasks rather than another? And within a given task such as word translation, how does the individual manage to produce words in one language and suppress the other? The goal of Green's proposal is to provide a preliminary account of the control apparatus that a bilingual would need to possess in order to effectively perform in this environment. An adequate model of these control mechanisms will presumably allow us to understand not only how bilinguals perform simple laboratory tasks, but also how they manage to engage the appropriate language during normal discourse, including code switching with other bilingual speakers.

In this commentary, we focus on two issues that we believe are central to an evaluation of Green's claims. Because Green cannot do away with a representational scheme entirely, we consider first the representational architecture that is operating implicitly beneath the watchful eye of the mental control device. Specifically, we discuss the interpretation that Green assigns to the Kroll and Stewart (1994) category interference effect in translation and consider alternative accounts. In brief, we will argue that although positing some control mechanism is desirable, the present model is unclear as to how much direct control is accomplished via the proposed schemas in contrast to the indirect control of the two languages that results as a consequence of representations that reflect their relative activation. Second, because one of the challenges in evaluating a proposal such as Green's is that much of the relevant empirical evidence is simply not yet available, we suggest a set of directions for future bilingual research that may begin to provide a basis for testing his model and related proposals.

An example that Green uses to illustrate the inhibitory control approach comes from a reinterpretation of the results of an experiment reported by Kroll and Stewart (1994). Kroll and Stewart had relatively fluent Dutch-English bilinguals translate words from one language to the other in list contexts that were either blocked by semantic category or randomly mixed. Translation from the first language (L1) to the second (L2) was slower than translation from L2 to L1. But the important result was that translation from L1 to L2 was also slower in the semantically blocked list than in the mixed list, whereas translation from L2 to L1 was unaffected by the semantic context. Kroll and Stewart interpreted the category interference effect in forward translation as reflecting competition at the conceptual level prior to lexical selection. They proposed that only translation from L1 to L2 was conceptually mediated and therefore subject to the consequences of competition at this level.

Green provides alternative explanations for the two main findings of the Kroll and Stewart (1994) study, the translation asymmetry and the category interference effect in L1 to L2 translation. Each of these alternatives is hypothesized to be the result of an interaction between the inhibitory control mechanism and the activation associated directly with the representations themselves. The translation asymmetry is thought to arise because the greater activation associated with L1 than with L2 will require that L1 be actively suppressed so that the L1 word itself will not be produced. As we understand Green's proposal, this suppression is accomplished by engaging a task schema, in this case for forward translation. Because L2 will produce less activation than L1, the process of suppressing L2 in order to speak L1 will not require the same expenditure of resources. Hence, the task of translating from L2 to L1 will require less time than the task of translating from L1 to L2.

Green suggests that the inhibition of L1 in forward translation is achieved by having a production schema for L2 (which is presumably part of the schema for the L1 to L2 translation task itself) suppress activated L1 lemmas. Because the production schema for L2 must be active in order for the L2 word to be spoken, the corresponding L2 lemmas will remain active and competition among them will accumulate over successive trials. The effect of semantic blocking will apparently be to increase the competition among the candidate lemmas, or at least those lemmas that possess the schema-appropriate language tag, and thus category interference will result. A parallel scenario is not expected for L2 to L1 translation because the inhibitory control model assumes that in contrast to L1, L2 can be suppressed easily, and Green further adopts the representational arrangement proposed by Kroll and Stewart (1994) in assuming that direct lemma links mediate translation from L2 to L1.

It seems to us that another version of Green's model might also account for the category interference observed in L1 to L2 translation. Even if we assume that the control mechanism can effectively suppress active L1 lemmas, it seems likely that the higher-level context available in a semantically categorized list is likely to re-activate the semantically relevant L1 lemmas repeatedly over successive trials. That is, the salience of conceptual information about category membership is likely to have the consequence of activating related lemmas from the more dominant language. The effect of repeatedly activating a related set of L1 lemmas will be to counter the intended suppression of the task schema, and make it more and more difficult over trials to select the correct L2 lemma for production. On this account, there is not necessarily additional competition among L2 lemmas on successive trials, but increasing difficulty in suppressing L1.

In some respects, our major concern comes down to the question of how we are to determine how much of the activation/suppression is attributable to the control schemas and how much to other factors that modulate activation of the appropriate representations. Green's case seems strongest in the domain of understanding how people come to know which task they are to perform. Surely none of us arrived equipped with a lexical decision schema, so there must be some other level of control that is operative in order to perform such a laboratory task at a reasonable level of accuracy. However, a variety of factors, including language mode, word type, and bilingual proficiency, appear to influence the relative activation of the bilingual's two languages (e.g., Dijkstra, van Jaarsveld, & Brinke, in press;

Grosjean, 1997; Kroll & de Groot, 1997). It is not entirely clear within Green's proposal how to weight the relative force of these factors against the effects of the control schemas. Without a principled account of the relation between the control mechanism and the variables that determine activation of the two languages per se, it would seem impossible to tell how things combine to produce a particular performance.

Despite the difficulty of teasing apart these issues, Green's proposal has the enormously positive consequence of encouraging us to think of new empirical tests that might begin to contrast the predictions of the inhibitory control model with those of standard representational models and to reconsider some old results that are now accepted within the literature. Green mentions a number of promising directions for this research, including studies of language and task switching in which it should be possible to identify the immediate effects of suppressing one language or the other when a switch is required. In addition to switching phenomena, we believe that the inhibitory control model also makes interesting predictions about performance on a wide range of bilingual tasks. For example, consider the translation Stroop task in which a bilingual is asked to translate from one language to the other in the presence of a distractor word (La Heij et al., 1990). If Green is correct that translation from L1 to L2 requires active suppression of L1 lemmas, then presenting a distractor word in L1 once L1 to L2 translation has been initiated might not be expected to produce the usual Stroop-like interference. Or, at the least, the time course of interference should be influenced by the hypothesized suppression function. Likewise, it is intriguing to speculate about how the inhibitory control framework can handle the effects of cognate status in tasks such as word translation (e.g., de Groot, Dannenburg, & van Hell, 1994). If it is possible to selectively suppress lemmas in one language only, then under some circumstances we might not expect to observe the facilitation normally associated with cognate translations.

Although we doubt that any of these theoretical or empirical issues will be resolved quickly, we look forward with great interest to the debate and discussion that they create.

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Mental control, language tags, and language nodes in bilingual lexical processing

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In this paper Green proposes an inhibitory control (IC) model of bilingual lexical processing. At the core of Green's arguments is the notion of "mental control", formulated in terms of inhibition, control schemas, and a supervisory attentional system. The very notion of control, it seems, suggests some sort of intentional, exogenous force at work (e.g., the supervisory attentional system). Presumably, mental control differs from automatic processes (Schneider & Schiffrin, 1977), yet in the IC model there is no precise computational specification of how the various parameters of the control system actually interact to determine automatic bilingual processes. In a computational view, the IC model has quite some symbolic AI flavor (e.g., with goal-oriented decision boxes and control schemas), but it also attempts to integrate activation-based accounts (e.g., interactive activation mechanisms). Again, because the model remains at a rather conceptual level as is presented, it is difficult to determine how successfully it will be in combining symbolic and connectionist approaches in understanding bilingual processing.

According to the IC model, there are multiple levels of control, with each level associated with a specific schema, from high-level event scripts to low-level articulatory controls. The particular level at which the IC model operates is an intermediate level, the lemma level, whereby an inhibitory mechanism suppresses the activation of lemmas that are tagged as belonging to the language other than the intended one. Crucial to the functioning of this mechanism are the language tags, tags that are believed to be part of the conceptual system of the lexicon. But what is the nature of the language tags? In what form do these tags exist in the mental representation? How can we identify them? These are some of the simple questions that arise immediately, but seem to be left unanswered in the IC model.

Imagine that in our bilingual lexical representation we tag every item of the lexicon as belonging to one or the other language, and that the tag is part of the semantic or syntactic information of the word (i.e., part of the lemma). Multilinguals would correspondingly assign multiple types of tag, one for each language. If this were true, we should probably expect language tags to play a pivotal role in distinguishing lexical items of one language from those of another, eliminating or minimizing inter-lingual lexical interferences, at least on the semantic or syntactic level. We could suppose that, due to their conceptual or morphological transparency, these tags would receive strongest weights in inter-lingual tasks, possibly realized as features in a weight vector such as the ones in connectionist networks. The strong weights can therefore serve to easily differentiate words in the two languages. However, there is overwhelming empirical evidence for the existence of both priming and inference effects in a variety of inter-lingual experimental tasks. Thus, it is difficult to see that the language tags can play a significant role in differentiating the two lexicons, or that language tags can be easily identified, or that even there are language tags. Some recent work by French and Ohnesorge (1997) shows that distinct patterns associated with the two lexicons may emerge as a function of the probabilistic learning of mixed language sentences, with no distinct language tags, in a simple recurrent connectionist network (Elman, 1990).

If there are no language tags, how can we explain language switching? The IC model assumes that language switching takes time, since to switch to another language involves the inhibition of previous language tags. Recent studies, however, have cast doubt on the notion that there is a cost associated with language switching, especially in natural speech situations (Grosjean, 1988, 1997; Grosjean & Miller, 1994; Li, 1996). Moreover, it seems that natural code-switching does not necessarily involve prior planning, and may be constructed on the fly. In the IC model, the inhibition of a particular stimulus shuts down the activation of all other related stimuli in the same language from top down; this assumption seems to contradict several activation-based accounts that the bilinguals' two languages may be always activated, though the strength of the activation differs in specific linguistic situation, depending on the frequency of the target words, the sentential context, the speaker's proficiency in the two languages, and the speech mode (Grosjean, 1988, 1997; Li, 1996).

Towards the end Green draws a parallel between the language tags in the IC model and the language nodes in the Bilingual Interactive Activation (BIA) model (Grainger, 1993; Dijkstra & van Heuven, 1998). The language nodes in the BIA model function to reinforce lexical activations of the currently activated language, while at the same time decreasing lexical activations in the other lexical system. It is quite unclear at this point whether the language nodes are ad hoc constructs or necessary components of bilingual processing, just as it is unclear whether language tags are necessary. The seemingly separate lexical representations of the two lexicons, and the related inter-lingual priming/inference effects, might arise as a result of lexical and grammatical learning in a simple recurrent network (as discussed earlier) or in a self-organizing neural network, in which no distinct labels are given to items of the two or more languages. For example, in a self-organizing feature map model of the lexicon such as the DISLEX model of Miikkulainen (1993, 1997), words from both languages may exist in the same topological map, but over time the network can develop localized patterns of activity in learning the mappings between phonology/orthography and semantics or between morphology and semantics. These localized patterns of activity may correspond to the learner's internalized, distinct representations of the two lexicons. Thus, an abstract or supra-lexical level of language nodes or language tags is unnecessary, but the effects of the language nodes or tags can be captured precisely in such a system.

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Lemma selection without inhibition of languages in bilingual speakers

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The planning of speech involves making successive choices in a hierarchy of options. In the case of bilingualism, these options are provided by two lexicons and grammars rather than one internalized by a speaker. Conceptualization processes map a communicative intention onto a message indicating the conceptual information to be verbalized to reach a speaker's communicative goal. In bilinguals, the illocutionary intention may be to express oneself in one language rather than the other, or to mix languages. Formulation processes activate and select lemmas and forms for the message concepts, and plan a syntactic and a morphophonological structure. Lemmas specify the syntactic properties of words, crucial for their use in sentences. The result of formulation is an articulatory program, which, when executed by articulation processes, yields overt speech. A central theoretical problem is how bilingual speakers manage to keep the options provided by the two languages apart in monolingual conversation, and how speakers are able to integrate the options in bilingual conversation where language mixing (i.e., code-switching or borrowing) may take place.

Green proposes an inhibitory competition (IC) model in which the selection of lemmas in one language is achieved by inhibiting lemmas of the other language. In particular, a "language task schema" inhibits all activated lemmas whose language "tag" does not correspond to the target language. Consequently, the inappropriate language is prevented from controlling production. "Inhibition is assumed to be reactive though previous episodes of suppression may exert their effects since it takes time for the effects of prior inhibition to be overcome". Green discusses in some depth how the inhibition mechanism works in a translation experiment. "According to the IC model, at the start of a block of trials, the L1 => L2 translation schema calls the production schema for L2. At the stage of selection for output, this schema actively suppresses those lemmas with an L1 tag. Competition then on trial N+1 is primarily among activated L2 lemmas since any L1 lemmas active on the previous trial (N) have been inhibited". To support inhibition, Green refers to competition effects in experimental studies of task switching, Stroop interference, and neuropsychological case reports.

I believe, however, that the evidence for inhibition is not conclusive. In this commentary, I therefore make a case for lemma selection without inhibition. Firstly, the evidence referred to by Green concerns competition between tasks, but not necessarily between lemmas. Secondly, competition effects at the behavioral level do not necessarily point to an underlying inhibition mechanism (cf. Dell & O'Seaghdha, 1994). Thirdly, inhibition does not seem to be the appropriate underlying mechanism for separating languages in monolingual conversation and integrating languages in bilingual conversation. Like monolingual production, bilingual conversation can be fluent. Green argues that if lemmas of one language are selected to fill lexical gaps in the other language, his model predicts no dysfluencies because then there are no competing lemmas. However, filling language gaps is only one of the many linguistic and social reasons for code-switching (e.g., Grosjean, 1982, for review). Furthermore, advance planning does not necessarily prevent dysfluencies. Finally, evidence from monolingual production suggests that lemmas in sentence production may be planned in parallel. If bilingual production is like monolingual conversation in this respect, code-switching points to the need to accomplish selection without inhibition. During the planning of mixed-language sentences, lemmas of both languages should be simultaneously active to a certain degree.

The evidence for parallel activation of lemmas in monolingual production comes from speech errors and chronometric studies. For example, word exchanges such as the reversal of "roof" and "list" in "we completely forgot to add the list to the roof" (from Garrett, 1980) suggest that several lemmas (i.e., "roof" and "list") were active at the same moment in time. Similarly, Meyer (1996) obtained chronometric evidence for parallel activation of lemmas in planning phrases and sentences. Speakers had to refer to pictured pairs of objects by producing noun phrase conjunctions (e.g., "the tree and the house") or sentences (e.g., "the tree is next to the house"). During each trial, spoken distractor words were presented. These distractors were semantically related or unrelated to the first or second noun (e.g., the semantically related distractor for "tree" would be "bush"). For the conjunctions and sentences, Meyer obtained semantic inhibition from relatedness both for the first and for the second noun. This suggests that the lemmas of the nouns are retrieved in parallel. Bilingual speakers can produce mixed-language sentences at the same rate as monolingual sentences, which suggests that the advance planning of utterances proceeds the same in both cases. However, if lemmas in one language are selected by having a task schema inhibit all active lemmas in the other language, then the parallel planning of lemmas in a mixed-language sentence is not possible.

Below, I propose a simple mechanism for selection without inhibition. The proposal concerns an extension to bilingualism of the mechanism in the monolingual theory of lexical access, WEAVER++, proposed by Levelt, Roelofs, and Meyer (in press; Roelofs, 1992, 1997). To account for control issues in the planning of speech, the theory combines a spreading-activation network with a parallel system of production rules (i.e., condition-action pairs). The network represents a speaker's knowledge about words, whereas the production rules account for the computational problem of selection. To explain production costs observed in tasks requiring filtering (such as Strooplike situations), the theory advances a competition-sensitive response time mechanism. In particular, a selection ratio is proposed that weights the activation of the target lemma against the activation of all the other lemmas in the lexicon. As a consequence, the speed of selecting a lemma depends on how active other lemmas are. This underlying selection mechanism without inhibition has been shown to account for both inhibitory and facilitatory effects at the behavioral level. For example, computer simulations have demonstrated that, with an appropriate parameterization, the selection mechanism accounts quantitatively for the Stimulus Onset Asynchrony (SOA) curves of the semantic facilitation and inhibition effects of word and picture distractors in picture naming, picture categorizing, and word categorizing (see Levelt et al., in press; Roelofs, 1992).

In conceptually driven access, a production rule selects "its" lemma if the lemma is activated and connected to the message concept. For the bilingual case, two additional assumptions are required. First, similar to what Green proposes, the lemmas in the lexical network and the task representation should be specified for language. Second, production rules should make reference to the target language (and to the source language in translation). Thus, the system should contain production rules that say, informally, for example: <IF the concept is HOUSE(X) and language is French, THEN select "maison">, where HOUSE(X) is the message concept, French the target language, and "maison" the corresponding lemma. Production rules marked for language would account for the computational problem of how bilingual speakers manage to keep the languages separate in monolingual conversation. The rules would also account for the problem of selection in rapid code-switching. They select lemmas of the appropriate language while keeping the lemmas of both languages active, which allows for parallel retrieval. For example, in planning the (artificial) mixed-language sentence "the tree is next to la maison", the production rules <IF the concept is TREE(X) and language is English, THEN select "tree"> and <IF the concept is HOUSE(X) and language is French, THEN select "maison"> would fire, possibly at the same moment in time.

In conclusion, I am not convinced that there exists conclusive evidence for selecting lemmas of one language by inhibiting those of the other language. Competition effects at the behavioral level do not necessarily point to an underlying inhibition mechanism. Furthermore, inhibition of one language does not seem to be the ideal candidate for selection in bilingual conversation where code-switching takes place. Therefore, I made a case for language markers as a means of selection (as Green assumes) but production rules (i.e., condition-action pairs) referring to these markers as the mechanism of selection. Certainly, the evidence for selection without inhibition is not conclusive either, which is just another way of saying that more bilingual research is needed.

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Mental control and language selection

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A surprisingly large part of the population of the world is at least bilingual. The question how people are able to control their language system is an important one and has been a highly active research topic in recent years. Until know models have been quite simplistic but Green places his model in a wider framework of attention and control, drawing our attention to the fact that the mechanisms involved in language control share basic properties with the systems in other cognitive domains. Green introduces the (not language specific) supervisory attentional system in combination with language task schemas which make it possible to adapt to the situation in which the bilingual system is functioning. Models of bilingual processing should be able to explain how lexical processing is affected by, among others, task demands (see also Dijkstra, van Jaarsveld, and ten Brinke, in press). By adding a general mechanism of attentional control that is independently motivated by general cognitive mechanisms, Green has enriched his previous model considerably. In what follows we will first make some general remarks about the model Green proposes. In a second part we will discuss some recent results from our group that nicely tie in with some of the basic properties of the model outlined by Green.

First, the model is linguistically too simplistic (as all models in this area). The conceptual system produces (language specific?) lexical concepts, lexical concepts activate their lemmas, and lemmas are tagged for language. L2 lemmas 'point to' their L1 translation equivalent. A lexical concept in L2 may activate also an L1 lemma to the extent that is shares properties with a lexical concept in L1. By speaking of lexical concepts IN L1 or lexical concepts IN L2 Green indicates that the lexical concepts are language specific. This in turn implies that the conceptualizer is producing messages which are language specific (or that the mapping of conceptual structure onto lexical concepts is left out of the model). Elsewhere (Bierwisch and Schreuder, 1992, de Bot and Schreuder, 1993) we have argued against this position. We will not discuss further this possible property of Green's model here, because it is a general property of many models. Here we want to point out that a linguistic simplification in Green's model is the assumption of one to one mappings between lemma's of different languages. But in fact mappings are sometimes one to many, or many to one, or even many to many. As a very simple example, Dutch does not make a distinction between 'nephew' and 'cousin' (in Dutch both 'neef'). And as we have discussed in earlier work cited above, languages may vary widely in their lexicalizations patterns. It may happen that one word in the lexicon in one language corresponds to a phrase or an expression in another language, and vice versa. If we also think of the fact that languages may vary considerably in their productive morphology it becomes clear that a one to one mapping of lemmas is linguistically and psycholinguistically an oversimplification (perhaps at this moment unavoidable). The production of words from a bilingual mental lexicon is a very complicated issue that needs much more theoretical and modeling effort (for some of the complexities of the issues involved in keeping languages separated in word production, see de Bot and Schreuder, 1993).

In the following part we will discuss some relevant recent results of our research group (Hermans, Bongaerts, de Bot, & Schreuder; in preparation). Green states: ".... the process of inhibitory control through tag suppression occurs after lemmas linked to active concepts have been activated." The mechanism of inhibition is 'reactive': only when a lemma is activated can its language tag be examined. If it is the wrong language the lemma can be inhibited. In a recent series of experiments we have examined whether or not words from a first language (Dutch) were activated during lexical access in a foreign language (English). In one of these studies we used a picture-word interference experiment where subjects were instructed to name the pictures in their second language, English. The interfering (spoken) stimuli were also English words. During the whole experiment no Dutch words were used. For instance, a picture of a mountain could be paired with a phonologically related interfering stimulus (IS) like MOUTH, a semantically IS (VALLEY), or unrelated IS (PRESENT). Crucially there was also an IS that was phonologically related to the DUTCH name of the picture (IS BENCH, the Dutch translation of 'mountain' is 'berg'). One of our predictions was that if the Dutch lemma were also activated during naming in English, then at some SOA, between picture and word lemma selection would be made more difficult because of competing lemma representations. The experiment was carried out with 4 SOA's (-300, -150, 0, 150 msecs; a '-' indicating that the onset of the auditory IS precedes the onset of the picture). Three interesting results were found in this experiment. First, a phonologically related IS (MOUTH) facilitated naming times for all SOA's. Second, semantic interference effects were found for SOA's -300, -150, and 0. But most crucially at a SOA of 0, an interference effect was also obtained for ISs that were phonologically related to the Dutch translation equivalent (BENCH). This occurred at an SOA where the English lemma must have been activated already (because of the semantic interference effect at that SOA). Hence we found evidence for the claim that the (more frequent) Dutch name of the picture is activated during the lemma selection process. (Other results indicated that the phonological form of the Dutch word was NOT activated, for details see Hermans et al. in preparation). In sum, the assumption of Green's model that inhibition takes place late and is reactive, is clearly supported by our results. Apparently it is not possible, even in a task situation where only one language is relevant, to suppress lemma activation of the non-selected language. Thus, on the one hand bilingual individuals cannot control the use of their lexicon at a certain level (that of lemmas) and on the other hand they can (at the level of word forms) since our subjects only very rarely produced a Dutch word instead of the required English. At the level of lemma activation bilingual speakers appear to be monolingual.

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The IC-model and code-switching

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In his contribution, Green proposes a very interesting model of bilingual speech processing, the Inhibitory Control Model. The model's aim is to account for the way bilinguals control their two language systems. Although the model was not developed to account for code-switching, the author explicitly goes into implications of his model for code-switching and this makes it very relevant for linguists working in that field. Until now, psycholinguistic aspects of code-switching have received far less attention in the literature than the syntactic aspects of code-switching. The model therefore offers an excellent starting point for incorporating insights from psycholinguistics into code-switching research and vice versa.

The IC model accounts, among other things, for the fact that bilinguals are able to translate from L_1 to L_2 without actually naming the L_1 word. This is done by assuming that lemmas are specified in terms of a language tag. Thus, each lemma has an associated language tag and this tag is one of the factors which affects the activation of the lemma. After lemmas have been linked to lexical concepts, the model allows for lemmas with the "wrong" tag to be inhibited, so that they cannot catch speech production during a translation task.

For many reasons, the concept of lemmas having associated language tags is a very attractive one. It is possible, however, that language tags exist at other levels as well. We know from studies of derivational morphology that a derivational morpheme like *-ity* is mainly attached to Romance or Latin roots such as *absurd* (*absurdity*) but not to native words like *red* (**redity*) (see Appel and Muysken, 1987). Although in more extreme cases of language contact the combination of morphemes from different languages is possible (see Thomason and Kaufman, 1988), it is clear that speakers somehow "know" that roots and inflections belong to language A rather than to language B. A possible way to account for this is to assume that roots and affixes have associated language tags. Of course, the advantages and disadvantages of this approach for models of bilingual processing need to be investigated in more detail.

One may also wonder whether a more differentiated view of language tags can be useful. In Optimality Theory, the lexicon marks for each element its phonological features, its semantic features and its formal features. It seems only natural to assume that - in the case of bilingual speakers - each element also has a language tag. Interestingly, Optimality Theory allows for features to be either strong or weak. It could be assumed that language tags associated with lemmas can also be strong or weak. For words that are phonotactically recognisable as belonging to language A the language tag would be a strong feature, whereas for others it would be a weak feature. Some evidence for this idea can be obtained from Grosjean (1995) language only (the guest language) are recognised sooner and with more ease than words not marked in this way. Applying this idea to established borrowings which have become fully integrated into the language, such as *pound* in English, is perhaps also interesting. It is clear that such words are no longer recognised as borrowings by native speakers of English. If we adopt the idea that language tags play a role in the recognition of borrowings, we may assume that in the course of time language tags are lost and/or replaced. As a result, *pound* can no longer be recognised as a borrowing. The concept of language tags functioning as strong or weak features of lemmas can perhaps also be exploited to account for differences in syntactic patterning of borrowings and single word switches (Poplack and Meechan, 1995).

A related issue is of course whether in borrowing or code-switching lemmas or lexical concepts are imported into the other language. There are probably different possibilities, which each in turn result in different patterns. Words can be borrowed/switched with all their semantic, syntactic and phonological characteristics, but this is not always the case. Well-known is the fact that nouns are often borrowed without their article, even though in some language pairs nouns can be borrowed in combination with their article. Assuming that the article belongs to the information contained in the lemma, does this mean that nouns are sometimes borrowed with and sometimes without their associated lemmas? An example from Brussels Dutch/Brussels French contact shows that syntactic information concerning the gender of nouns, which is assumed to be contained in the lemma, is transferred in the process of borrowing in some cases, but not in all cases. When borrowed into Brussels Dutch many French nouns keep their original French gender, but they behave like Dutch nouns in other respects. Thus *tember* from French *timbre* (stamp), which is masculine in French, obtains a Brussels Dutch masculine article, when borrowed into Dutch, which indicates that gender borrowing has taken place. (see Treffers-Daller, 1994; in press). In the case of other nouns, such as *plafond* (ceiling), the French gender is not transferred, and it remains questionable whether any syntactic information is imported at all.

In the cases cited above it appears that there is a rather loose association between the lexical concept and the syntactic information contained in the lemma, and that one can be borrowed without the other[1]. Syntactic information contained in the lemma is sometimes borrowed only in part. This issue could be important for the model Green proposes. In the IC model a checking procedure establishes whether a lemma is linked to the appropriate lexical concept. This binding-by-checking solution seems to work well in monolingual discourse, but it is difficult to imagine how this works in the cases mentioned above. The French borrowings *plafond* and *tember* are clearly not associated with their French lemmas when they are used in Dutch discourse. The most attractive solution is probably to say that a new Dutch lemma is created on the spot for these French borrowings. The syntactic information from the French lemma is only partly integrated in the new lemma.

A final important issue concerns the status of interlingual cognates, such as English *carrot* and French *carotte.* The question which interests us here is what language tag(s) these items have. The code-switching literature contains many examples which show that cognates trigger code-switching, as in the Brussels-Dutch/Brussels French example (1):

(1) *Un petit canari* doe geen vuil

"A small canary doesn't make anything dirty." (Treffers-Daller 1994: 235)

The switch from French to Dutch takes place at the point where the two languages overlap, that is at the cognate *canari*. Although the sentence starts off in French, somehow Dutch becomes activated in the course of the sentence production, and it is likely that the cognate has triggered this change of base language[2]. Could this be because cognates have two languages tags? Or are there two lemmas involved with differing language tags which compete to catch speech production? Clearly the concept of a language tag needs to be investigated in more detail in order to account for the cases studied above.

It would also be very interesting to further investigate Green's idea that in code-switching cooperation rather than competition between word production schemas is taking place. It is in this context that links can be established with both Grosjean's (1985, 1997) model of bilingual speech processing and Optimality Theory. According to Grosjean's model speakers can be in a monolingual mode, and in that situation words from the other language are deactivated as far as possible. In other contexts they may be in a bilingual mode, and both languages are activated. How does cooperation between word production schemas take place in the latter case? When formulated in terms of Optimality Theory, does this mean that the candidate set generated by the generator contains different possible constructions which are all equally acceptable to the evaluator? As the evaluator operates with syntactic constraints, it is at this point that research into constraints on code-switching can become relevant.

From the discussion above it is evident that Green's model opens new perspectives for studies into psycholinguistic aspects of code-switching and a further exploration of these can hopefully provide new insights in the way bilinguals control their languages.

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Footnotes

1 Borrowing of lemmas without their associated lexical concepts would probably be termed lexical interference by many researchers.

2 The article *un* is actually cognate with the Dutch indefinite article *een*, which makes it very difficult to say whether we are dealing with a Dutch or a French NP.

Schemas, tags and inhibition

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The commentators raise many important issues and suggest fruitful lines of development. I thank all of them for their efforts. My paper focused on how bilingual speakers control the lexico-semantic system rather than on the nature of that system. It glossed over the processes of word recognition (Carr, Dijkstra) and considered only cursorily issues such as the mapping of thought into language (Schreuder & Hermans), the role of conceptual activation in lemma selection (Kroll & Michael) and the range and nature of the semantic relationships between words (Schreuder & Hermans, Treffers-Daller, Ping Li). I will comment on these matters as I address three concerns about the proposed control processes: 1. the nature of schemas and their role in control (Carr, De Groot, Dijkstra) 2. the notion of a tag: its psychological reality (Ping Li, Treffers- Daller), its relationship to a language node (Dijkstra) and its role in selection (Carr) and 3. the question of inhibition as the general means of lemma selection (Carr, De Groot, Roelofs).

The notion of a schema

The intended sense of a schema is procedural. A schema implements a declarative representation of the instructions in order to achieve the control of action. It is therefore not equivalent to understanding experimental instructions (De Groot). The procedural usage of the term dates from the time of Head (1926) and stemmed from the recognition of the specificity of motor skills. Its lineage can be traced. Schmidt (1975, p. 235) proposed that a specific action is controlled by a motor response schema formed by abstraction from movements of the same general type. Arbib (1985) elaborated the notion and argued that subcomponents of a skill are each represented by lower-level schemas that need to be coordinated with one another. At a higher level, concepts such as scripts or Memory Organization Packets (Schank, 1982), have been proposed to represent the organization of well learned activities such as going to a restaurant. At this level of action the detailed physics of movement are not specified: there are many ways of going to a restaurant and other unrelated, actions can be interleaved. At an intermediate level of action are actions such as making breakfast where subactions are cognitively represented. We can elect to perform an action such as pouring the coffee but parallel actions (e.g., brushing one's teeth) rarely occur.

The immediate precursor to the notion of schema in the inhibitory control (IC) model was the work of Norman and Shallice (1986) who proposed that selecting an intermediate level action involved activating its schema above threshold. Schemas receive activation bottom-up if the stimulus matches specified sets of perceptual conditions. Activation is also received top-down from higher-order schemas. Schemas were held to be in lateral inhibitory competition with one another, with the degree of lateral inhibition dependent on the degree of overlap between the schemas in their requirements for executing the associated action.

Schemas in the IC model concern language actions (e.g., naming a picture in one language, L1 rather than in another, L2). In an interactive activation framework, we can characterise a schema network whose nodes correspond to a variety of language action schemas. Selection of a schema occurs when the activation of its node exceeds some threshold. Activation of a schema (e.g., translate into L1) affects the flow of activation within the lexico-semantic system. Activation of a low-level schema triggers specific actions (e.g., articulate word or press a button). The model is not implemented but its simulation would involve both continuous variables (degree of activation) and discrete variables (the binding by checking mechanism) and would be an instance of a hybrid model (Ping Li).

Certainly, identification of schemas in the IC model requires a thorough analysis of the task individuals are asked to perform (Carr, Dijkstra). Experimental and real-life tasks comprise goals, triggering conditions (the nature of their input), a specification of the sequencing and timing of operations (including their iteration) and process-specific information about what counts as goal attainment (e.g., in an experiment, the relationship between reaction time and error). In the bilingual case such an analysis can help determine the nature of the operational demand and language demand (Carr).

But how do we go from such an analysis to suppositions about the schemas involved in controlling the bilingual lexico-semantic system. In the IC model, lexical decision schemas or picture naming schemas are held, in certain circumstances, to mutually inhibit one another. But why assume, for instance, that there are two separate schemas for lexical decision, one for L1 and one for L2. Why not a single generic lexical decision schema that can take different parameters (Dijkstra)? Schemas can be viewed as methods to achieve goals (Cooper & Shallice, 1997) and so it is perfectly reasonable to envisage a system in which one goal replaces another in a generic schema. In fact, the IC model assumes a hierarchy of schemas so a translation schema for translating from a second language (L2) into a person's first language (L1) calls a production schema in L1. The translation schema alters the default input of the L1 production from conceptual activation (as in spontaneous speech) to one determined by an external verbal input. But where does one stop in this process of adapting a task schema? Consider a reductio ad absurdum. There is a schema termed "act". A different task requires changing parameters in this open-ended schema. Rather than commit ourselves to this reductio we assume that there are separable schemas characterised in terms of overlap in their goals, input conditions, processing operations and output conditions. So why not a generic lexical decision schema?

Let us consider how a specific lexical decision schema, for instance, might be constructed. A goal node (e.g., evaluate input as L1) could be linked to a generic lexical decision schema to create a language-specific lexical decision schema (i.e., one designed to answer the question: "is this letter string a word in L1?"). A new language-specific lexical decision task involves creating a new goal node (evaluate input as L2). But how does the new goal node link up to the generic schema? There must be a process (involving the supervisory attentional system) that constructs the link to the schema and suppresses the pre-existing link between the schema and the previous goal node. Suppose the experiment involved switching between an L1 lexical decision task and an L2 lexical decision task. The links between the schema and the goal nodes are used repeatedly. Under repeated use, a generic task schema with goal replacement may naturally evolve into two distinct schemas that compete to control action. Moreover, the creation of two specific schemas may be efficient since activating such a schema would reinstate in one move the various parameters suited to performance in a given a language (e.g., in the lexical decision task, one such parameter might be the time interval that individuals tolerate before deciding that the letter string is not a word). However, in the case of a lexical decision task in which individuals can respond "yes" if they detect a word in either language, it does seem more natural, to assume a single schema linked to two goal nodes, one for L1 or one for L2 (Dijkstra). But this too, will, with repeated use, become a specific schema.

Schemas can be readied in advance through the supervisory attentional system and so part of the process of control is proactive (cf. De Groot). A task that requires the naming of a picture in a particular location involves modulating the representation of information in that region of space. Such activation will speed processing of such items. Individuals may also be able to mark a system of lemmas as "active" rather than "dormant" on the basis of instructions. However, control cannot be solely proactive. A solely proactive system cannot explain why it is that switching between tasks incurs a reaction time cost even when the time interval between the two tasks exceeds the duration of that switching cost (Rogers & Monsell, 1995).

Reconfiguration of task schemas seems to require a relevant stimulus input and not simply an anticipation of such an input.

Tags, language nodes and the locus of selection

A language schema specifies the language required as part of its goal. Tags provide a means to check that any response meets the language goal. If there is no explicit marker for language, and language is merely implicit in a network of connections (Ping Li), there must still be a way to monitor goal achievement by the supervisory attentional system. A process that checks that a response has emerged from a specific network, or part of that network, is arguably a tag in disguise. Indeed, rather than eliminating the notion of tag, Treffers-Daller suggests there may be merit in extending and differentiating it.

It is worth stressing that the notion of a language tag is entirely compatible with the idea that lexica are self-organizing. The IC model adopted the subset hypothesis (Paradis, 1989) which presumes that the bilingual lexico-semantic system is composed of self-organized networks. Such networks still need to be controlled in order to achieve intended tasks (see Miikkulainen, 1997, p. 350). Tags may also be a way to ensure that thinking for speaking can be language-specific. Languages differ in their lexicalization patterns (Bierwisch & Schreuder, 1992; Schreuder & Hermans) and in their lexical concepts (e.g., Slobin, 1996). Granted a non-linguistic representational system (e.g., one involving images) thinking for speaking involves specifying the language of expression. Two factors are likely to be involved here: global activation of lexical concepts (i.e., making the set of concepts active and so available for the construction of a message) and the discourse topic and context that activates domain-specific concepts (Grosjean, 1997).

In the IC model, the primary role of a language tag is in lemma selection. We can answer the question the question of the relationship between a tag and a language node (Dijkstra) by considering how the notion of a tag can be implemented computationally. Suppose a localist implementation of the type used in the BIA model (Dijkstra & Van Heuven, 1998; see also Roelofs, 1992). Each lemma would have a link to a language node (which could be a network of neurones not just a single neurone) just as each lemma is linked to a syntactic node (e.g., noun) and to a node specifying its grammatical gender (e.g., Schriefers, 1993). A word's language tag in this implementation is the link between the word's lemma and the language node.

Such an implementation of the IC model contrasts with the current BIA model in assuming that the connection between a word and a language node is at the lemma level and not at the level of the word's orthographic representation. A lexical decision, for instance, is based on the activation of this lemma-language node link. That is, just as a decision about a word's grammatical gender requires activation of a gender node, a language-specific lexical decision requires activation of the language node. Patterns of activation in the orthographic input system also affect lexical decision-time (Carr, Dijkstra).

How might these be explained? Consider, the study by Dijkstra, Van Jaarsveld & Ten Brinke, 1998 (see Dijkstra) in which lexical decision times to an interlingual homograph such as "angel" (meaning heavenly messenger in English and sting in Dutch) are only delayed over those for control words when real Dutch words are included in the items for English-specific lexical decision. Most likely, a single Dutch word is sufficient to shift the Dutch lexicon from "dormant" to "active". Conceivably, instructions to expect a Dutch word are sufficient to render the system active. Either way, once the Dutch lexicon is active, the lexical decision schema for English will receive contradictory information via the Dutch lemma of the interlingual homograph. It remains to be determined whether or not there are independent effects from the orthographic level to the lexical decision schema that cannot be explained in terms of lemma activation or whether, as in the study described by Schreuder & Hermans, such effects are mediated by competition at the lemma level.

To claim that response selection is mediated by inhibitory processes at the lemma level is not to deny the possibility that in a given task other representations may be subject to inhibition (see Tipper, 1992 for a discussion of different loci of inhibition). It is to just to claim that where a task requires that responses are selected in terms of language then selection at least involves inhibition at the lemma level. Switching between languages in a semantic task in which individuals are required to judge whether or not a presented word refers to an animate or to an inanimate entity will not incur a switching cost.

The IC model postulates that inhibition is not simply a relative global inhibition of lemmas in the non-target language: it is reactive and necessarily selective. Given a localist interpretation of a tag how is the inhibition of competing responses achieved? The language schema for L2 suppresses the competing language node for L1 biasing against selection of items in L1 but not precluding competition. Selectivity may be achieved either directly, via attentional control, or indirectly via lateral inhibitory links between competing responses. Translation equivalents are presumed to be connected through lateral inhibitory links. In consequence, the greater the activation of a lemma for L1 when the required lemma is for the translation equivalent in L2, the greater the suppression of the L1 lemma. However, the IC model also supposes that inhibition can be applied via a language schema to semantically-unrelated but competing items for which it seems implausible to suppose any pre-existing lateral inhibitory connections (see Anderson & Bjork, 1994, pp. 304-308 for evidence of such effects in memory experiments). In the bilingual area there is a need for a convincing demonstration of such selective, and not merely global, inhibitory effects and to specify their computational basis more fully.

In discussing Kroll and Stewart's finding of an effect of category blocking in forward translation (L1=>L2), but not in backward translation (Kroll & Stewart, 1994; see Kroll & Michael), I noted that their result could have arisen because of the activation of L1 lemmas and the consequent requirement to inhibit these in order to produce a response in L2. Kroll and Michael urge this interpretation. They are right to do so. The IC model supposes reactive control. On a given trial in the category blocking condition, although the L1=> L2 (forward) translation schema can bias against the selection of L1 lemmas, L1 lemmas can be activated and must then be inhibited. L1 lemmas from previous trials do not enter competition but conceptual activation together with the strong links between lexical concepts and lemmas in L1 will yield L1 competitors for selection. This suggests that there are likely to be two different effects involved in category blocking in forward translation: conceptual activation boosts competition from an L1 lemma on each trial and, in addition, it boosts competition from previously active L2 lemmas and these compete for selection as well. The category blocking effect in forward translation is a phenomenon worthy of further study. Do L1 words show category-specific inhibition?

In discussing translation only single word contexts were considered. Schreuder and Hermans point to the real complexity. For instance, often as not there is no one to one mapping between lemmas. The word "sibling" in English, for example, must be expressed as the phrase "brother or sister" in Dutch. This would block any backward translation via a lemma-to-lemma link. Treffers-Daller points to other interesting phenomena in the area of lexical borrowing. A lexical concept in Brussels-Dutch may be imported either with, or without, its original gender. But the single word translation equivalents do offer further opportunities to explore competition between lemmas. Consider instances where translation equivalents possess different genders (e.g., for moon: la lune vs. der Mond). Judging the gender of an L2 noun should be slower when the L1 noun possesses a different gender. The context of such an interference will provide evidence of the conditions under which lemma competition arises.

Inhibitory processes of selection

The Levelt/Roelofs model (e.g., Levelt, Roelofs, & Meyer, in press; Roelofs, 1992) implements a mathematical rule (the Luce choice rule) in which the time required to select a lemma is a function of the activation level of other lemmas. This model is an existence proof that selection can occur without inhibition and it fits a body of experimental data. But is this how selection is achieved psychologically? Inhibitory process are ubiquitous in the nervous system (e.g., Houghton & Tipper, 1994) suggesting that an inhibitory control mechanism is plausible. But as Carr emphasizes we need to establish adequate criteria before concluding that inhibition is actually involved in a given task.

Mathematically, there is no reason to reject an inhibitory control model. A model in which selection is based on the most active node in a network involving inhibitory connections (technically, one that implements a Thurstonian noisy-choice process) gives similar outcomes to a model that implements the Luce choice rule (e.g., Page, 1997). But is there any reason to prefer this kind of solution? There is. The Thurstonian approach is simple to implement in terms of a localist model and so may be more realistic neurally (Page, 1997). Second, a combination of excitatory and inhibitory processes is more efficient in achieving selection than excitatory processes alone. Consider the situation in which there is a target and a distractor. Selection could be achieved by activating target items more than distractor items but computationally Houghton and Tipper (1994) have shown that a mechanism that excites target items and inhibits distractor items can double the rate at which the two kinds of material can be separated. The inhibitory proposals contained in the IC model may therefore be an efficient solution to the problem of selection.

Inhibitory processes can also explain certain effects that activation-only models have difficulty explaining. The work of Levelt and colleagues (e.g., Levelt et al., in press) has focused on the impact of distractors on the time required to respond to a concurrent target item. But we also need to explain why it is that individuals respond more slowly to a target if it was a distractor on an immediately preceding trial. On a direct application of the Luce rule, it is difficult to account for such "negative priming". However, if the distractor has been subject to inhibition (i.e., it is at a lower level of activation than a control item - see Anderson & Bjork, 1994) we can predict that a subsequent response to it will be slower in certain circumstances.

One way to explore this question is to examine performance changes as a function of proficiency. As Dijkstra noted, automaticity, fluency and control are interlinked concepts: concept-lemma links and lemma-word form links change with fluency. Competition between alternative responses should increase with fluency in contexts where both languages are active. Increased competition should induce greater inhibition of unwanted competitors. Recent experimental data by Neumann, McCloskey & Felio (1998) are consistent with this suggestion. Individuals on a prime trial were asked to name a target word in English and to ignore an unrelated distractor word. On an immediately following probe trial individuals made a lexical decision about a Spanish target word and had to ignore an unrelated English word. On the probe trial, the time required to make the Spanish lexical-decision was greater (relative to that for a matched control item) if the target for lexical decision was a translation equivalent of the previously ignored distractor. Critically, this negative priming effect was much greater in proficient, relative to less proficient, English-Spanish bilinguals. According to the IC model, in situations where both languages are active, translation equivalents compete to control output. The competitor is more activated for proficient bilinguals and so requires a greater degree of inhibition.

Is inhibitory control irrelevant as a mechanism in code-switching? The IC model correctly predicts a cost in switching between languages in certain circumstances such as when a response is externally cued. It also predicts dysfluency in circumstances when normal code-switching is precluded. In code-switching, lexical concepts from both language are active though one language may act as the base language. The relationship between the language production schemas must therefore be cooperative rather than mutually inhibitory. But such a cooperative relationship does not entail the general absence of inhibitory control. Code-switches can be triggered by lexical overlap (Treffers-Daller) which suggests the importance of local activation, rather than intentional activation in code-switching. But to the extent, a code-switch is intended then it is part of the message. In such circumstances, any dominant non-target competitor lemma must be inhibited. Likewise, the production of the words in the correct serial order, given the parallel activation of lemmas, may be best modelled, like any complex action, in terms of inhibitory mechanisms.

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