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Mental control of 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.

There has been progress in understanding the nature and organization of processes underlying the performance of specific tasks (e.g., single word production, see 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). On 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.

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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 (called 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

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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 and van Heuven, 1998), 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 demonstrated that individuals can be influenced by the nature of a non-selected language (i.e., one that is apparently switched off, though see Grosjean, 1997, 1998, 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, 1997, 1998). A comparable view has also been adopted by individuals researching visual word recognition in bilingual speakers (Grainger, 1993; Dijkstra and Van Heuven, 1998).

The purpose of this paper is to stimulate debate and exploration of the mechanisms of language control in bilinguals. The remainder of paper is structured as follows: The first section likens mental control in language processing to the control of action, a thought which 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. The second section describes a specific inhibitory control model, the IC model, 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 third 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 (1985a, 1997, in press) 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; see 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 and 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 and Schreuder, 1993; Grainger and 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 and Farringdon, 1995; Cooper and Shallice, 1997) based on an interactive activation network (McClelland and 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 and Shallice, 1996). Figure 1 depicts the proposal. 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

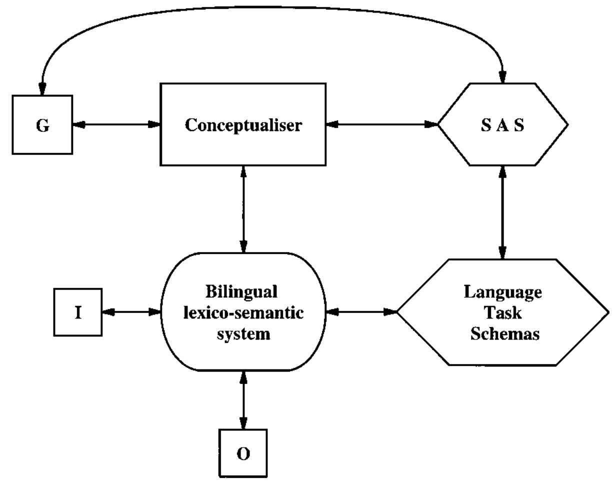

Figure 1. The regulation of the bilingual lexico semantic system displaying multiple levels of control.

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 of 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 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 and 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. However, only knowledge of language performance before brain-damage can really indicate whether or not such behaviour reflects a deficit or a communicative device normally used with bilingual addressees (see Grosjean, 1985b). 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 (i.e., 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.[1] 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 and Obler, 1978, for earlier usage; see also Green, 1986, 1993; Monsell, Matthews and 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 and 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 the 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 and 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

[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 comprehen sion 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 under stood, 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 interfer ence. 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.

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. Figure 2 presents their model; the relative size of the box indicates size of vocabulary. 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.[2,3] 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.

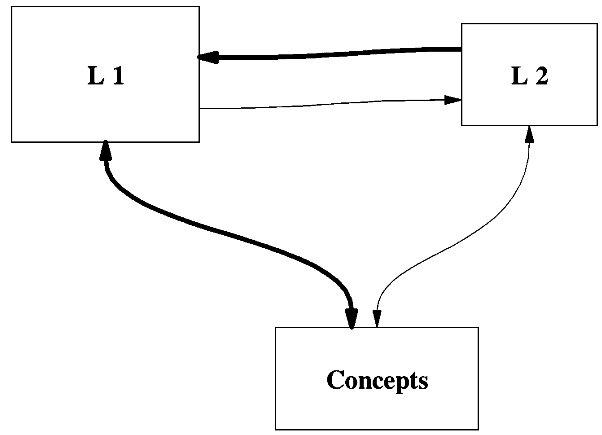

Figure 2. The revised hierarchical model of Kroll and Stewart, 1994.

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 and 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

[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.

[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.

speech production. Indeed, Kroll and De Groot (1997, pp. 189 93) 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 to, rather than instead of, direct links between word forms.

The revised hierarchical model has generated much productive research (see De Groot, 1995; Kroll and 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 and Comijs, 1995) though recent research (see Kroll and 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 and van der Velden, 1996) and/or the product of acquisition history (see Kroll and 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 with 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 and Stewart, 1994, 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 and 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 may take time (1) because it involves a change in language schema for a given task, and (2) 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. Of course, in normal speech situations that permit prior planning of an utterance, intentional code-switching can be fluent and smooth (see Grosjean and Miller, 1994).

Language switching in reception 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, that is, there is predictable switching between languages. We will describe the study by Von Studnitz and Green (1997; see also Thomas and 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.

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 a particular language requires activation of its associated lemma and tag. But we note, as Grainger and

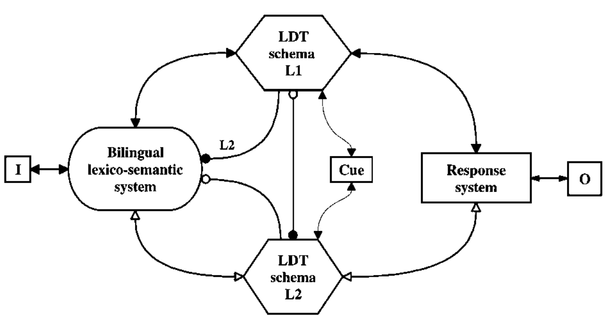

Figure 3. Regulatory processing in a lexical decision task involving language switching (self inhibitory links on schemas are not depicted). The L1 task schema is shown to be suppressing the L2 task schema and inhibiting L2 lemmas in the bilingual lexico semantic system.

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, 1997 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 and 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 languages in certain word production tasks such as numeral naming: different language schemas 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 languages 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 be 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 and 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 with 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 Leiser (1990, Experiment 1) support 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 with neutral or congruent trials. However, congruent trials showed equal facilitation. According to the IC model, the colour naming schema dominates the word reading schema when individuals know that there is a high proportion of incongruent trials. The effect of the 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, from the competition for selection in naming the probe picture in French, the English lemma associated with the lexical concept evoked by the definition.

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, 1997), visual word recognition (Dijkstra and van Heuven, 1998) and speech production (de Bot and Schreuder, 1993; Poulisse and 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, 1985a, 1997). 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 and to the proposals of Paradis (1984, 1997), models based directly on Levelt's production model (De Bot and Schreuder, 1993; Poulisse and Bongaerts, 1994; see also Poulisse, 1997) 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 (1997) 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 and 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, 1997, 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 and Beauvillain, 1987). BIMOLA (**B**ilingual **M**odel of **L**exical **A**ccess) can account for these effects in terms of the bottom-up flow of activation between levels together with within-level inhibition between competing candidates.

In contrast to Grosjean's model (Grosjean, 1997) but like the IC model, Dijkstra and van Heuven (1998) 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 and 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 a 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.

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. 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. In contrast, 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 (1997), dysfluencies and involuntary language mixing can arise and such effects should increase with additional load on SAS.

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 are also more likely to name the distractor 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 and Fox, 1997, 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 begun an exploration of these circuits using positron emission tomography, PET (Green, von Studnitz and Price, 1997). German-English bilinguals were scanned whilst reading or translating unrelated, visually presented words. We found (1) 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, (2) 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 and DiGirolamo, in press), and (3) 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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PEER COMMENTARIES

Mechanisms of control in activating and deploying lexical knowledge

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David Green's excellent paper "Mental control of the bilingual lexico semantic system" raises three fundamental questions. My goal is to suggest elaborations on his answers that might make the arguments stronger and more comprehensive.

Green's first question is how to integrate task demands into models of lexical processing. Most current modeling focuses on the architecture and operation of an underlying "lexico semantic system" assumed to exist independently of any particular task performance. Yet it is data on particular task performances from which we infer the underlying system. Hence we must be very explicit about how that system is used to carry out tasks, and how choice of task might alter the system's operation and its apparent functional architecture (Carr, Pollatsek, & Posner, 1981; Grainger & Jacobs, 1996; Grosjean & Frauenfelder, 1997). A "task" consists of a universe of stimuli, a set of decisions or thought processes to be applied to those stimuli, and a set of responses or actions that result from the thinking. Where bilingualism is concerned, two types of task demand constrain cognitive activity. "Language demand" defines which of the performer's languages is relevant at the input and output ends of the task. "Operational demand" defines the decision or thought process that must be carried out, and hence determines the particular sequence of computations that must be executed. Changing either the language or the operational demand changes the task. For example, if the operational demand specifies "pronunciation" and the language demand specifies both the input stimuli and the output responses as L1, then the "task" is speeded pronunciation or naming. If the operational demand specifies "pronunciation" and the language demand specifies the stimuli as L1 but the responses as L2, then the task changes to "forward translation". Reversing L1 and L2 changes the task to "backward translation". And so on. Analyzing and investigating similarities and differences among tasks is complicated. The experimenter's natural love of such complexity makes this a rich and attractive situation, but the experimenter is a human being. The human being's natural limits in dealing with complexity make this a dangerous situation full of sticky intellectual tar pits.

Does any tar stick to Green? The language demand is Green's primary concern. In tasks that might activate both lexicons, how do bilinguals ensure that the right lexicon is the source of information on which performance is based? The problem is obvious in translation, which explicitly demands that both lexicons be consulted, but can also arise in pronunciation and lexical decision if there is automatic spreading activation between languages. This issue leads directly to Green's proposal regarding an inhibitory mechanism of selection. Unfortunately, attending carefully to the language demand sometimes diverts Green from the complexities of the operational demand. Discussion of pronunciation and translation of written words revolves around which language is input and which is output. Predictions derive entirely from the asymmetrical interlanguage connectivity proposed by Kroll and Stewart (1994). This analysis is powerful once processing has reached "the lexico semantic system", but it skips over the critical role played by prelexical orthographic analysis in visual word recognition. Formation of an orthographic code representing visual form is widely held to be a prerequisite for gaining access to lexically specific knowledge (e.g., Carr & Posner, 1995; Coltheart et al., 1993; Plaut, in press; Ziegler et al., 1997). When L1 and L2 writing systems are similar, orthographic encoding for L2 can rely heavily on mechanisms already established for L1. When writing systems differ, problems increase. For example, Haynes and Carr (1990) found that among accomplished Taiwanese undergraduates who had been reading and studying English for years, orthographic processing efficiency measured in same different matching of words, nonwords, and random letter strings varied considerably. This variation predicted reading comprehension and learning new vocabulary from context, even after a wide range of other factors were taken into account. Similar patterns might occur in speech processing as a function of L1 and L2 phonological similarity. Such levels of processing, which prepare perceptual representations and feed them to the lexico semantic system, are currently ignored in Green's theorizing. Would taking them into account force changes in his model? We don't know. And if changes were needed, would they alter the instructional recommendations that would result when the model is used as an aid to designing curriculum? Again we don't know, until these levels of processing are included in the model.

Another area in which task analysis falls a bit short involves one very commonly used task, lexical decision. This task invites a straightforward analysis: if a word's representation in the mental lexicon gets activated above some threshold level, respond "word". If a sufficiently long time goes by without a word code exceeding the threshold, respond "nonword". Green adds the idea that each word code has a language tag. If the task requires responding "word" only to L1, or only to L2, then check the language tag before responding. The problem here is that while this analysis is intuitively appealing, it is too simple. Despite hundreds of lexical decision experiments, we still don't have a very good idea of how people do this task, but we do know that it is much more complicated than Green's analysis. The best developed theory is that of Grainger and Jacobs (1996). According to them, people rely on two more pieces of evidence than are included in Green's account, total activation in the lexicon summed across all word codes and the rate at which total activation is growing. And even Grainger and Jacobs' theory is known to be insuffi cient, since it deals neither with what happens if people pronounce the stimulus to themselves nor with what happens when semantic priming influences activation. To Green's credit, he notes the existence of Jacobs and Grain ger's more complex theory. However, he goes on to inter pret lexical decision in terms of his own analysis, the one that can be integrated easily into his overall theory of how the bilingual lexico semantic system is controlled. Perhaps an interpretation of bilingual lexical decision based on a more complete and defensible task analysis would still fit very comfortably into Green's framework. But at present we don't know, and we can't accept Green's model until we find out. The bottom line here is this: accurate task analysis is absolutely essential for proper theoretical interpretation. Accurate task analysis is not easy, and it often turns out that even the simplest seeming task requires enormous amounts of conceptual and empirical work to understand.

Green's second question is what the notion of "selection for action" (Allport, 1987) might contribute to under standing task control. Green describes three candidate selection mechanisms (1) horse race like competition among independently activatable codes, (2) shifting deci sion criteria to favor wanted over unwanted codes, and (3) active inhibition of unwanted codes. He proposes a theory of "selection for bilingual lexical action" that adds active inhibition to Kroll and Stewart's (1994) architecture. Pro posing active inhibition as a method of selection has a venerable history (Pillsbury, 1908) and is currently popular (Dagenbach & Carr, 1994a). However, it is distressingly difficult to demonstrate that selection actually does involve such a process. I have run up against this problem in my own research, where Dagenbach and I (Dagenbach & Carr, 1994b; Carr et al., 1994) have proposed that an inhibitory selection mechanism is used to retrieve newly learned word meanings in the face of competition from similar but better learned lexical concepts. Anderson and Bjork (1994) provide an excellent but sobering introduction to the com plexities of identifying inhibition.

Suppose we could convince ourselves that active inhibi tion is the mechanism of selection or, aiming higher, suppose we could convince Anderson and Bjork! Then Green's third question becomes relevant. At what level of processing is inhibition implemented? Green's position is that inhibitory selection operates on lemmas. This means that instead of ideas, lexical concepts, or word forms, the inhibited code is a grammatical representation that carries information about syntactic function (Bock & Levelt, 1994). I must admit that I don't see a *thorough* and *compel ling* evidentiary argument that lemmas are the locus of inhibition, and it certainly seems possible that other codes could be inhibited (for proposals, see Anderson & Bjork, 1994; Dagenbach & Carr, 1994b; Dell & O'Seaghdha, 1994; Eberhard, 1994; Simpson & Kang, 1994). Maybe I have misunderstand or just plain missed the argument. However, the implications for language processing in multi language environments would be very different depending on just exactly what gets inhibited when a speaker or perceiver chooses one language over another. Hence this is an important argument to lay out and defend as explicitly as possible.

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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 and made more sense to the subjects, and infre quent 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 stereo typical 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 infor mation processing and memory functioning, such as infer encing, elaborating, stereotyping, reconstruction, false memorization, and the occurrence of slips in task perfor mance. 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 con struction 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 the subjects, of their mental representation of these instruc tions. By referring to them as schemas, the already extre mely 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 perfor mance, 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 retroac tively 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 activa tion 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 (BIA) model developed by Grainger and Dijk stra (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 adaptation of Levelt's language production model to the bilingual case (see Poulisse, 1997), the goal to produce one language and not the other is reached by installing a language cue as one of the concep tual 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 inap propriate language (whose language cue mismatches with the language cue in the conceptual representation). As a consequence the former lemma is the one eventually as signed 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 them from being 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 fol lowed 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 auto matic reading of a color name in the Stroop task calls forth an irrelevant task schema interfering with uttering the color's name. To what extent will the schema for word naming compete with other task schemas as well, for instance, for lexical decision? Which factors (overlap, auto maticity, 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 homo graph 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 activa tion in the bilingual system. In an English lexical decision task, reaction times to interlingual homographs and exclu sively 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 contribu tion 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 impor tant than whether the model proves to be right on parti cular 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 perform effectively 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 entirely with a representational scheme, 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 rather 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 lan guage. 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 profi ciency, appear to influence the relative activation of the bilingual's two languages (e.g., Dijkstra, van Jaarsveld, & ten Brinke, 1998; 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 very least, the time course of interference should be influenced by the hypothesized suppression function. Like wise, 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, Dannen burg, & van Hell, 1994). If it is possible selectively to suppress lemmas in one language only, then under some circumstances we might not expect to observe the facilita tion 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). Presum ably mental control differs from automatic processes (Schneider & Shiffrin, 1977), yet in the IC model there is no precise computational specification of how the various parameters of the control system actually interact to deter mine 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 presented, it is difficult to determine how successful it will be in combining symbolic and connectionist approaches in un derstanding 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 con trols. The particular level at which the IC model operates is an intermediate level, the lemma level, whereby an inhibi tory 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 morpholo gical 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 net works. The strong weights can therefore serve easily to 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 again cast doubt on the notion that there is a cost associated with language switching, especially in natural speech situations (Grosjean, 1988, 1997; Gros jean & 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 contra dict several activation based accounts that the bilingual's two languages may be always activated, though the strength of the activation differs in specific linguistic situations, depending on the frequency of the target words, the senten tial 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 lan guage 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. First, 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 more than one lemma (i.e., "roof" and "list") was 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 the 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 Stroop like situations), the theory advances a competition sensitive response time mechanism. In particular, a selection ratio is proposed that weighs 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 demon strated that, with an appropriate parameterization, the selection mechanism accounts quantitatively for the Sti mulus 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 lan guage (and to the source language in translation). Thus, the system should contain production rules that say, infor mally, for example: <IF the concept is HOUSE(X) and the language is French, THEN select "maison">, where HOUSE(X) is the message concept, French the target language, and "maison" the corresponding lemma. Produc tion rules marked for language would account for the computational problem of how bilingual speakers manage to keep the languages separate in monolingual conversa tion. 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 sen tence "the tree is next to la maison," the production rules <IF the concept is TREE(X) and the language is English, THEN select "tree"> and <IF the concept is HOUSE(X) and the 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 as to how people are able to control their language system is an important one and has been a topic for highly active research in recent years. Until now, 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, 1998). 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 the 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 are 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 it 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 lemmas 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 are "neef"). And as we have discussed in the 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: "This 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 (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 four SOAs (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 SOAs. Second, semantic interference effects were found for SOAs 300, 150, and 0. But most crucially at an 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, at the level of word forms, they can, 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 (IC) model. The model's aim is to account for the way in which 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 syn tactic 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 L1 to L2 without actually naming the L1 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 asso ciated 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 minimalist ap proaches to syntax, 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, the 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), who shows that words which are phonotactically recognisable as belonging to one 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 bor rowing. 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 bor rowings 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, each of which in turn results 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 trans ferred 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 bor rowing 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 interlin gual 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:

Un	*petit*	*canari*	doe	geen	vuil
A	small	canary	does	no	dirt

"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 investigate further 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 model of bilingual speech processing and minimalism (1985, 1997). 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 coop eration between word production schemas take place in the latter case? When formulated in minimalist terms, 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 psycholin guistic aspects of code switching, and it is to be hoped that a further exploration of these cany provide new insights into the way in which bilinguals control their languages.

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[1] Borrowing lemmas without their associated lexical concepts would probably be termed lexical interference by many re searchers.

[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.

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AUTHOR'S RESPONSE

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, 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, Dijk stra); (2) the notion of a tag: its psychological reality (Li, Treffers Daller), its relationship to a language node (Dijk stra) 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 abstrac tion from movements of the same general type. Arbib (1985) elaborated the notion and argued that subcompo nents 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 inter leaved. At an intermediate level of action there 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 inter mediate 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 (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 lan guage 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 this possibility. There is a schema termed "act." A different task requires changing parameters in this open ended schema. Rather than commit ourselves to this possibility 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 deci sion 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 con structs 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 para meter 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 with repeated use, this too will become a specific schema.

Schemas can be readied in advance through the super visory 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 mod ulating 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). Reconfigura tion 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 (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 orga nizing. 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 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 lan guage 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 representa tion. 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 delayed over those for control words when real Dutch words are included in the items for English specific lexical decision. Most probably 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 inhibi tory 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 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 competi tion. Selectivity may be achieved either directly, via atten tional 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 equiva lent 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 acti vation 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, as 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 back ward 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 inhibi tory control mechanism is plausible. But, as Carr empha sizes, 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 inhibi tory 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 Thursto nian 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. Con sider 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 and 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 languages 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 that 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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First clues to the existence of two input languages: Pragmatic and lexical differentiation in a bilingual child*

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While it is now commonly accepted that simultaneous bilingual children can differentiate their two languages from very early in development, it is still not very well understood how they come to understand that there are two languages in their input. The purpose of this study was to examine how a bilingual child might come to an understanding of the existence of two languages in terms of pragmatic differentiation (use of the appropriate language for the context) and lexical differentiation (use of translation equivalents). Using data from a Portuguese English bilingual child from 1;0 to 1;6, this study showed that the child showed evidence of pragmatic differentiation before lexical differentiation. If these results are replicated, they suggest that bilingual children's understanding of the appropriate social use of their two languages may lead to an understanding that the translation equivalents in their vocabulary belong to two distinct input languages.

How and when simultaneous bilingual children come to understand that there are two languages in their input has been a matter of debate. One argument has been that bilingual children come to understand that there are two input languages with great effort and rather late in the course of development (around three years of age). For example, Leopold (1939) reported that Hildegard, his German-English bilingual daughter, initially used a single phonological system to produce words from both languages. In a subsequent book (Leopold, 1949), he added that Hildegard initially mixed both languages within utterances; he took these phenomena as evidence that her initial linguistic system had fused her two input languages. Following Leopold, several other researchers found evidence for a Unitary Language System (ULS) (Genesee, 1989), that is, that bilingual children initially use their languages as if they were a single system, in terms of phonology, lexicon, syntax, and pragmatics (i.e., speaking the appropriate language for an addressee). For example, Volterra and Taeschner (1978) reported that three bilingual children used almost no translation equivalents until after the age of two years (see also Redlinger & Park, 1980).

Genesee (1989) pointed out that studies supporting the ULS hypothesis were weak on several methodological grounds, including a failure to examine systematically children's language use in particular contexts. In correcting the methodological problems of earlier studies, other researchers have argued that by the time bilingual children begin speaking, they already show signs of understanding that there are two input languages (see also Pavlovitch, 1920; Ronjat, 1913). In discussing when bilingual children might show evidence of the existence of two languages in their input, I will review here evidence based on their linguistic productions because there is little systematic evidence on differentiation in comprehension. Two studies have shown differentiated prosodic systems for bilingual children, at least after they have a 50-word vocabulary (Ingram, 1981; Paradis, 1996); neither study looked at the prosodic systems before this point. Similarly, two studies have shown that bilingual children have a fairly stable rate of translation equivalents (about 30 per cent) soon after they begin talking (Pearson,

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Fernández, & Oller, 1994; Quay, 1995; cf. Vihman, 1985). For syntax, several studies have now shown that as soon as there is evidence of syntax, bilingual children use the two syntaxes differentially (Döpke, 1997; Meisel, 1990; Meisel & Müller, 1992; Paradis & Genesee, 1996). Thus, in terms of phonology, lexicon and syntax, children seem to produce their two languages differentially from very early in development.

Children's ability to show pragmatic differentiation, or the use of the appropriate language for the interlocutor, may not necessarily show the same developmental pattern as the other kinds of language differentiation, as I will discuss below. It should be noted that the goal in pragmatic differentiation is not necessarily monolingual behavior in two contexts, but rather the ability to use the languages as required by the pragmatic context. Even when parents in bilingual families adopt a one person-one language rule, their language use is rarely restricted entirely to one language (e.g., Nicoladis & Genesee, 1996). Furthermore, the language choice required by the pragmatic context cannot necessarily be said to be either static or determined entirely by the parents, since the context can always be renegociated by any or all participants (e.g., Lanza, 1992). In spite of these limitations in determining pragmatic differentiation, it is still possible to discuss when bilingual children start to show sensitivity to the predominance of use of one language by a particular person (e.g., Genesee, Nicoladis, & Paradis, 1995). When bilingual children can use their two languages as if they were monolinguals may be much later than their initial sensitivity to the existence of two languages in different contexts (Nicoladis & Genesee, 1997; see Grosjean, 1998, for discussion of this issue).

Some studies of bilingual children's pragmatic differentiation have indicated that there may be an initial stage in which children do not show sensitivity to the predominance of use of one language by one parent. In diary studies, authors have reported pragmatic differentiation at 1;4 (Ronjat, 1913) and 2;0 (Pavlovitch, 1920; although this child's exposure to his second language only started when he was 1;2). More recent studies with careful empirical analyses have supported the reports that pragmatic differentiation can be seen around two years of age. Köppe and Meisel (1995) observed two French-German bilingual children interacting with adult observers who pretended to be monolingual. Both children almost never deviated from using their interlocutor's language starting from the time the study began, when Annika was 2;0 and Ivar was 2;5. To see if there might be an earlier stage during which children did not show pragmatic differentiation, Nicoladis and Genesee (1996) examined the language use of four French-English bilingual children regularly from the time they were about 1;7 until they were about 3;0. All four children initially used their languages in the proportion that would be expected by their dominant language. However, between 1;9 and 2;4, the children started to use more of their interlocutor's language than would be expected by their dominance (see also Döpke, 1992; Genesee, Nicoladis, & Paradis, 1995; Lanza, 1992). A more sensitive test of bilingual children's pragmatic differentiation is to see whether they use their translation equivalents with speakers of the language (e.g., "casa" to Spanish speakers and "house" to English speakers). Two studies have examined bilingual children's use of translation equivalents and have shown that around the age of 1;7 to 2;4, they use almost all words for which they know translation equivalents appropriately (Quay, 1992; Nicoladis & Genesee, 1996). In sum, bilingual children have been shown to choose the appropriate language for the interlocutor starting around the age of two years, although with considerable individual variation. It also seems that there may be an initial stage during which pragmatic differentiation is not seen in bilingual children. Indeed, it would be odd if children were born with an understanding that a different language should be addressed to different interlocutors, since this is not true of monolingual children and furthermore not all bilingual families adopt a one language-one person rule (e.g., Tabouret-Keller, 1963).

The position that bilingual children show evidence that they understand that there are two languages in their input from the time they begin speaking is also not without its critics. An alternative view has been suggested by Nicoladis (1997), who pointed out that studies showing that bilingual children produced translation equivalents early on could not say whether the *rate* of translation equivalents was theoretically meaningful. She compared the rate of translation equivalents in four bilingual children's first 50 words with the rate of synonyms in eight monolingual children's first 50 words. The results showed no significant difference between the rates, if they were counted in the same way. This finding suggests an initial lack of lexical differentiation, in spite of the existence of translation equivalents. A comparable view can be found in Vihman (1985), who reported of her Estonian-English bilingual son that at 1;2 (a month after he started to speak), 10 per cent of his vocabulary was in translation equivalents and the rate increased gradually over time. These results suggest that there may be a stage (up until they know about 50 words) when bilingual children do not differentiate their languages while they use translation equivalents during that period, the rate is no greater than the rate of synonyms for monolingual children, implying that what may appear to be translation equivalents from the adult perspective may in fact be more like synonyms for the bilingual child. It should be pointed out that if bilingual children's ability to differentiate their two languages emerges with a vocabulary of about 50 words, then their language development is qualitatively similar to that of monolingual children. The latter have been shown to systematize their phonology once they have a vocabulary of around 50 words (Ingram, 1976). It would be no surprise if bilingual children also systematized the phonology of their two languages once they had a vocabulary of about 50 words.

Once bilingual children can produce words with two distinct prosodic systems, they might then come to an understanding that there were cross-language translation equivalents (rather than synonyms) in their vocabulary. They might then understand the pragmatic rules in their environment with regard to language use, such as learning to address one parent in one language, if such a rule existed in the child's environment. The reason for speculating that lexical differentiation precedes pragmatic differentiation is that the age of lexical differentiation has generally been reported to be earlier than the age of pragmatic differentiation. In studies in which lexical differentiation has been defined as the use of words that were translation equivalents from an adult perspective, making sure the words refer to the same concepts, lexical differentiation has been reported as early as 1;2 (Vihman, 1985) and 1;4 (Quay, 1995). Pragmatic differentiation has been reported as early as 1;7 (Quay, 1992), although it is more usually reported closer to 2;0 (Döpke, 1992; Genesee, Nicoladis & Paradis, 1995; Köppe & Meisel, 1995; Nicoladis & Genesee, 1996). The age reported for using translation equivalents with an appropriate interlocutor has been similar to the age of pragmatic differentiation, namely between 1;7 (Quay, 1992) and about 2;0 (Nicoladis & Genesee, 1996). If lexical differentiation always precedes pragmatic differentiation, then it is possible that bilingual children use the fact that they have translation equivalents in their lexicon as a cue to learning how to use their two languages according to the pragmatic rules in their environment (see also Clark, 1987). Because no single study has examined the interaction between the two kinds of differentiation, it is possible to question this order. In fact, two studies reporting on the same child have shown that while a Spanish-English bilingual child used translation equivalents from the age of 1;4 (Quay, 1995), she did not reliably use them with an appropriate interlocutor until 1;7 (Quay, 1992). Given the Nicoladis (1997) finding that the rate of translation equivalents in bilingual children's early vocabulary may indicate that they do not yet understand that there are two distinct languages in their input, we can speculate that bilingual children might first come to an understanding of the social rules of the languages in their input which would allow them to reanalyze the "translation equivalents" in their vocabulary as belonging to two separate languages. The purpose of the present study was to examine the relationship between lexical differentiation and pragmatic differentiation to see if the former does indeed precede the latter in the course of bilingual development. This study concerned only one child learning two languages in the context of his family and can thus be viewed as a preliminary foray into this topic.

Method

This was a case study of a child learning Brazilian Portuguese from his father and American English from his mother in a suburb of Boston, Massachusetts, in the United States. The parents reported that they spoke primarily one language with the child. Both parents have earned graduate degrees. The father worked full-time outside the home throughout the study while the mother cared for the child full-time at the start of study and started working at a job part-time outside the home when the child was 1;2. When the mother was at work, an English-speaking neighbor cared for the child. The boy was the only child in the family throughout the course of this study.

This study followed the family from the time the child was 1;0.12 and had a productive vocabulary of 7 words according to parental report, until he was 1;6.6, with a cumulative productive vocabulary of 122 words, according to the videotaped sessions, the parents' weekly recall, and the mother's report on the MacArthur Communicative Development Inventory (see Fenson, Dale, Reznick, Thal, Bates, Hartung, Pethick, & Reilly, 1993) at 1;6.6. At this point in time his parents reported that the child was using a lot of Portuguese with his father and a lot of English with his mother. Further discussion on how the child's vocabulary was counted is found below.

The child was filmed every week over the six-month range, except for three weeks when first the family was on holiday and then the child was sick. The parents were told that we were interested in bilingual language development in general and were asked to play as they normally would with the child. Every week, the child was filmed in two separate 15-minute sessions, one with each parent (see Table 1 for the exact age of the child at each session). The

Table 1. *The child's exact age at each observation session, and the extent of the cumulative vocabulary*

Observation session	Child's age at recording session with: Mother	Father	Number of words in cumulative vocabulary*
1	1;0.17	1;0.14	10
2	1;0.24	1;0.21	14
3	1;1.1	1;0.28	17
4	1;1.8	1;1.9	19
5	1;1.15	1;1.12	20
6	1;1.22	1;1.20	27
7	1;1.29	1;1.27	28
8	1;2.5	1;2.3	28
9	1;2.12	1;2.11	31
10	1;2.19	1;2.18	31
	Family holidays/illness		
11	1;3.10	1;3.11	36
12	1;3.17	1;3.16	41
13	1;3.24	1;3.21	44
14	1;4.0	1;3.28	44
15	1;4.7	1;4.4	48
16	1;4.14	1;4.13	48
17	1;4.21	1;4.18	51
18	1;4.28	1;4.25	53
19	1;5.6	1;5.3	59
20	1;5.13	1;5.11	63
21	1;5.20	1;5.18	69
22	1;5.25	1;5.24	78
23	1;6.6	1;6.4	87

* According to parental report and videotape only.

number of days between sessions with the two parents ranged from one to three and averaged 2.1 days. Note that because 10 sessions were filmed with the father before the three-week break and 11 sessions with the mother, the first session with the mother (when the child was 1;0.12) was discounted from the following analyses (and thus is not included in Table 1). The sessions with the mother were filmed by a native speaker of American English who knew no Portuguese at the beginning of the study and whose exposure to Portuguese throughout the study was mainly from the words learned by the child. The sessions with the father were filmed by a native speaker of Brazilian Portuguese, whose spoken English was poor at the beginning of the study although improved over the course of the study. By having virtually monolingual observers, we thought we might bias the context of the filming sessions to be fairly monolingual. Such a context was ideal for testing issues of language differentiation, although may not be representative of the family's usual language choice in the absence of the observers. The rate of the language choice by the parents is reported in the results section.

The sessions were transcribed in CHAT format (MacWhinney, 1991) and coded for the language and addressee of an utterance. In addition, broad phonetic transcription of the child's utterances was also performed. The language categories coded were: Portuguese-only, English-only, mixed, either, or unassignable (following Genesee, Nicoladis, & Paradis, 1995). The analyses were performed only on the child's Portuguese-only and English-only utterances. For the most part, we used dictionary definitions to categorize words as either Portuguese or English. The few exceptions to this rule were included in the "either" language category, described briefly below. While using a dictionary definition of the language categories could have resulted in counting words used by all members of the family as either Portuguese or English, we observed no instances of the parents deviating from these categories before the child himself started using a particular word or a word (or words) with similar meaning (see Nicoladis & Secco, 1998). By adhering to the dictionary definition of Portuguese and English, we hope to be able to track the creation of family words. The child used no mixed utterances (that is, utterances consisting of at least one morpheme from English and one from Portuguese) during the study. The "either" language category consisted of words that could belong to either Portuguese or English, such as proper nouns or interjections. This was done on the basis of findings from other studies showing that bilingual children sometimes have only one proper noun per referent in the early stages (Saunders, 1988). "Mommy" and "Daddy" were counted as part of either language until session 15, when he learned the Portuguese translation of the latter word, "Papai." At that point, both "Mommy" and "Daddy" were counted as English words. Unassignable utterances were utterances that could be transcribed phonetically but could not be assigned a clear language category. As for coding the addressee, the default assumption was that the child was addressing the parent present unless it was clear that the child was talking to himself, a toy, or the observer.

To check inter-rater reliability, the child's utterances in ten sessions were independently transcribed by the observer who was not present at the filming session. The coding agreement was 88 per cent and differences were resolved by discussion.

Cumulative vocabulary

To get as complete as possible a list of the child's productive vocabulary, the parents were asked on a weekly basis to recall any new words the child might have said. In addition, the transcripts of the videotapes were used to confirm and enhance the parental reports. The parents reported that they felt they could give fairly accurate recall of the child's new words over the course of a week until the last few weeks of the study when the child learned a lot of new words in a single week. A fairly conservative definition of a word was used in counting the child's vocabulary (see Vihman & McCune, 1994, for an excellent discussion of this issue). That is, only words based on clear adult targets were included; several reliably produced, child-invented forms were thus excluded. Also, the interjections "hmm", "mm" and "oh" were excluded on the intuition that they were less word-like than other words. Finally, words were included in the vocabulary count only when the child used them spontaneously and at least several times within a day or two.

In Table 1, the child's total cumulative vocabulary is reported. The reliability between the video recordings and the parental reports for the first 50 words was quite high (see Nicoladis, 1997). Soon thereafter, the child started acquiring so many new words in a week that some words appeared during the taped sessions that were not recorded by the parents and many words were reported by the parents that did not occur during the taped sessions. Thus, as the child got older there were fewer words that could be confirmed by video recordings. Having confirmed that the parents and the researchers seemed to be using a similar definition of "word" when counting the child's words, it seems safe to assume that the words reported by the parents that did not occur in the taped sessions would also have been counted by the researchers as words.

Lexical differentiation

Translation equivalents were counted only when the child used a word in both languages to refer to a similar class of objects, events or situations. To illustrate this point, let us first look at a pair of words that were not counted as translation equivalents even though they may have been from an adult perspective. In session 3, the child started using the Portuguese word "não" ("no") to answer yes/no questions and in session 4, he started using the English "no no" to refer to things he was prohibited from doing (see Vihman, 1985, for a similar story). Because the child used these words with such clearly distinct meanings, "não" and "no no" were not counted as translation equivalents for these sessions. The child's first translation equivalents were recorded in session 6: "bola" and "ball". These words did not necessarily refer to the same ball, but they did refer to the same class of objects, namely balls. For this reason, they were counted as translation equivalents. Table 2 lists the words categorized as translation equivalents.

Table 2. *The child's active translation equivalents and sessions in which they were active*

Portuguese word	English word	Sessions active
bola	ball	6 8
Papai	Daddy	15 23
não	no	19 23
tchautchau	byebye	19 23
oi	hi	20 23
mais	more	20 23
Mamãe	Mommy	20 23
chave	key	21 23
batata	potato	22 23
fora	out/outside	23

Since children's early words are sometimes known to have a high mortality rate (Bloom, 1973; Leopold, 1939; Nelson, 1973), it was important only to count translation equivalents in terms of active words. A translation equivalent was considered active between the first session in which the word was recorded and the last session in which it was recorded. For example, the word "bola" was first recorded in session 5 (but not counted as a translation equivalent until session 6 when the word "ball" appeared) and was last recorded in session 8. This translation equivalent was therefore considered to be active for sessions 6, 7, and 8, even though no instances of "bola" were recorded in sessions 6 and 7. Table 2 also summarizes the observation sessions during which the child's translation equivalents were considered to be active.

Pragmatic differentiation

Pragmatic differentiation was examined in two ways (see Nicoladis & Genesee, 1996). The first method did not rely on the child using translation equivalents. Namely, the child's number of utterances in Portuguese and English addressed to each parent were counted. Chi-square analyses were calculated based on the assumption that if the child did not know the pragmatic rule to use Portuguese with his father and

English with his mother, he would use his languages in proportion with his dominance. So, for example, if he were 18 per cent dominant in Portuguese, it would be expected that approximately 18 per cent of his utterances would be in Portuguese. If, in contrast, he knew that he could differentiate his languages pragmatically, he would use more Portuguese with his father *and* more English with his mother than would be expected by his dominance. The language dominance measure is described below.

The second way of examining pragmatic differentiation was to look at the child's use of translation equivalents with each parent. When he could differentiate his languages pragmatically, it was expected that he would use the Portuguese word almost exclusively with his father and the English word almost exclusively with his mother.

One previous study with older bilingual children who were observed every two months showed that these two measures of pragmatic differentiation seemed to co-occur (Nicoladis & Genesee, 1996). As will be seen in the results section, however, these two measures may point to two slightly different times of emergence of pragmatic differentiation in this study.

Child's language dominance

In order to estimate the child's potential ability to use either Portuguese or English, his dominance was calculated on the basis of the number of vocabulary items in Portuguese and English in his cumulative vocabulary. Naturally, when possible, it is desirable to have multiple estimates of dominance when studying bilingual children; however, besides vocabulary, there is little else to measure in a child in the one-word stage that would be at least somewhat independent of the measures of language differentiation. The number of Portuguese words and English words the child knew is presented in Table 3. His dominance in Portuguese (that is, the number of Portuguese words out of the total number of words in English and Portuguese) is also given in this table. To present his dominance in Portuguese was an arbitrary choice; his dominance in English would simply be the Portuguese dominance score subtracted from 100 per cent. The number of words in Table 3 does not always add up to vocabulary reported for the same session in Table 1 because the vocabulary items common to both languages (either-language words) were excluded in the dominance measure. Based on this dominance measure, the child had an average of 18 per cent Portuguese words in his cumulative vocabulary; thus he was consistently dominant in English throughout the course of this study.

Table 3. *The number of word types in Portuguese and English in the child's cumulative vocabulary (the child's language dominance was defined as the percentage of his cumulative vocabulary in Portuguese)*

Observation session	Portuguese word types	English word types	Language dominance
1	1	7	12.5%
2	1	10	9.1%
3	2	12	14.3%
4	2	14	12.5%
5	3	14	17.6%
6	4	20	16.7%
7	4	21	16.0%
8	4	21	16.0%
9	5	23	17.9%
10	5	23	17.9%
11	6	27	18.2%
12	6	32	15.8%
13	8	33	19.5%
14	8	33	19.5%
15	9	38	19.1%
16	9	38	19.1%
17	9	41	18.0%
18	9	43	17.3%
19	12	46	20.7%
20	14	48	22.6%
21	16	51	23.9%
22	17	59	22.4%
23	19	66	22.4%

Results

Parents' language use

Collapsed across the six-month period, 98 per cent of the mother's utterances addressed on videotape to the child were in English and 91 per cent of the father's utterances to the child were in Portuguese. Thus, to the extent that the language context can be created by the parents' language choice, the contexts observed in this study were fairly monolingual. The slightly lower rate of native-language use for the father might be attributed to the fact that he spoke the child's non-dominant language. It has been observed before in bilingual families that the parent who speaks the child's non-dominant language adheres less strictly to the one person-one language rule than the parent who speaks the child's dominant language (Genesee, Nicoladis & Paradis, 1995; Nicoladis & Genesee, 1996). Another factor contributing to the father's slightly higher use of his non-native language was that the parents spoke English to each other, so English could be considered the language of the home. Further details on the parents' language use with the child can be found in Nicoladis and Secco (1998).

The fact that both parents used less than 100 per cent of their native language with the child means that the child's goal in pragmatic differentiation could not, as noted earlier, be a strict one person-one language rule. At best the child's goal could be to speak primarily one language with each parent, and perhaps use more code-mixed utterances with his bilingual father than with his virtually monolingual mother. One study has shown that the age at which bilingual children can be expected to use their languages in a similar fashion to their parents is around three years and then only if they are relatively balanced in their proficiency in their two languages (Nicoladis & Genesee, 1997). Thus, we cannot expect a child of the age in this study to show strict language separation by parent, or even the use of primarily one language with each parent. The analyses of pragmatic differentiation described above were designed to test the earliest signs of sensitivity to the parents' use of primarily one language with the child.

Lexical differentiation

From Table 2 we can see the number of words in the child's vocabulary that were classified as active translation equivalents. In sessions 6 to 8, he had one active translation equivalent (ball-bola) but the Portuguese word disappeared after session 8. The next translation equivalent (TE) did not appear until session 15 (Daddy-Papai), and there were no other active TEs until session 19. After this session, the number of TEs increased rather dramatically, to 18 active TEs in the last session.

Figure 1 shows the proportion of the child's vocabulary included under TEs. As can be seen, the dramatic increase in number of TEs is mirrored by the dramatic increase in percentage of vocabulary in TEs. The increase goes from 0 per cent in session 14 to about 4 per cent in session 15, with a jump to 10 per cent in session 19 and finishing with 21 per cent in the last session. Note that this child seems to be unique compared with other published reports of the rate of TEs acquired over time. In contrast, Vihman (1985) reported a gradual change in rate of TEs for her bilingual son over approximately the same time frame, and Quay (1995) reported a fairly stable rate of TEs (approximately 36 per cent of the child's vocabulary) over time after the child in her study

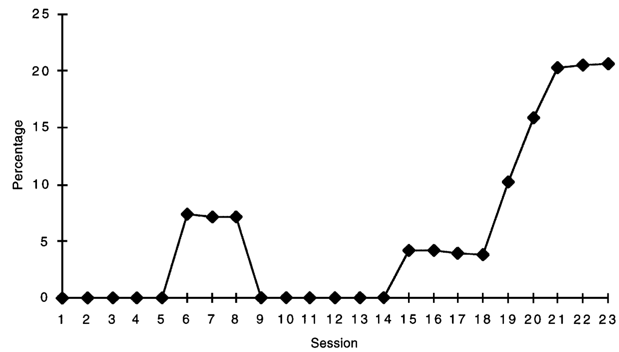

Figure 1. The proportion of child's cumulative vocabulary in translation equivalents.

began to use TEs. To consider the possibility that the difference may have been due to methodological differences between the studies, the percentage of cumulative TEs out of the child's cumulative vocabulary in his non-dominant language (Portuguese) was also examined on a monthly basis, following Vihman (1985). There were no TEs at 1;0, then a fairly stable rate of TEs (about 25 per cent) between 1;1 and 1;4 and then a sudden increase to 53 per cent TEs at 1;5. In short, all analyses have yielded the same results, namely a dramatic increase in the number and percentage of TEs around session 19 (when he was about 1;5). Given these results, it seems reasonable to conclude that this child did not initially show lexical differentiation and then clearly showed such differentiation around session 19.

Pragmatic differentiation

In this section, I report the results of the analyses of both measures of pragmatic differentiation. Table 4 summarizes the number of utterances in Portuguese and English addressed to each parent. The results of the chi-square analyses are also summarized in Table 4; when the child used significantly more English to his mother *and* significantly more Portuguese to his father than would be expected by his dominance, the chi-square scores are emphasized in bold type. Session 16 was the first time he showed pragmatic differentiation to both his parents according to this measure and then in sessions 20 and 23. The unstable achievement of pragmatic differentiation using this measure has been reported before in the literature (Nicoladis & Genesee, 1996).

To examine the child's use of translation equivalents, we can refer to Table 5. For the purpose of detecting the child's pragmatic differentiation, "appropriate" context was used to describe the child's use of English words to his mother and Portuguese words to his father. The "inappropriate" context was

Table 4. *The number of the child's utterances by language and addressee (chi-square scores indicating pragmatic differentiation are in bold type face; *p<.05)*

Observation session	Addressee	English utterances	Portuguese utterances	χ^2
1	Mother	7	0	1.00
	Father	1	0	0.14
2	Mother	5	0	0.50
	Father	1	0	0.10
3	Mother	12	0	2.00
	Father	8	4	3.55
4	Mother	7	0	1.00
	Father	0	0	
5	Mother	16	0	3.42
	Father	1	3	9.09*
6	Mother	19	3	0.15
	Father	11	0	2.21
7	Mother	15	0	2.86
	Father	5	3	2.75
8	Mother	34	6	0.03
	Father	12	4	0.96
9	Mother	18	3	0.19
	Father	5	0	1.09
10	Mother	15	0	3.27
	Father	13	0	2.83
11	Mother	27	4	0.58
	Father	13	4	0.32
12	Mother	32	3	1.37
	Father	2	5	16.28*
13	Mother	33	3	2.86
	Father	5	11	24.72*
14	Mother	35	14	2.57
	Father	7	5	3.76
15	Mother	21	1	3.02
	Father	11	7	4.56*
16	Mother	43	2	**6.26***
	Father	5	8	**15.15***
17	Mother	17	6	1.02
	Father	7	5	4.55*
18	Mother	42	11	0.44
	Father	5	14	42.22*
19	Mother	18	4	0.08
	Father	9	12	16.99*
20	Mother	47	1	**11.55***
	Father	9	7	**4.09***
21	Mother	43	7	2.69
	Father	14	26	37.15*
22	Mother	21	10	1.73
	Father	5	11	19.77*
23	Mother	20	0	**5.77***
	Father	12	15	**17.08***

Table 5. *The percentage and number of translation equivalents by context of use*

Observation session	"Appropriate" context only	Both contexts	"Inappropriate" context only
6	100% 1	0	0
7	0	0	100% 1
8	100% 1	0	0
9 14			
15	100% 1	0	0
16	0	0	0
17	0	0	0
18	0	0	0
19	67% 2	33% 1	0
20	83% 5	17% 1	0
21	75% 6	0	25% 2
22	67% 4	17% 1	17% 1
23	100% 5	0	0

used to describe the child's use of English words to his father alone or Portuguese words to his mother alone. The child used very few TEs before session 16 and averaged 75 per cent appropriate use only (but with only two different types of TEs). After session 17, he averaged 77 per cent appropriate use only, although now with 16 different types of TEs. Thus, while it appears that his correct usage did not increase from before and after the point of pragmatic differentiation, he used so few TEs before that it is difficult to make any firm conclusions on that basis. The majority of his TEs in the inappropriate-only context can be accounted for by the single Portuguese word "batata" ("potato") which he learned by session 22 and his mother reported that he enjoyed saying.

Note that the first indicator of pragmatic differentation suggested that the child's earliest sensitivity to the two pragmatic contexts was session 16. As for the second indicator, this child used so few TEs before session 1 that it is impossible to say for certain that he understood in which pragmatic context the words were to be used. On the basis of these analyses, it is possible to interpret these results as suggesting that the child first understands that there are two pragmatic contexts and then learns equivalent words to be used differentially in the two contexts. I return to this point in the discussion.

Discussion

While by predicting from the ages in other studies we might have thought we would see lexical differentiation before pragmatic differentiation, this child in fact first showed pragmatic differentiation (namely, using more of a parent's language with that parent than would be predicted by his language dominance) about three weeks *before* he showed evidence of lexical differentiation (namely, a dramatic increase in the number of translation equivalents). This finding suggests that the child's understanding of the pragmatic rule that he should address one language primarily to one parent may have led to his reanalysis of the few translation equivalents in his vocabulary as belonging to two distinct languages. This knowledge may then have enabled the child to turn his attention to the acquisition of translation equivalents which he could then use almost always only with the parent who spoke that language. This interpretation fits in well with the claim by Nicoladis (1997) that bilingual children's earliest "translation equivalents" may be, from their perspective, something like synonyms. Because this is a case study, there is no way of knowing whether these results are applicable only to this child or whether they will prove to be generally true for bilingual children. If replicable, these results may only apply to bilingual children whose input languages are separated by a clear context, such as person or place. To tease out the relevant variables, future research on children's first clues to understanding the existence of two input languages might compare different input conditions.

If future research continues to show that an initial pragmatic differentiation is necessary for bilingual children to learn translation equivalents, the results of Quay (1992, 1995) could be refined. Quay's studies were based on Clark's (1987) idea that a principle of contrast, an understanding that different words signal different meanings, is a necessary prerequisite to language-learning. In showing that the Spanish-English bilingual child in her study had translation equivalents, words encoding the same meaning only a different language, Quay reported that Manuela first learned a large number of translation equivalents and then started to use them appropriately. Because of the focus of her study, Quay did not have any measures of pragmatic differentiation that were independent of translation equivalents. It is possible, then, that there is earlier evidence of pragmatic differentiation, namely the child's use of utterances in a particular language to a particular person. If no such earlier evidence can be found and bilingual children can in fact sometimes learn a large number of translation equivalents before they show pragmatic differentiation, then an explanation unifying the two courses of development is necessary.

In any case, further research on how bilingual children use various clues in understanding that there are two languages in their input is needed. The results of this study, along with other studies, suggest that language differentiation does not occur instantaneously but is instead constructed on the basis of multiple cues from the input. I will briefly sketch out a possible developmental course for complete language differentiation in simultaneous bilingual children. This sketch is based on a couple of assumptions, the first of which is probably oversimplifying and the second which is certainly false. First, I assume that children's behavior is an accurate reflection of their knowledge, so that when they demonstrate the ability to produce, say, systematic prosodic differences, they then understand that there are two prosodic systems in their input. This assumption is extremely conservative and may highly underestimate children's competence. However, whether children understand from the moment that they are born that there are two languages in the input and do not have the cognitive resources to demonstrate such an understanding or whether they require further information from their own linguistic analyses (i.e., comprehension and production) may well turn out to be indistinguishable empirically. A second assumption on which I base my sktech is that the age of different children from different studies is an accurate marker of developmental stage. This assumption is obviously false. In spite of basing my hypothesis on oversimplifications, by making explicit predictions, I hope that more studies will refine the description of the developmental course of language differentiation by focusing on the different kinds of language differentiation in the same children.

The beginnings of language differentiation probably begin long before children's first linguistic productions. From soon after birth, it is quite likely that infants are able to distinguish prosodic differences between the languages in their input (see Jusczyk, 1992). When children start using identifiable words, one of the first clues from their production that they understand that there are two input languages comes from prosodic differentiation (Ingram, 1981; Paradis, 1996). The results of this study suggest that the next clue to two input languages may come from pragmatic differentiation. The ability to show pragmatic differentiation may lead to the beginnings of the creation of two lexicons, in terms of a rapid increase in the number of translation equivalents that can be used almost exclusively with interlocutors who use that language. Lexical differentiation may precede differentiation in terms of segmental phonology, which has been noted in children around the age of two years (Burling, 1959; Deuchar & Clark, 1996; Schnitzer & Krasinski, 1994), which in turn may precede syntactic differentiation (Döpke, 1997; Meisel, 1990; Meisel & Müller, 1992; Paradis & Genesee, 1996). At this point there is no way of knowing if the clues from the different kinds of differentiation are necessary to the next kind of differentiation. For example, the reason that phonological differentiation is seen earlier in terms of prosody than in segmental phonology is undoubtedly because this is the usual order of development in all children (see Jusczyk, 1992). Furthermore, even if this description of the developmental progression of language differentiation were roughly accurate, it would almost certainly not be stage-like. That is to say, that the different clues to language differentiation would probably be relevant in different ways at different times and a sensitivity to one clue may cause refinement of already used rules. For example, it is possible that pragmatic differentiation emerges a bit at first and then gets refined and more stable with new information from lexical differentiation. In spite of these limitiations, as noted above, by sketching out a possible order it is hoped that more studies will focus on bilingual children's ability to demonstrate more than one kind of differentiation.

In any case, if it is found to be generally true that pragmatic differentiation precedes lexical differentiation, then it is possible that cues from the pragmatic context can indicate to children that it is necessary to reorganize their lexicon(s). This possibility is not incompatible with the necessity of a principle of contrast for language acquisition. Clark (1996) argued that the principle of contrast needed to be refined, to include the fact that the existence of two words with similar meaning in the input indicates a difference of pragmatic perspective. However, the results of this study point to the possiblity that the principle of contrast is not innate but created with exposure and use of language. That is, it is possible that children might first have to learn that there are differences in pragmatic perspective before they can learn to use synonyms or translation equivalents in large numbers in different pragmatic contexts. Naturally, further evidence from other studies is needed before such a conclusion can be drawn.

In closing, it should be reiterated that the social context of the family (and hence the pragmatic perspective of the child participating in family life) is not a fixed one and that parents and children are involved in negotiating how language use should take place within a context (see, for example, Lanza, 1992). For example, in this study, in response to the child's use of the Portuguese word "batata", the English-speaking mother usually code-switched to use the word in her response. For further discussion about the role of translation equivalents in the family's communication, see Nicoladis and Secco (1998). Understanding the complex interactions between parents and children and children's creation of social language use deserves further study.

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Non temporal determinants of bilingual memory capacity: The role of long-term representations and fluency*

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Two experiments examine the view that the variation in bilingual short term memory capacity is determined by differential rates of subvocal rehearsal between the languages. Auditory memory span and articulation time were measured for three bilingual groups who spoke Finnish at home and Swedish at school (FS), and either Finnish (FF) or Swedish (SS) in both the home and the school. The results of Experiment 1 indicate that memory span for words varied in a lawful manner as a function of both articulation time and language dominance for SS and FF. For FS, however, an equivalent memory span between the languages was noted despite a shorter articulation time in Finnish than Swedish. Experiment 2 found that for items with no pre existing lexical representations (nonwords), articulation time was a more reliable predictor of memory span than language dominance for all three groups. The finding that within language memory span was greater for short items than long items shows that, ceteris paribus*, bilingual short term memory capacity is sensitive to the effects of word length in both the dominant and non dominant language. Taken together, these findings moderate the view that bilingual short term memory capacity is mediated exclusively by subvocal rehearsal and indicate an influential contribution from factors related to language fluency and the strength of lexico semantic representations.*

What factors determine the variation in short-term memory capacity between the bilingual's languages (e.g., Hoosain, 1979)? It has been suggested that one influential mediator of bilingual digit span is a difference in the rate of subvocal rehearsal between the languages. Ellis and Hennelly (1980), for example, observed that Welsh-dominant, Welsh-English bilinguals took longer to articulate digits in Welsh than in English and that the variation in spoken duration (word length) between the languages predicted a larger digit span for English than Welsh. When digit span was measured under a condition in which subvocal rehearsal was precluded, however, the language difference was abolished. It was thus concluded that the bilingual digit span effect was causally related to a difference in word length between Welsh and English digits; an interpretation that converged with working memory theory (see, e.g., Baddeley, 1990).

Working memory theory holds that the time taken to articulate words is an influential determinant of memory span (Baddeley, Thomson, & Buchanan, 1975). Consequently, immediate memory for short words (e.g., *school*, *zinc*, and *mumps*) is greater than for long words (e.g., *university*, *aluminium*, and *tuberculosis*): the word length effect. The effect of word length on short-term memory capacity is neatly accommodated by the component of working memory theory dedicated to the processing of verbal information: the *phonological loop*. The working memory architecture conceptualises this constituent of the short-term memory buffer as consisting of two subsystems: a passive *phonological store* and a dynamic *articulatory control process*. The phonological store maintains speech-based information briefly where it is subject to trace decay and becomes irretrievable after approximately 2 s. Material may be retained within the phonological store more or less

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indefinitely, however, by the intervention of the articulatory control process which restores the fading traces through the action of subvocal rehearsal. Words with a short articulation duration occupy less temporal capacity within the phonological store and are thus subvocally refreshed at a faster rate than words with a long articulation duration. Consequently, at the point of recall short words are less likely than long words to have decayed beyond the point at which the traces are no longer available for retrieval from phonological storage.

When the articulatory control process is occupied by demands required for the production of irrelevant material, such as *the-the-the* (Murray, 1965), during presentation (articulatory suppression), the renewal of decaying traces in the phonological store is no longer possible. The disablement of the articulatory control process thereby diminishes the involvement of the phonological loop with the consequence that variation in word length ceases to be a determinant of a memory span that is now mediated by non-phonological factors (Baddeley, Lewis & Vallar, 1984).

Working memory theory posits that the rate of subvocal rehearsal is indexed by overt speech rate. This suggestion is supported by the linear relationship between speech rate and memory span observed in adults (Baddeley et al., 1975) and children (Nicholson, 1981) and correlations between the variables (Standing & Curtis, 1989). In addition, Hulme, Thomson and Muir (1984), Hulme and Muir (1985), and Henry and Millar (1991) have demonstrated that memory capacity remains constant after early childhood and that the enlargement of memory span is causally related to corresponding increases in speech rate.

The time-limited basis of the phonological loop provides a natural explanation for the finding that digit span varies across languages: ranging from 9.9 for Chinese (Hoosain, 1984) to 5.7 for Arabic (Naveh-Benjamin & Ayres, 1986; see also Stigler, Lee, & Stevenson, 1986). Languages with short words for digits (e.g., Chinese where the digits 1 9 are monosyllabic) thus make fewer temporal demands on working memory compared with languages with long words for digits (e.g., Finnish with six bisyllabic and three trisyllabic digit names). The finding that cross-linguistic differences in digit span are eliminated under articulatory suppression (Chincotta & Underwood, 1997a) is consistent with the view that memory capacity is mediated by the rate of subvocal rehearsal.

Several studies, however, have provided compelling evidence against a simple working memory theory interpretation of the relationship between speech rate and memory span. Hulme and colleagues (Hulme, Maughan, & Brown, 1991; Roodenrys, Hulme, & Brown, 1993; Brown & Hulme, 1995), for example, have demonstrated that factors independent of speech rate are influential determinants of memory span. Hulme et al., for instance, found that memory span was greater for words than nonwords, even when the words were matched for articulation duration. Under these circumstances, the memory span difference between words and nonwords could not be attributed to variation in word length and the rate of subvocal rehearsal. In addition, Hulme, Roodenrys, Brown, and Mercer (1995) have identified a crucial contribution of long-term phonological representations in reactivating fading traces in the phonological store.

The Ellis and Hennelly (1980) finding that articulatory suppression eliminated the Welsh-English digit span differential, therefore, rests uneasily with the alternative view of working memory functioning proposed by Hulme and colleagues (1991, 1993, 1995). For, in bilinguals, when the influence of word length on memory span is diminished by articulatory suppression and recall is dependent on non-temporal factors, it seems reasonable to expect a larger suppressed memory span in the language in which, by definition, stronger long-term memory representations are present: the dominant language. Variation in the strength of long-term representations has been shown to have a similar effect in monolinguals. Gregg, Freedman, and Smith (1989), for example, showed that under articulatory suppression memory span for high-frequency words was larger than for low-frequency words. How then, can the Ellis and Hennelly (1980) findings be reconciled with recent understanding of the factors that determine short-term memory capacity?

Bilingual memory span has typically been examined using digits (Chincotta & Hoosain, 1995; Chincotta & Underwood, 1996; da Costa Pinto, 1991). Two contingent problems are associated with a reliance on these overlearned and highly familiar stimuli. First, cross-linguistic variation in word length makes it impossible to establish whether bilingual digit span effects are mediated by a variation in language fluency or articulation time, or by an interaction between the factors. A second shortcoming is that claims of a causal relationship between word length and digit span have typically been based on the assumption that language differences in word length are indexed accurately by the speeded reading of Arabic numerals (*1, 2, & 3*, etc.; Chincotta & Hoosain, 1995; Chincotta & Underwood, 1996; da Costa Pinto, 1991; Ellis & Hennelly, 1980). It has been shown, however, that the use of language-neutral stimuli such as numerals in the estimation of speech rate is injudicious, since such metrics index fluency rather than actual differences in articulation duration (Chincotta & Underwood, 1997b; Chincotta, Hyönä, & Underwood, 1997).

The problems associated with the use of visual representations of digits are, of course, circumvented by measuring auditory digit span and estimating speech rate with methods that do not require the recognition of printed stimuli. Here too, however, a simple working memory theory explanation in terms of differing rates of subvocal rehearsal does not account for the full range of findings. Chincotta and Underwood (1997c), for example, found that children who spoke Finnish in the home and were schooled in Swedish had a shorter articulation time for digits in Swedish than Finnish but equivalent memory span between the languages (see also Elliot, 1992).

The shortcomings associated with the use of digit stimuli in previous studies place serious constraints upon understanding of the processes that mediate bilingual short-term memory capacity. Where, then, does this leave the notion that bilingual memory span capacity is determined by word length and the rate of subvocal rehearsal? Two experiments examined the relationship between speech rate and memory span for stimuli other than digits (words and nonwords respectively) in three groups of bilinguals with varying degrees of fluency in each language.

We took advantage of the bilingual characteristics present in Finland where both Finnish and Swedish are official languages. The majority of Finns are classified by census as Finnish-speaking and approximately 6 per cent of the population is classified as Swedish-speaking (Brunell & Linnakylä, 1994). Nationally, Finnish is overwhelmingly the more pervasive language (although regional variation exists). Intermarriage between the linguistic groups creates a wide diversity of individuals fluent in the same languages but with different linguistic experiences. The provision of separate education systems for each language (from kindergarten to university) allows choice and ensures that there are comparable levels of academic achievement between the language populations.

One of the groups comprised balanced bilinguals who spoke Finnish in the home and attended a Swedish-medium school (FS). The remaining groups spoke either Finnish (FF) or Swedish (SS) in both the home and school. Although dominant in Swedish, SS bilinguals have a level of fluency in their second language that is generally comparable to native speakers of Finnish, as these individuals live in a pervasively Finnish-speaking environment and use it frequently outside the home and school environs (see, e.g., Chincotta & Underwood, 1996). With regard to FF, the level of Swedish for these bilinguals is not comparable with that of native speakers, as this is generally learned in school as a second language and there are few opportunities to use this language in a country were Finnish is the lingua franca. The FF group, therefore, consisted of individuals who had studied Swedish as a second language in school for approximately six years. In the area of Finland in which the study was conducted, it is not possible to find Swedish or Finnish monolinguals. Under these circumstances, the FF and SS groups served as controls for FS performance in Finnish and Swedish respectively.

In a digit span study of the same bilingual groups (Chincotta & Underwood, 1996), an orderly relationship was noted between numeral reading time and memory such that SS and FF showed a superior performance in their respective dominant languages. As Chincotta et al. (1997) have demonstrated, however, numeral reading indexes fluency rather than word length. Thus, for these two groups it is difficult to ascertain whether digit span was determined by language fluency, word length or an interaction between the variables. As far as FS bilinguals are concerned, despite a shorter articulation time in Swedish than Finnish, auditory digit span was equivalent between the languages (Chincotta & Underwood, 1997c). In the visual modality, however, FS bilinguals read numerals at equivalent rates in Finnish and Swedish and no language difference in memory span was noted (Chincotta & Underwood, 1996). If, as Chincotta et al. have suggested, numeral reading is a measure of language dominance, this suggests that FS bilinguals had a balanced level of bilingual fluency in Finnish and Swedish and this may have been the critical factor in mediating the equivalence in numeral span between the languages. Taken together, these findings indicate that the role of word length and the rate of subvocal rehearsal in determining the bilingual digit span effect may have been overestimated.

It has been suggested that articulation time measures are influenced by long-term memory factors (Tehan & Humphreys, 1988; Henry & Millar, 1991). In the case of bilinguals, therefore, the finding of an association between speech rate and memory span could simply be indicative of the level of relative fluency between the languages. When examining bilinguals, therefore, it is not possible to match experimental materials for word length across groups, since such metrics are, by definition, speaker-dependent and vary as a function of fluency. Although seldom used in studies of bilingual memory span, comparing the performance of FS bilinguals with native speaker controls (FF and SS) was one way of comparing the relative level of fluency between Finnish and Swedish for the former. If the articulation time measures by FS were equivalent to performance in the respective dominant languages of the SS and FF bilingual types, the possibility that memory span performance for the former was affected by discrete levels of verbal fluency between the languages could be reasonably discounted.

The first experiment, then, measured speech rate and memory span for short (one syllable) and long (three syllable) words in Finnish and Swedish in the three bilingual groups described above. As discussed, an equivalence in Finnish and Swedish digit span has been noted in both children and adult FS bilinguals (Chincotta & Underwood, 1996 & 1997c). The aim of this experiment was to examine memory span performance by FS for items that were matched more closely in terms of word length between the languages than is possible with Finnish and Swedish digits. If, as suggested by a simple working memory theory interpretation of the bilingual digit span effect (Ellis & Hennelly, 1980; Chincotta & Hoosain, 1995; Chincotta & Underwood, 1996), speech rate is the critical variable mediating performance, articulation time should be a reliable predictor of memory span. If, on the other hand, factors such as long-term memory representations are influential determinants of bilingual memory span, articulation time should be a relatively poor predictor of Finnish and Swedish memory span for the FS group. Alternatively, it has been suggested (Chincotta & Underwood, 1997c) that bilingual short-term memory capacity may be jointly determined by a complex interaction between speech rate and long-term memory representations.

Experiment 1

Method

Participants The participants, 36 grade 9 (approximately 15 years old) Finnish-Swedish schoolchildren from Turku, Finland, were selected as follows. The entire Grade 9 cohort of a Swedish-medium school (approximately 100 children) completed a detailed questionnaire that established the language used to communicate with each parent, sibling, caregivers, friends, and so on, and the language of schooling history for each individual. Teachers were consulted on the reliability of the questionnaire responses. The questionnaire data were used to select a group of twelve children who spoke Finnish exclusively at home and received all their schooling in Swedish (FS). An equivalent number of participants who spoke Swedish exclusively both at home and in school (SS) was then selected at random. A third group of children who spoke Finnish exclusively in both the home and school (FF) was selected at random from a Finnish-language school, subject to the criterion that these participants had learned Swedish as a second language for a minimum of six years. The strict criteria by which the participants were selected ensured that language experiences within each group were as homogenous as possible.

Materials Four word pools consisting of eight short (one syllable) and eight long (three syllable) nouns in both Finnish and Swedish (see appendix) were constructed using frequency counts for each language (Saukkonen, Haipus, Niemikorpi, & Sulkala, 1979; Allén, 1971 respectively). Analysis using a *t*-test indicated no differences in frequency among the word pools.

For the measurement of articulation time, a set of four word pairs was constructed at random for each of the word pools, with the restriction that each word occurred once in the set. These sets were then varied systematically to make a total of eight sets for each pool. For the measurement of memory span, a set of random word sequences was constructed for each word pool with the restriction that the same words should not occur contiguously. Each set commenced with two, two-word sequences, followed by two, three-word sequences, and so on until a maximum of two, eleven-word sequences was reached.

Procedure The participants were tested individually by the same fluent bilingual and the language of instruction was counterbalanced. Before commencing the experiment, the participants were asked to repeat each word in order to test the reproduction of the items. Then, measures of memory span were taken. The word sequences were read aloud by the Experimenter at the rate of one word per s. When the sequence was completed the Experimenter indicated that recall should commence. Testing continued until two errors at the same sequence length were made. Memory span was operationalised as the length of the last correctly recalled sequence. If both sequences at this length were correct a score of 0.5 was added. The sequences were blocked by language and word length and counterbalanced by a Latin square.

Next, measures of articulation time were taken. The Experimenter read the word pairs and the participants were asked to articulate these as fast as possible until instructed to stop. The participants continued to repeat the word pairs until ten repetitions were counted by the Experimenter and the time taken was measured by stopwatch. The word pairs were blocked by language and word length and counterbalanced by a Latin square.

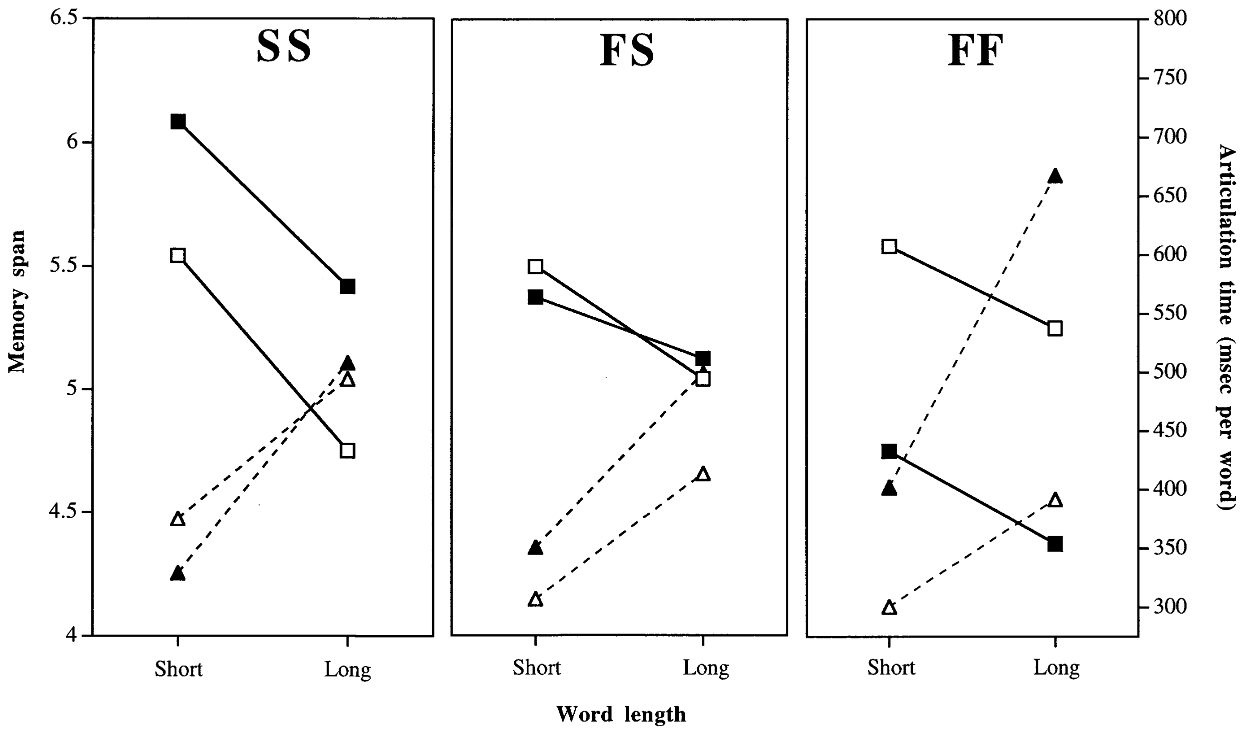

Figure 1. Mean memory span (solid lines) in Finnish (□) and Swedish (■) and articulation time (broken lines; ms per item) in Finnish (△) and Swedish (▲) for short and long words for SS, FS, and FF bilingual types.

Results

Articulation time The data from the articulation task were averaged and converted into measures of time per word (ms/word) and are summarised in Figure 1. These data were subjected to a three-way analysis of variance in which bilingual type (FF, FS, or SS) was a between-subjects factor, and language (Finnish or Swedish) and word length (short or long) were within-subjects factors. This revealed reliable main effects of language ($F\,(1, 33) = 160.9$, $p < .001$) with a shorter articulation time in Finnish than Swedish (means = 380 and 459 ms/word respectively), and word length ($F\,(1, 33) = 758.65$, $p < .001$) with a shorter articulation time for short words than long words (344 and 496 ms/word respectively). The two-way interactions between bilingual type and language ($F\,(2, 33) = 91.14$, $p < .001$), bilingual type and word length ($F\,(2, 33) = 7.08$, $p < .01$), and language and word length ($F\,(1, 33) = 83.22$, $p < .001$) were reliable and were qualified by a significant second-order interaction between the factors ($F\,(2, 33) = 17.32$, $p < .001$).

Analysis of the three-way interaction by simple main effects indicated that articulation time for short words was shorter than for long words in both languages and for the three bilingual types (all (1,33), $45 < F < 388$, $p < .001$). For the FS bilingual type, articulation time was shorter in Finnish than Swedish for both short words ($F\,(1, 33) = 8.43$, $p < .01$, means = 307 and 351 ms/word respectively) and long words ($F\,(1, 33) = 30.99$, $p < .001$, means = 414 and 499 ms/word respectively). For the FF bilingual type, articulation time was shorter in Finnish than Swedish for both short words ($F\,(1, 33) = 43.97$, $p < .001$, means = 300 and 402 ms/word respectively) and long words ($F\,(1, 33) = 326.56$, $p < .001$, means = 391 and 668 ms/word respectively). For the SS bilingual type, articulation time was shorter in Swedish than Finnish for short words ($F\,(1, 33) = 9.06$, $p < .01$, means = 329 and 375 ms/word respectively), but no difference was present for long words ($F < 1$, means = 508 and 494 ms/word respectively).

Articulation time in Finnish and Swedish by FS was compared with performance by controls (FF and SS, respectively) using a *t*-test. The results showed that FS articulation time for short and long words was equivalent to that of SS when performance was specified in Swedish (both $t\,(22) < 1$, $p > .05$) and to that of FF when performance was specified in Finnish (both $t\,(22) \leq 1.22$, $p > .05$). Performance between the control groups, however, varied in a lawful manner such that FF had a shorter articulation time for short and long words than SS in Finnish (both t (22) $\geq$ 2.90, $p < .05$) and vice versa (both t (22) $\geq$ 2.99, $p < .05$).

To summarise, the results of the articulation task indicate that FS and FF bilinguals articulated words faster in Finnish than Swedish, whereas SS had a shorter articulation time in Swedish than Finnish for short words and no difference was noted between the languages for long words. The findings suggest that, as far as SS and FF are concerned, articulation time varies as a function of fluency with a shorter time associated in the dominant language. In the case of FS, however, articulation time was equivalent in both languages when compared with Finnish- and Swedish-dominant controls. This finding clearly demonstrates that, as far as articulation time is concerned, FS performed at native speaker levels and discounts the possibility that performance on the memory span task would be affected by an imbalance in fluency between the languages.

Memory span

The memory span data were subjected to a corresponding three-way analysis of variance and are summarised in Figure 1. This indicated a reliable main effect of word length (F (1, 33) = 13.12, $p < .01$) with a larger span for short words than for long words (means = 5.47 and 4.99 respectively). The interaction between bilingual type and language was reliable (F (2, 33) = 28.09, $p < .001$). The remaining first-order interactions and the second-order interaction between the factors were not reliable (all $F < 1$).

Analysis of the interaction between bilingual type and language by simple main effects indicated a language difference in memory span for FF (F (1, 33) = 38.28, $p < .001$, means Finnish = 5.42, Swedish = 4.56) and SS (F (1, 33) = 19.15, $p < .001$, means Finnish = 5.14, Swedish = 5.75). For the FS bilingual type, however, no language difference was noted ($F < 1$, means Finnish = 5.27, Swedish = 5.25). Finnish memory span was equivalent across the three bilingual groups ($F < 1$), whereas a difference was present for Swedish memory span as a function of bilingual type (F (2, 66) = 6.45, $p < .01$). Analysis by t-test indicated that Swedish memory span for both SS and FS was greater than for FF (t (22) = 3.46, $p < .001$, and t (22) = 2.27, $p < .05$ respectively), whereas no difference was present between SS and FS.

To summarise, the results of the memory span task were relatively straightforward. Memory span was larger in the respective dominant languages of SS and FF bilinguals, whereas FS bilinguals obtained an equivalent memory span in Finnish and Swedish. All bilingual types performed equivalently in Finnish and no difference in Swedish memory span was noted between SS and FS who, in turn, obtained larger memory spans in Swedish than FF.

Table 1. *Correlations between articulation time and memory span for Finnish and Swedish for word stimuli for each bilingual type in Experiment 1*

	Language	
Bilingual type	Finnish	Swedish
Finnish mother tongue, Finnish schooled (FF)	0.27	0.52**
Finnish mother tongue, Swedish schooled (FS)	0.51**	0.52**
Swedish mother tongue, Swedish schooled (SS)	0.46*	0.28

* $p < .05$ ** $p < .01$

A series of Pearson correlations was performed on the data to examine the relationship between articulation time and memory span in Finnish and Swedish for each bilingual type; they are summarised in Table 1. The results showed that for both FF and SS, articulation time was reliably correlated with memory span in the less-dominant language, whereas for FS the variables correlated significantly in both languages. A test of the significance of the difference between correlations (Cohen & Cohen, 1983) indicated that the differences in the magnitude of the correlation coefficients between articulation time and memory span in Finnish and Swedish were marginal for FF (t = 1.50, $p < .10$) and SS (t = 1.45, $p < .10$). No difference between the correlations (t = 0.10) was noted for FS.

Discussion

The results of Experiment 1 indicate that for SS and FF performance on both the articulation time and memory span tasks varied in an orderly manner with respect to language dominance. In other words, with the exception of SS articulation time for long words, the control groups had a shorter articulation time and larger memory span in their respective native languages. At first blush, these findings could be taken as support for working memory theory, since a superior memory span was noted in the language in which articulation time was shorter. Such a conclusion, however, is premature, as it ignores that for these two groups (FF and SS) the superior memory span could be equally attributed to factors related to language dominance and a variation in the strength of long-term memory representations between the languages (Brown & Hulme, 1995; Hulme, et al., 1991, 1995 ; Roodenrys, Hulme, & Brown, 1993). A closer scrutiny of the results is required before it can be concluded that memory span is mediated by subvocal rehearsal alone.

Articulation time in Finnish was shorter for FF than SS, whereas this pattern was reversed for Swedish. These findings support the suggestion that speech rate is affected by long-term memory factors as typified by language dominance in this case (Henry & Millar, 1991; Tehan & Humphreys, 1988). Memory span on the other hand did not vary between the control groups for Finnish, whereas when performance was specified in Swedish a larger span was noted for SS. These results thus support the notion that SS bilinguals have a near-to-native fluency in Finnish, whereas the reverse is not so for the FF group. More importantly, however, these findings suggest that articulation time is not the critical determinant of memory span for, if this were the case, a shorter articulation time in Finnish for FF relative to SS should have occasioned a larger memory span for the former when performance was specified in the same language. Instead, performance on the memory span task by these two groups is consistent with the pattern of language dominance typical of the specific bilingual environment in which the participants live.

For FS, between-language memory span was equivalent despite a shorter articulation time in Finnish than Swedish. Moreover, FS had an equivalent articulation time and memory span in Finnish and Swedish compared with dominant language performance by SS and FF controls respectively. The FS bilinguals thus had a level of proficiency in Finnish and Swedish for both the articulation time and memory span tasks comparable to native speakers of these languages. This finding discounts the possibility that FS memory span was mediated by discrete levels of proficiency between the languages. But how, then, may the equivalence in memory span noted for FS be accounted for?

The correlational analysis indicated a trend towards a stronger correlation between articulation time and memory span in the non dominant than the dominant language for both FF and SS, whereas for FS, a reliable correlation was noted in both languages. This finding suggests a differential level of phonological loop involvement between the dominant and less dominant languages for bilinguals with an asymmetric level of proficiency (FF and SS). Moreover, the equivalent correlations in both Finnish and Swedish noted for FS suggest that short-term memory processes for these bilinguals differ with respect to controls in that a greater dependence on the phonological loop was noted in both languages.

Although matched for word frequency according to monolingual norms, the Finnish and Swedish items used in Experiment 1 were likely to vary in terms of subjective frequency as a function of language dominance (see, e.g., Dijkstra & van Heuven, 1998). It is thus reasonable to suggest that the items also varied in terms of the strength of lexico-semantic representations between the bilingual groups. If this is so, it is plausible that items in the less dominant language (in which the strength of long-term memory representations is weaker) made greater demands on phonological memory than those in the dominant language (in which the additional long-term memory support is available).

Gathercole and Baddeley (1995) have suggested that the repetition of low wordlike nonwords is principally mediated by phonological memory, whereas items with high wordlikeness engage long-term lexical knowledge. The present findings suggest a similar dissociation between the use of phonological and lexical processes in bilinguals when the level of fluency is not balanced such that phonological memory processes are more actively engaged in the language in which proficiency is lower. In the dominant language, on the other hand, long-term memory makes a greater contribution to short-term memory capacity, and hence the marginally lower correlation between articulation time and memory span. In the case of FS, however, phonological processes make an equivalent contribution to memory span in both languages as evidenced by the equivalent correlations between articulation time and memory span for Finnish and Swedish.

This unexpected finding indicates that, although equivalent to controls in absolute terms, the underlying processes by which performance was mediated for FS differed from dominant language performance by FF and SS. A plausible explanation for this finding is that FS bilinguals may be in a permanently mixed language mode, whereas FF and SS may find it easier to deactivate or inhibit the language in which performance is not specified (see, e.g., Grosjean, 1998; Green, 1986). In the present paradigm, the consequence of having two codes in a state of activation is that both languages are processed in a manner that resembles less dominant language performance by controls: a greater contribution from the phonological loop.

To summarise, the results of Experiment 1 indicate that both the articulation time and memory span performance measures were influenced by language dominance. It is thus not possible to dissociate the relative involvement of temporal and non-temporal factors in mediating bilingual memory span performance conclusively. The finding that performance on the articulation time task did not mirror that of the memory span task, however, provides some suggestion that bilingual short-term memory capacity is not mediated exclusively by the rate of subvocal rehearsal. The finding that FS performed at native speaker control levels in both the articulation time and memory span tasks indicates that FS were highly balanced bilinguals with a native level of fluency in both Finnish and Swedish. For these bilinguals, however, articulation time did not predict a memory span equivalence between the languages.

The next experiment examined the effect of long-term, lexico-semantic knowledge in mediating bilingual memory capacity. The use of nonwords is an effective means of controlling for differences in the strength of long-term memory representations (Hulme et al., 1991). In Experiment 2, therefore, the word stimuli were replaced with nonwords. If, as suggested above, bilingual memory span capacity is mediated by factors related to fluency and language dominance, two specific outcomes should be noted under conditions in which the contribution of long-term lexico-semantic memory to short-term memory capacity is diminished. First, under these circumstances, articulation time should be a reliable predictor of memory span for all the bilingual groups. Second, reliable correlations between articulation time and memory span should be noted in both Finnish and Swedish for the three bilingual groups.

Experiment 2

Method

Participants The same participants were tested after an interval of approximately two weeks.

Materials and procedure Four nonword pools consisting of eight short (one syllable) and eight long (three syllable) phonotactically legal Finnish and Swedish nonwords (see Appendix) were constructed with assistance from Finnish- and Swedish-speaking linguists. First, measures of memory span were taken. Before testing in each condition, the Experimenter introduced the nonwords by pronouncing these individually, after which the participants were asked to repeat the items. A new item was not attempted until it was established that participants could pronounce the previous item clearly. The remaining procedural details were identical to those described for Experiment 1.

Results

Articulation time The data from the articulation task were subjected to a corresponding three-way analysis of variance and are summarised in Figure 2. The results indicated reliable main effects of language (F (1, 33) = 181.56, $p < .001$) with a shorter articulation time for Finnish nonwords (458 ms/item) than Swedish nonwords (621 ms/item) and word length (F (1, 33) = 334.72, $p < .001$) with a shorter articulation time for short items than long ones (means = 394 and 685 respectively). The two-way interactions between bilingual type and language (F (2, 33) = 9.937, $p < .001$), bilingual type and word length (F (2, 33) = 4.36, $p < .05$), and language and word length (F (1, 33) = 16.76, $p < .001$) were all reliable. The higher order interaction was not reliable ($F < 1$).

Analysis of the interaction between bilingual type and language by simple main effects indicated that articulation time was shorter in Finnish than Swedish for all bilingual types (all F (1,33) $\geq$ 18.80, $p < .001$, means FF = 411 and 631 ms/item; SS = 543 and 633 ms/item; FS = 422 and 599 ms/item respectively). No between-group difference was noted for Swedish ($F < 1$), but a language difference was present as a function of bilingual type for Finnish (F (2, 66) = 4.21, $p < .05$). Comparison of the means by planned t-test indicated that SS articulated Finnish nonwords more slowly than FF (t (22) = 1.93 $p < .05$) and no other comparisons were reliable. These findings indicate that the three bilingual types had shorter articulation times in Finnish than Swedish. The SS group had a longer articulation time than FF, and hence the interaction term.

A corresponding analysis of the interaction between bilingual type and word length revealed that the three groups had a shorter articulation time for short nonwords than long nonwords (all F (1,33) $\geq$ 71.4, $p < .001$, means FF = 404 and 637 ms/item; SS = 414 and 761 ms/item; FS = 364 and 657 ms/item respectively). No between-group difference was noted for short nonwords ($F < 1$), but a difference was present as a function of bilingual type for long nonwords (F (2, 66) = 3.33, $p < .05$). Comparison of the means by planned t-test indicated that SS articulated long nonwords slower than FF (t = 1.83 $p < .05$) and no other differences were reliable. The findings thus suggest that short nonwords were articulated faster than long nonword by the three groups. Long nonwords were articulated more slowly by SS than FF, and hence the interaction term.

Finally, the analysis of the interaction between the language and word length factors by simple main effects indicated that short nonwords were articulated faster than long nonwords in Finnish (F (1, 66)

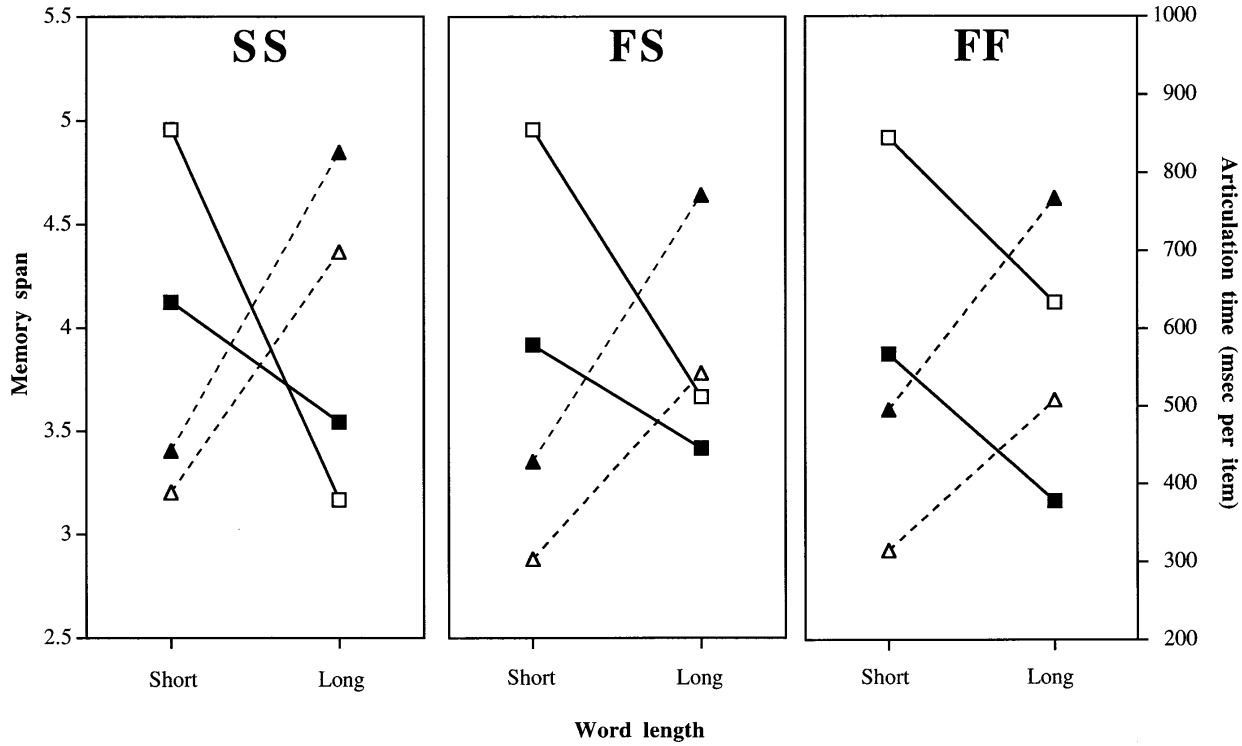

Figure 2. Mean memory span (solid lines) in Finnish (□) and Swedish (■) and articulation time (broken lines; ms per item) in Finnish (△) and Swedish (▲) for short and long nonwords for SS, FS, and FF bilingual types.

= 170.14, $p < .001$, means = 334 and 582 ms/item respectively) and Swedish (F (1, 66) = 307.62, $p < .001$, means = 454 and 788 ms/item respectively). The between-language comparisons showed that articulation time was shorter for Finnish than Swedish at the short (F (1, 66) = 56.46, $p < .001$, means = 334 and 454 ms/item respectively) and long (F (1, 66) = 165.637, $p < .001$, means = 582 and 788 ms/item respectively) word length levels. These findings indicate that articulation time was shorter in Finnish than Swedish and that short nonwords were articulated faster than long nonwords in both languages.

Although the absence of a higher order interaction between the factors indicates that articulation time was equivalent between FS and the respective Finnish and Swedish control groups, this suggestion was examined in more detail by a series of planned t-tests. The results confirmed that FS had an equivalent articulation time to SS when performance was specified in Swedish and no difference between FS and FF was noted when performance was specified in Finnish (all t (22) $\leq$ 1.75, $p > .05$).

To summarise, articulation time was shorter in Finnish than Swedish and short nonwords were articulated faster than long nonwords by all bilingual types. More importantly, the nonword articulation time results converged with those of Experiment 1 in that FS articulated Finnish and Swedish nonwords at a rate equivalent to performance by native speakers of each respective language.

Memory span

The memory span data were subjected to a corresponding three-way analysis of variance and are summarised in Figure 2. The results indicated reliable main effects of language (F (1, 33) = 52.35, $p < .001$) with a larger memory span for Finnish (4.3) than Swedish (3.64), and word length (F (1, 33) = 96.79, $p < .001$) with a larger memory span for short items than long ones (means = 4.46 and 3.51 respectively). The two-way interactions between bilingual type and language (F (2, 33) = 6.65, $p < .01$) and language and word length (F (1, 33) = 9.26, $p < .01$) were reliable. The interaction between bilingual type and word length (F (2, 33) = 1.8), and the higher order interaction between the factors (F (2, 33) = 2.07) were not reliable.

The interaction between bilingual type and language was examined by simple main effects. This indicated a larger memory span in Finnish than Swedish for FS (means = 4.31 and 3.67 respectively) and FF (means = 4.52 and 3.52, both F (1,33) $\geq$ 5.01, $p < .001$). The language difference for the SS group was marginal (F (1, 33) = 2.35, $p < .10$, means = 4.06 and 3.8 respectively). Inspection of the means suggested that this marginal effect may have been due to a different relationship between Finnish and Swedish at the short- and long-item levels. This was examined using a t-test. The results showed that SS had a larger memory span in Finnish than Swedish for short nonwords (t (11) = 2.75, p <.05, means = 4.96 and 4.13 respectively), but not for long nonwords (t (11) = 1.92, p >.05, means =3.17 and 3.54 respectively). No difference was present across the bilingual types for Finnish (F (2,66) = 1.45) or Swedish (F (2,66) < 1). The interaction between the bilingual type and language factors is thus likely to be a consequence of a shorter memory span by SS for Finnish long nonwords.

A corresponding analysis of the interaction between the language and word length factors indicated that memory span was greater for short nonwords than long nonwords in both Finnish (F (1, 66) = 75.03, $p < .001$, means = 4.94 and 3.65 respectively) and Swedish (F (1, 66) = 16.04, $p < .001$, means = 3.97 and 3.75 respectively). The between-language comparisons showed that memory span was larger for Finnish than Swedish for short nonwords (means = 4.94 and 3.97 respectively) and long nonwords (means = 3.65 and 3.38 respectively, both F (1,66) $\geq$ 3.80, $p < .05$).

Although the absence of a higher order interaction between the factors indicated that memory span was equivalent between FS and the respective Finnish and Swedish control groups, this was examined in more detail using a t-test. The results confirmed that FS had an equivalent memory span to SS when performance was specified in Swedish and no difference between FS and FF was noted when performance was specified in Finnish (all t (22) $\leq$ 1.07, $p > .05$).

The results of the nonword memory span task may be summarised as follows. Memory span was larger in Finnish than Swedish for all three groups with the exception of SS at the long word length level, and FS memory span was equivalent to native speaker controls.

A series of Pearson correlations was performed on the Finnish and Swedish articulation time and memory span data for each bilingual type, and they are summarised in Table 2. The results indicate that for items with no pre-existing lexical representations, articulation time was correlated reliably and consistently with memory span in both languages for the three groups.

Wordlikeness

One important difference between the findings of Experiments 1 and 2 was that in the former, the language relationship between articulation time and memory span varied in a lawful manner across the control groups. That is, FF had a shorter articulation time and larger memory span in Finnish, whereas SS had a superior performance in Swedish. By contrast, in Experiment 2 a superior memory span and a shorter articulation time for Finnish was noted in both control groups. This finding suggests that the Finnish nonwords in Experiment 2 varied in some, as yet unspecified, way which facilitated both the articulation and recall of these items relative to Swedish nonwords. One obvious way in which the Finnish and Swedish nonwords may have differed was in the degree to which the items resembled actual words in each respective languages.

Measures of wordlikeness were, therefore, taken to examine the extent to which the results of Experiment 2 were influenced by a variation in the degree to which the nonwords resembled actual words between the languages. Two groups of psychology undergraduates from the Swedish (n = 12) and Finnish (n = 22) language universities in Turku and from the same language backgrounds as the participants in the above experiments (i.e., FF and SS) were recruited for participation in the wordlikeness rating exercise. Each group rated the nonwords for their respective language in separate sessions. Each item was spoken twice by a native speaker of each respective language immediately after which the participants were asked to rate the wordlikeness of the item on a scale of 1 5 (1 = very unlike a real word, 5 = very like a real word) and so on until all 16 items were rated (see, e.g., Gathercole, Willis, Emslie, & Baddeley, 1991).

The wordlikeness data were subjected to a two-way analysis of variance in which language (Finnish or Swedish) was a between-language factor and word length (short or long) was a within-subject factor. This showed that the main effects of language

Table 2. *Correlations between articulation time and memory span for Finnish and Swedish nonword stimuli for each bilingual type in Experiment 2*

Bilingual type	Language: Finnish	Language: Swedish
Finnish mother tongue, Finnish schooled (FF)	0.51**	0.51**
Finnish mother tongue, Swedish schooled (FS)	0.36*	0.52**
Swedish mother tongue, Swedish schooled (SS)	0.64***	0.53**

* $p < .05$ ** $p < .01$ *** $p < .001$

(*F* (1,32) = 2.91) and of word length (*F* (1,32) < 1) were not reliable. The interaction between the factors, however, was reliable (*F* (1,32) = 8.55, *p* <.01). Analysis of the interaction by simple main effects indicated that the short Swedish items were rated more wordlike than the short Finnish nonwords (*F* (1,64) = 11.17, *p* < .01, means = 3.11 and 2.28 respectively). No difference in wordlikeness was noted between the Swedish and Finnish long nonwords (*F* (1,64) = 1.38, means = 2.51 and 2.80 respectively). A difference in wordlikeness was noted between the short and long Finnish nonwords (*F* (1,32) = 5.31, *p* < .05) and the difference between the Swedish items was marginal (*F* (1,32) = 3.74, *p* = .06)

The wordlikeness results thus indicate that short Swedish nonwords were rated as more wordlike than short Finnish nonwords and that the latter were, in turn, rated as less wordlike than long Finnish nonwords. Although the wordlikeness results indicate a degree of variation between the nonwords at both the language and length factors, there is no convergence between these ratings and performance on the articulation time and memory span tasks in Experiment 2. Short Swedish nonwords, to take one example, were rated as more wordlike than the short Finnish items. This wordlikeness advantage, however, did not occasion either a shorter articulation time or a larger memory span for short Swedish items compared with short Finnish ones. The findings of the wordlikeness ratings task thus suggest that the pattern of results in Experiment 2 was unlikely to be mediated by a language difference in the degree to which the nonwords approximated actual words.

Discussion

The results of Experiment 2 indicate that, with the exception of SS performance at the long word level, nonword articulation time was a reliable predictor of memory span for all three bilingual types. The most notable finding, however, was that under these circumstances FS bilinguals had a larger memory span in the language in which articulation time was shortest. These findings are to be contrasted with those of Experiment 1 in which FS articulated words faster in Finnish than Swedish items but, nevertheless, had an equivalent memory span between the languages. Thus, when the differential in the strength of long-term memory representations between the languages was controlled by the use of items with no pre-existing lexico-semantic representations, articulation time was a reliable predictor of the relationship between Finnish and Swedish memory span.

It will be noted that SS, and to a lesser extent FS, seem to have specific problems in remembering Finnish long nonwords compared to FF. In terms of articulation time SS took longer to articulate the same items compared with FF, whereas the short Finnish nonwords were articulated at the same rate between these two groups. This suggests that there is something about the long Finnish nonword items that occasions a slower speech rate and poorer recall in bilinguals that are not dominant in Finnish.

Although the present study was incapable of identifying the exact source of this difficulty, the findings of the wordlikeness ratings indicate that the relatively poorer performance for these items could not be attributed to a difference in the extent to which the items approximated words between the languages.

General discussion

The aim of the present study was to examine the relationship between articulation time and memory span in bilinguals in more detail than has previously been possible. Our main interest focused on a specific bilingual pairing comprised of individuals that speak Finnish in the home and are schooled exclusively through the medium of Swedish: the so called FS bilingual. It has been shown that these individuals have equivalent digit spans in Finnish and Swedish (Chincotta & Underwood, 1996c, 1997). Owing to the limitations associated with the use of digit stimuli, however, these studies could not examine the relative contribution of articulation time and long-term memory representations in mediating bilingual short-term memory capacity. The use of word stimuli in Experiment 1, on the other hand, allowed a tighter control over the variable of word length between the languages.

The findings show that controls generally articulated words faster and had a larger memory span in their respective dominant languages. For these bilinguals, therefore, it could not be determined whether memory span capacity was mediated by factors related to language dominance or the rate of subvocal rehearsal. For FS, however, despite a shorter articulation time in Finnish, memory span was equivalent between the languages. In addition, the finding that FS did not differ from dominant language performance by controls discounted the possibility that the equivalence in memory span between Finnish and Swedish was mediated by discrete levels of fluency between the languages. This finding was taken as an initial indication that bilingual memory span was determined by factors other than subvocal rehearsal and phonological loop functioning.

The use of items with no pre-existing lexical representations has been demonstrated to be an effective means of dissociating the relative contribution of articulation time and long-term memory representations to short-term memory capacity (e.g., Hulme et al., 1991). In Experiment 2, therefore, words were replaced with nonwords. The results show that nonword articulation time was shorter in Finnish than Swedish for the three bilingual types and, with the exception of performance for long items by the SS group, nonwords were recalled better in Finnish than Swedish across the three groups. As in Experiment 1, performance by FS was equivalent to dominant language performance by controls in both the articulation and memory span tasks.

The findings of Experiment 2 thus indicate that for FS the between-language relationship noted for the memory span task was reliably predicted by articulation time when the items had no pre-existing lexical representations. This contrasts with the results of Experiment 1 where articulation time did not predict the equivalence in memory span for words in the same group of individuals. These findings further support the notion that the equivalence in memory span between Finnish and Swedish by FS noted in Experiment 1 was occasioned by factors related to language fluency and the strength of long-term memory representations.

It has been posited that the absence of a variation in Finnish and Swedish digit span in FS bilinguals may have been occasioned by an interplay between a shorter word length for Swedish digits and stronger long-term memory representations for Finnish digits (Chincotta and Underwood, 1996; 1997c). By contrast, the present findings suggest that the equivalence in memory capacity in FS bilinguals is a consequence of a comparable level of fluency in both languages: a non temporal factor. This account is corroborated by the finding that FS bilinguals read numeral representations of digits at the same rate in Finnish and Swedish (Chincotta and Underwood, 1996; 1997c) as this measure of speech rate has been demonstrated to be an reliable index of bilingual fluency (Chincotta, Hyönä, Underwood, 1997). The finding that articulation time varies in a lawful and predictable manner as a function of language dominance (Experiment 1) suggests that these variables are confounded. One plausible explanation as to why memory span has been attributed to the rate of subvocal rehearsal, therefore, is that articulation time, and hence word length, is sensitive to language fluency. Under these circumstances, an association between articulation time and memory span could be attributed equally to a variation in either speech rate *or* to language dominance.

Taken together, the present findings question the working memory theory account of the bilingual digit span effect proposed by Ellis and Hennelly (1980) which attributes the variation in memory span between the languages to a difference in the rate of subvocal rehearsal. Instead, we take the view that bilingual short-term memory capacity is mediated by non-temporal factors related to long-term, lexico-semantic knowledge of the languages in question. The view that non-temporal factors are critical determinants of bilingual memory span is further supported by the findings of a recent study of Welsh-English bilinguals. Chincotta and Adlam (submitted) found that an objective measure of long-term knowledge of language in the form of a test of expressive vocabulary was a more reliable predictor of Welsh-English auditory digit span than articulation time. In this study, individuals with a high proficiency in Welsh had a larger digit span in Welsh than English, whereas the reverse was found for individuals with a low proficiency in Welsh. Crucially, this pattern of results was noted despite a shorter articulation time for English digits than Welsh digits in both proficiency groups.

In short, the present findings suggest that the role of articulation time and subvocal rehearsal in determining short-term memory capacity in bilinguals has been overplayed. This is not to say that the word length variable is without consequence. The finding that all the present bilingual groups had a shorter articulation time and larger memory span for short words than long words for both Finnish and Swedish indicates that *ceteris paribus*, bilingual short-term memory capacity is sensitive to within-language word length. Our account of the factors that mediate the bilinguals memory span thus converges with recent models of short-term memory capacity (Hulme et al., 1991, 1995) that have demonstrated the contribution of long-term memory factors in determining monolingual memory span.

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Appendix

Finnish short and long words used in Experiment 1

	Finnish				
Short words			Long words		
	Word frequency per million	English equivalent		Word frequency per million	English equivalent
jää	83	ice	hedelmä	80	fruit
kuu	108	moon	paperi	115	paper
tee	30	tea	sipuli	33	onion
maa	2015	earth	ihminen	1893	human
säe	18	verse	osoite	19	address
yö	305	night	tavara	278	object
suo	123	swamp	aurinko	230	sun
voi	65	butter	peruna	55	potato
Mean	343.38			341.5	

Swedish short and long words used in Experiment 1

	Swedish				
Short words			Long words		
	Word frequency per million	English equivalent		Word frequency per million	English equivalent
regn	28	rain	gräsmatta	29	lawn
sak	453	thing	regering	387	government
par	427	pair	område	398	district
kri	264	war	utställning	233	exhibition
bild	474	picture	arbete	512	work
eld	55	fire	semester	52	holiday
bok	876	book	människa	844	man
mat	93	food	innehåll	98	content
Mean	335			318.13	

Finnish and Swedish short and long nonwords used in Experiment 2

Finnish nonwords		Swedish nonwords	
Short	Long	Short	Long
nuu	askura	app	paltenpes
mäy	hanekus	spöl	untufes
loo	ihunna	risp	mastuplin
ruo	lokusa	stry	hirramit
hii	olunti	tirk	gurrafrud
pei	pikolis	prul	flusdinnel
reu	solanu	svick	dyskafus
äi	tinulo	fipp	firrstypa

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Studying bilinguals: Methodological and conceptual issues*

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Because the field of bilingualism is still relatively new, studies in the linguistics, psycholinguistics, language development and neurolinguistics of bilingualism have often produced conflicting results. It will be argued in this paper that some of the difficulties encountered by researchers could have been lessened, if not avoided, had close attention been paid to methodological and conceptual issues. Among the issues covered are bilingual participants, language mode, stimuli, tasks as well as models of bilingual representation and processing. Each issue is dealt with in the following way: first it is explained, then the problems it causes are discussed, and, finally, tentative solutions are proposed. Examples are taken from descriptive and experimental studies of normal bilingual adults and children as well as bilinguals suffering from aphasia and dementia.

Most researchers who have studied both monolinguals and bilinguals would undoubtedly agree that working with bilinguals is a more difficult and challenging enterprise. Many reasons come to mind as to why this might be so: bilingualism has been studied less extensively than monolingualism, theoretical models in areas such as bilingual competence, language development and processing are less well developed, conceptual notions and definitions show a great deal of variability, specific methodological considerations have to be taken into account, and so on. One outcome of this situation is that research dealing with bilinguals has often produced conflicting results.

In the field of experimental psycholinguistics, for example, some researchers have proposed that language processing is selective (e.g., Scarborough, Gerard and Cortese, 1984; Gerard and Scarborough, 1989), while others have suggested that it is non-selective (e.g., Altenberg and Cairns, 1983; Beauvillain and Grainger, 1987); some studies have shown evidence for a language-independent lexicon (e.g., Kolers, 1966; Schwanenflugel and Rey, 1986), while others have supported language-dependent lexicons (Tulving and Colotla, 1970; Taylor, 1971); some papers propose that lexical representation is best explained by a word association model or a concept mediation model (both proposed by Potter, So, von Eckhart and Feldman, 1984), while others put forward a revised hierarchical model (Kroll and Stewart, 1994) or a conceptual feature model (de Groot, 1992); some researchers have shown that code-switches in continuous text take time to produce and perceive (e.g., Macnamara, 1967; Macnamara and Kushnir, 1971), while others have shown the opposite (Wakefield, Bradley, Yom and Doughtie, 1975; Chan, Chau and Hoosain, 1983). In the field of bilingual language development, some studies have found evidence that children who acquire two languages simultaneously go through a fusion stage (e.g., Volterra and Taeschner, 1978; Redlinger and Park, 1980), while others have questioned this stage (Meisel, 1989; Paradis and Genesee, 1996), and in the field of neurolinguistics, such questions as hemispheric lateralization and localization of language in bilinguals have been disputed (for a critical review see Zatorre, 1989), as has the inability

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of some bilingual aphasics to control the production of mixed language in a monolingual environment (e.g., compare Perecman, 1984, with Grosjean, 1985b). This list is not exhaustive and other controversial findings bear on such topics as variability in code-switching patterns in various communities, perceptual boundaries in bilingual listeners, the existence or not of an input or output switch in bilinguals, the lexical routes taken when bilinguals are translating from their weaker language to their stronger language, and so on.

In what follows it will be suggested that some of the difficulties encountered by researchers, and some of the conflicting results they have obtained, could perhaps have been lessened, if not avoided, had close attention been paid to methodological and conceptual issues. Among the issues covered are participants, language mode, stimuli, tasks and models. Concerning participants, I will review the main defining characteristics of the bilingual individual (language history, language proficiency, language use, etc.), list the problems that are encountered in choosing participants, and show that some factors that are not always taken into account in studies clearly affect the results obtained. With regard to language mode, I will describe the language modes bilinguals find themselves in, and show how this affects such issues as code-switching patterns in bilingual speech, the independence or interdependence of language representation, language fusion in very young bilingual children, mixing in aphasics, and so on. As concerns stimuli, I will question the comparability of stimuli within and across studies and will show how some of their characteristics need to be controlled for. As for tasks, I will examine the side-effects that some of them induce, what it is they are tapping into and what aspects of the results are task-specific. I will end with a discussion of the advantages but also the problems of models of bilingual representation and processing, such as the monolingual outlook of some, their use of discrete classifications, the absence of certain components or levels, and the scarcity of global models. (For lack of space, such issues as data collection procedures in naturalistic environments, transcription and categorization of bilingual speech, as well as the problems associated with the statistical analysis of these kinds of data, will not be addressed here.)

Each issue will be dealt with in the following way: first it is explained, then the problems it causes are discussed, and, finally, tentative solutions for future research are proposed. Several points need to be made. First, a lot of what follows has been stated in one way or another over the years by researchers in the field. I will try to do justice to their comments and suggestions but I will probably not be able to refer to everyone concerned for lack of space. If this paper can act as an echo chamber for the field and create further discussion and action around these issues, it will have served its purpose. Second, even though the discussion of each issue will end with suggestions for solutions, it is clear that these are quite tentative and that it is the field as a whole that will solve the problems that have been raised (all researchers have to struggle with these issues and finding solutions is a common challenge). Finally, even though I will mainly consider experimental studies done with adult bilinguals, I will also cover work done with speakers recorded in more natural environments and children, as well as with aphasic and demented patients. Thus, of the five issues that will be discussed, three (participants, language mode and models) concern all researchers working on the bilingual individual, and two (stimuli and tasks) are primarily of interest to experimentalists.

Participants

Issue

Most researchers would probably agree that bilinguals, that is those people who use two (or more) languages (or dialects) in their everyday lives, can be characterized by a number of general features. First, they are usually influenced by what has been called the complementarity principle (Grosjean, in press a), that is, the fact that they usually acquire and use their languages for different purposes, in different domains of life, with different people. Second, and as a direct consequence of this first characteristic, bilinguals are rarely equally fluent in all language skills in all their languages. Level of fluency depends in large part on the need for and use of a language (and a particular skill). Third, some bilinguals may still be in the process of acquiring a language (or language skill), whereas others have attained a certain level of stability. Fourth, the language repertoire of bilinguals may change over time: as the environment changes and the needs for particular language skills also change, so will their competence in these skills. Finally, bilinguals interact both with monolinguals and with other bilinguals and they have to adapt their language behavior accordingly (see the section on language mode).

Even though some research questions may be able to abstract away individual differences that exist among bilinguals (e.g., theoretical questions dealing with aspects of the bilingual's grammars), many others will not be able to do so. Among these differences we find:

- Language history and language relationship: Which languages (and language skills) were acquired, when and how? Was the cultural context the same or different? What was the pattern of language use? What is the linguistic relationship between the bilingual's languages?
- Language stability: Are one or several languages still being acquired? Is the bilingual in the process of restructuring (maybe even losing) a language or language skill because of a change of linguistic environment? Has a certain language stability been reached?
- Function of languages: Which languages (and language skills) are used currently, in what context, for what purpose and to what extent?
- Language proficiency: What is the bilingual's proficiency in each of the four skills in each language?
- Language modes: How often and for how long is the bilingual in a monolingual mode (i.e. when only one language is active) and in a bilingual mode (i.e. when both languages are active)? When in a bilingual mode, how much code-switching and borrowing is taking place?
- Biographical data: What is the bilingual's age, sex, socio-economic and educational status, etc.?

Of course, many other factors can be added to this list but these are the ones that are most often mentioned in the bilingualism literature.

Problems

Two main problems relate to the participants issue. The first is that some researchers, admittedly only a few, do not yet fully share the field's understanding of who bilinguals really are, and the second is that the factors that have been taken into account when choosing participants are often diverse, insufficient or controversial. As concerns the first problem, some people still feel that bilinguals have or should have equal and perfect fluency in each of their languages (what has been called the two monolinguals in one person viewpoint; Grosjean, 1985a; 1989); others still see language mixing as an anomaly, be it in children acquiring their languages simultaneously or successively, or in adult bilinguals; and others still fail to remember that many bilinguals are also bicultural and that their languages will reflect this dimension. The consequences are that erroneous claims may be made about a particular bilingual behavior, inappropriate comparisons may be made with monolinguals, and exceptional cases may be taken to apply to bilinguals in general. Three examples taken from the literature will illustrate this. First, in a study pertaining to spontaneous translation and language mixing in a polyglot aphasic, Perecman (1984) finds various types of language mixing at all levels of linguistic description in the patient under study. Basing herself on earlier work by Weinreich (1966), who unfortunately did not differentiate between interferences and code-switching, she states that language mixing is inappropriate switching from one language to another and that these "errors" can also be found in normal polyglots. However, language mixing in the form of code-switches and borrowings in bilingual interactions has long been known to be perfectly normal behavior among bilinguals interacting with one another (Poplack, 1980; Grosjean, 1982).

A second example concerns the so-called "semilingualism" of certain bilingual children. Supposedly these children possess less than native-like skills in both languages. They show quantitative deficiencies such as smaller vocabularies when compared with monolingual children, they deviate from monolingual norms, they mix their languages a lot, and so on (see Romaine, 1995, for a survey and a critical review of the question). What proponents of "semilingualism" need to ask themselves before classifying a child in this category are the following three questions: is the child still in the process of becoming bilingual (either learning two languages simultaneously or learning a second language and most probably restructuring the first one)? Is the child mostly in a bilingual, mixed language mode at home and is he or she just discovering the monolingual version of one or of the other language (in the school environment, for example)? Finally, has the child been meeting his or her communicative needs up to then (before entering school, for example)? Answers to these questions will probably show that the "semilingual" child is in the process of adjusting to such things as a new social context, a new language, new language skills and language varieties, new domains of use, etc. One should also remember that the complementarity principle will explain, as it does for the bilingual adult, why the child will never become two monolinguals in one person (Grosjean, in press a).

A third example comes from the field of psycholinguistics. In a study on speech segmentation, Cutler, Mehler, Norris and Segui (1992) used participants who they reported were as bilingual in English and French as they could find: they were accepted as native speakers of French by other speakers of French and accepted as native speakers of English by other speakers of English, they used both languages on an everyday basis, and they had been exposed to both languages simultaneously from one year of age.

The authors concluded that their participants had, to all intents and purposes, equally perfect command of the two languages. The participants were tested on English and French stimuli but, in the authors' words, the results produced "a puzzling picture," as they were not really comparable to those of either monolingual group. The authors decided therefore to subdivide the participants into subgroups (we will return to how they did this below) since, they report, the overall analysis left them with no obvious point of departure for interpretation of the bilingual results. The point to make here is that bilinguals are speakers-hearers in their own right who will often not give exactly the same kinds of results as monolinguals. One should be ready to accept this and maybe not always seek alternative solutions.

The second problem that relates to participants is that the factors that have been taken into account when choosing participants are often diverse, insufficient or controversial. On the first problem, diversity, one only needs to examine the "participants" section of most papers to realize that they are chosen very differently from one study to the next. Some researchers put the stress on fluency and use various scales or tests to evaluate their bilinguals; others stress language use (which languages are used with whom and for what); still others put the emphasis on language stability (whether their participants are still learning a language or not) and in what context they learned their two (or more) languages, and some few give their participants actual screening tests (reading aloud, counting, understanding a passage, etc.) in addition to presenting biographical data. What is clear is that because the information is so diverse, and the tools of assessment so different, we probably have very different bilinguals in the studies published. Some participants are still acquiring their second language (using language learners is a phenomenon that is on the increase), some are strongly dominant in one language, some others appear to be equally fluent in the spoken but not in the written modality, and some few appear to be quite balanced and active bilinguals. This variability is found between groups and is present within groups also.

At times the information given about participants is simply insufficient to get an idea of who they are. For example, in an often cited study by Caramazza and Brones (1980) that deals with the bilingual lexicon, we are only told that the Spanish-English bilinguals were native speakers of Spanish who ranged in their self-ratings of bilingual fluency from good to excellent (mean rating of 5.5 on a seven point scale). No explanation is given as to what "bilingual fluency" means and none of the factors listed above (language history, language stability, function of languages, etc.) are mentioned. This problem of insufficient information is especially present in studies that deal with aphasic and demented patients. Very little information is given about the patient after the onset of the pathology and even less about him or her prior to it. For example, Perecman (1984) simply gives us the age of the patient (H.B.), where he was born, the order of acquisition of his languages and the fact that English was the language he used primarily from age eighteen on. We know nothing about the patient's proficiency in the four skills in each language prior to his aphasia, the function of his languages, the amount of language mixing he did with other bilinguals, etc. The same problem is also present in child language studies (see, for example, Redlinger and Park, 1980; Vihman, 1985), where little is said about the children's proficiency in each language (admittedly harder to assess), the function of their languages, the amount of time they spent using the languages with monolinguals and bilinguals, and so on (see de Houwer, 1990, for a critical review).

Finally, a few studies take into account controversial factors when choosing or dividing up their participants. One approach that comes to mind is that used by Cutler et al. (1992) to break their participants down into two groups, a French-dominant and an English-dominant group. It should be recalled that these fluent and balanced bilinguals had been chosen because they had equally perfect command of their two languages. The authors tried out several approaches to divide them up and finally found one that produced interpretable data according to them: they asked participants to indicate which language they would choose to keep if they developed a serious disease and their life could only be saved by a brain operation which would have the unfortunate side effect of removing one of their languages. One could discuss at length whether such a question is appropriate (after all, isn't a person bilingual because he or she needs two or more languages in his or her everyday life?) but what should be stressed here is that we have no evidence concerning the validity of such a question for assessing language dominance. As a consequence, we do not really know what kinds of participants fell into each of the two groups. One unfortunate outcome is that replicating the results with similar groups of participants will be very difficult. This is exactly what Kearns (1994) found when she used the same type of highly fluent participants whom she also broke down into subgroups using the same question. Whereas her "French dominant" participants did not show the classic crossover interaction with French stimuli (what has since been called the French syllable effect), Cutler et al.'s

"French dominant" participants did show it.[1] In addition, and surprisingly, Kearns's "English dominant" participants showed a syllable effect with French stimuli whereas Cutler et al.'s participants did not. In sum, what is at stake here is not dividing up participants into subgroups in order to understand better the results obtained but rather the approach that is used to do so.

The problem of participant selection and description would be less crucial if we did not have evidence that the defining factors listed above (i.e. language history, language stability, function of languages, etc.) are important. In fact, this evidence does exist; concerning the language history and language relationship factor, Segalowitz (1997) shows that there is considerable variability between participants in L2 learning and that this has an impact on language knowledge and language processing; Mayo, Florentine and Buus (1997) present data showing that perception in noise is affected by age of acquisition of the second language; de Groot (1995) suggests that recent use, but also disuse, of a language affects one's lexical representations, etc. As concerns language stability, Kroll and Curley (1988) and Chen and Leung (1989) both show that the processing paths followed during simple word translation is different in language learners and bilinguals who have attained a certain stability and fluency in their languages. As for language function, it is a well known fact that certain domains of life of bilinguals are usually covered exclusively by one language (e.g., work, religion, sports, etc.) and that many bilinguals simply do not have translation equivalents in their other language for these domains, especially if they did not acquire either language in school. Regarding language proficiency, Poplack (1980) shows that one obtains different code-switching patterns depending on how fluent speakers are in their two languages (see also the four switching styles described by Bentahila and Davies (1991) that depend in part on proficiency); Dornic (1978) shows that various linguistic tasks given to bilinguals take more time and are harder to accomplish in their non dominant language; de Groot (1995) reports that the effect found with a bilingual Stroop test depends on the participants' language proficiency; Lanza (1992) demonstrates that the type of mixing young bilingual children do depends on their language dominance; Zatorre (1989) argues that less lateral cerebral asymmetry found in some studies for a bilingual's non dominant language could be due to comprehension problems (and not laterality reasons); Hyltenstam (1991) finds a relationship in demented patients between proficiency in a language and the ability to keep to it separate from the other language, and so on. As for the language mode factor (to which we will return in the next section), Genesee (1989) makes the point that more mixing takes place in children who hear both languages used interchangeably by the same interlocutors. Finally, it is a well known fact that certain biographical variables such as sex and handedness play an important role in language laterality studies (Zatorre, 1989; Vaid and Hall, 1991).

[1] According to Frauenfelder and Kearns (1997), a syllable effect is generally characterized as a significant interaction of target type and word type. Participants are faster or more accurate in detecting targets which correspond exactly to the first syllable of a word than targets which correspond to more or less than the first syllable. The authors add that according to a more stringent criterion, to be able to infer a syllable effect there must be a significant crossover interaction between target type and word type.

Tentative solutions

Concerning the first problem, the lack of understanding of who bilinguals really are, all that can be said is that there are a sufficient number of general introductions to the field to help researchers not to fall into this trap (see, for example, Grosjean, 1982; Beatens-Beardsmore, 1986; Appel and Muysken, 1987; Edwards, 1995; Romaine, 1995). As for the second problem, factors that have to be taken into account in choosing participants, one can always make bilingual assessment measures covariate variables during the analysis of results or allow participants to be their own control when the study permits it (which is not often the case). But the main solution will no doubt be for the field to agree on the kind of information that should be reported to describe the main types of bilinguals used (adult bilinguals, second language learners, bilingual children, polyglot aphasics or demented patients, etc.). For example, papers in experimental psycholinguistics could be expected (if not required) to have an appendix containing the following information on the group(s) used: biographical data (mean age, number of males and females, educational level of participants); language history (age participants started acquiring each skill in each language; manner of acquiring the languages, etc.); language stability (skills in the languages still being actively acquired); function of languages (which languages are used and in what contexts); proficiency (proficiency ratings in the four skills in the participants' languages); language mode (amount of time spent in the monolingual and in the bilingual mode). Each of these factors may have an impact on processing and representation and should therefore be assessed. Of course, much of the information can be collected via questionnaires by means of scales and can be reported numerically (central tendencies and dispersions). Other domains may choose to add or take out factors and one could even think of adding actual performance measures. Two points need to be made. First, it is important that if self rating scales are used, differences in the way people rate themselves be controlled for. It appears to be the case that due to various factors, some individuals, and even some groups, have no problem using endpoints of scales, and sometimes over-rate themselves, while others are more conservative in their self evaluation. Anchoring scales properly will therefore be very important for comparison across groups. For example, one could use as a yardstick native speakers of a language. Second, it appears crucial to distinguish between language learners in an academic setting who do not usually interact socially with their two languages and who therefore are not really bilingual (at least yet), and people who are acquiring a language in a natural environment and who are using both languages on a regular basis. The former should be characterized as "language learners", and maybe not as "novice" or "non fluent" bilinguals, at least until they start using both languages on a regular basis.

Language mode

Issue

In their everyday lives bilinguals find themselves in various language modes that correspond to points on a monolingual-bilingual mode continuum (Grosjean, 1985a, 1994, 1997). A mode is a state of activation of the bilingual's languages and language processing mechanisms. This state is controlled by such variables as who the bilingual is speaking or listening to, the situation, the topic, the purpose of the interaction, and so on. At one end of the continuum, bilinguals are in a totally monolingual language mode in that they are interacting only with (or listening only to) monolinguals of one or the other of the languages they know. One language is active and the other is deactivated. At the other end of the continuum, bilinguals find themselves in a bilingual language mode in that they are communicating with (or listening to) bilinguals who share their two (or more) languages and where language mixing may take place (i.e., code-switching and borrowing). In this case, both languages are active but the one that is used as the main language of processing (the base or matrix language) is more active than the other. These are end points, and bilinguals also find themselves at intermediary points depending on the factors mentioned above.

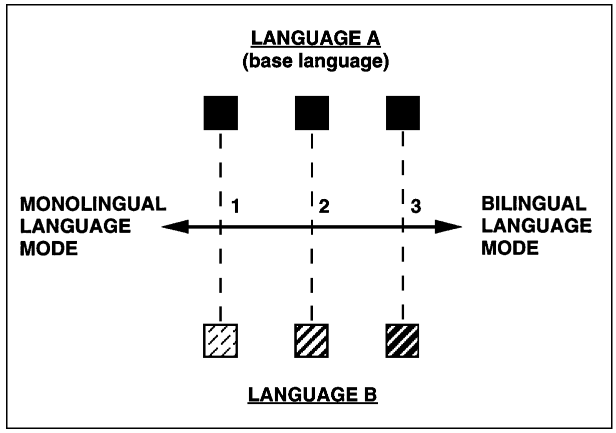

Figure 1. Visual representation of the language mode continuum. The bilingual's positions on the continuum are represented by the broken vertical lines and the level of language activation by the degree of darkness of the squares (black is active and white is inactive).

Figure 1 is a visual representation of the continuum. The languages (A and B) are represented by a square located in the top and bottom parts of the figure and their level of activation is depicted by the degree of darkness of the square: black for a highly active language and white for a deactivated language. Although the figure can be used to illustrate the level of activation of the two languages during both production and perception, I will concentrate on production first and then deal with perception.

Three hypothetical positions for the same bilingual are presented in the figure (broken lines numbered from 1 to 3). In all positions, the bilingual speaker is using language A as the main language of communication (the base language) and it is therefore the most active (black square). In position 1, the speaker is in a monolingual mode: language A is totally active whereas language B is deactivated (Green (1986) would even say that it is inhibited). This mode arises when the person being spoken to is monolingual (in this case, in language A), and/or the topic, the situation or the purpose of interaction require that only one language be spoken to the exclusion of the other(s). It is in this mode that interferences, that is, speaker-specific deviations from the language being spoken due to the influence of the other deactivated language, are the most visible (they can also occur in the bilingual mode but they are difficult to separate from other forms of language mixing such as code-switches and borrowings). In position 2, the speaker is in an intermediary mode. Language A is still the most active language (it is the language of communication) but language B is also partly activated. This kind of mode arises, for example, when a bilingual is speaking to another bilingual who does not wish to use the other language (in this case, language B) or when a bilingual is interacting with a person who has limited knowledge of the other language. Any number of combinations of interlocutor, topic, situation and purpose of interaction can lead to this intermediary position. In position 3, the speaker is at the bilingual end of the continuum. Both languages are active but language B is slightly less active than language A as it is not currently the language of communication. This is the kind of mode bilinguals find themselves in when they are interacting with other bilinguals who share their two (or more) languages and with whom they feel comfortable mixing languages. They usually first adopt a base language to use together (language A here, hence its greater level of activation) but the other language, often referred to as the guest language, is available in case it is needed in the form of code-switches and borrowings. A code-switch is a complete shift to the other language for a word, a phrase or a sentence, whereas a borrowing is a word or short expression taken from the less activated language and adapted morphosyntactically (and sometimes phonologically) into the base language. Borrowings can involve both the form and the content of a word (these are called nonce borrowings) or simply the content (called loan shifts). Of course, a change of topic or of situation may lead to a change of base language. In our example, language B would then become the most active (it would be represented by a black square) and language A would be slightly less active (the black square would contain white diagonal lines). It should be noted that bilinguals differ among themselves as to the extent they travel along the continuum; some rarely find themselves at the bilingual end whereas others rarely leave this end (for example, bilinguals who live in communities where mixed language is the norm).

Because Figure 1 presents two variables (the base language on the vertical axis and the language mode on the horizontal axis), it is important that both are mentioned when describing the situation a bilingual is in. Thus, for example, a French-English bilingual speaking French to a French monolingual is in a "French monolingual mode." The same bilingual speaking English to an English monolingual is in an "English monolingual mode." If this person meets another French-English bilingual and they choose to speak French together and code-switch into English from time to time, then both are in a "French bilingual mode". Of course, if for some reason the base language were to change (because of a change of topic, for example), then they would be in an "English bilingual mode", etc. It should be remembered that the base language variable is usually independent of the language mode variable. Hence, saying that a bilingual is in a English language mode leaves totally open whether the mode is monolingual or bilingual.

Everything that has been said about speakers also pertains to listeners or readers. For example, and whatever the base language, if listeners determine (consciously or not), or find out as they go along, that what they are listening to can contain elements from the other language, they will put themselves partly in a bilingual mode, that is, activate both their languages (with the base language being more strongly activated). This is also true of readers, whether they are reading a continuous text or looking at individual lexical items interspersed with items from the other language. Simply knowing that there is a possibility that elements from the other language will be presented (in an experiment, for example) will move the bilingual away from the monolingual endpoint of the continuum. Just one guest word in a stream of base language words can increase this displacement towards the bilingual endpoint.

Evidence for the language mode continuum concept is starting to be quite extensive. For example, in a production study, Grosjean (1997) manipulated the language mode participants were in when retelling stories that contained code-switches. He found that the three dependent measures (number of base language syllables, number of guest language syllables and number of disfluencies produced) were all affected by the language mode the speakers were in. In a developmental study, Lanza (1992) found that the same child mixed languages much more when in a bilingual context (represented by her father) than in a monolingual context (represented by her mother). As for evidence from an adult naturalistic setting, it can be found in a study by Treffers-Daller (1997) that is described below.

Problems

Because the mode a bilingual is in corresponds to a state of activation of the bilingual's languages and language processing mechanisms, it has an impact both on language production (maintenance or change of the base language, amount and type of language mixing that takes place, etc.) as well as on language perception (speed of processing of a language, access to one or to both lexicons, role of the less activated language, etc.). It appears critical therefore that one control for the mode participants are in when they are being recorded or tested experimentally. This has not been the case very often, as can be seen by examining examples from a number of different domains. In a first domain, research on interferences (also known by some as transfers; for a review see Odlin, 1989), the mode bilingual participants are in when interferences are observed has rarely been reported. Thus, what might appear on the surface as an interference could also be a code-switch or a borrowing produced by the speaker who is aware that his or her interlocutor knows the other language (to some extent at least). For example, although "baving" (from the French verb "baver" (to dribble)), produced in an English monolingual mode, is probably the result of the deactivated language "intruding" onto the language being spoken (an interference, therefore), in a bilingual mode it is either an interference or, more probably, the normal access of a word in the less activated lexicon and its integration into the base language (a borrowing). It is now widely recognized that in Weinreich's (1966) classical work on bilingualism, the concept of interference covered the whole range of possible bilingual productions (true interferences in both the monolingual and the bilingual mode as well as code-switches and borrowings in the bilingual mode). This is also clearly the case with the interferences discussed by Taeschner (1983) in her study of two bilingual children. In sum, to have any chance of identifying interferences correctly one needs to be sure that the data collected come from a truly monolingual mode. (See Grosjean, in press b, for further discussion of this.)

A second domain of study where it is important to know where bilinguals are positioned on the language mode continuum concerns natural interview situations. This information is not often given in the description of the interview setting and yet Treffers-Daller (1997), among others, has shown that depending on the speaker's position on the continuum (based on the interlocutor, the topic, the situation, etc.), different types of language behavior will be obtained. In her study, she placed the same speaker, a Turkish-German bilingual, in three different positions by changing the context and the interlocutors, and she found quite different code-switching patterns. For example, when the participant was speaking to another bilingual he did not know well, his code-switches were less numerous, more peripheral and contained various types of pauses (the latter have been called flagged switches). However, when the participant interacted with a very close bilingual friend, the code-switches were more numerous, they were both intra- and intersentential and they were produced without hesitations or special highlighting (these have been termed fluent switches). Based on these results (also observed by Poplack (1981) in a different context), Treffers-Daller concludes that the language mode continuum concept may offer a new approach to study variable code-switching patterns within and between communities (e.g., Poplack, 1985; Bentahila and Davies, 1991) because it can help predict the frequency and type of switching that takes place.

A third domain where the language mode needs to be controlled for is experimental psycholinguistics. Several domains of research are concerned, but I will concentrate here on the language representation issue. This pertains to whether bilinguals have an integrated semantic memory for their two languages (also called a shared or a common store) or whether they have two separate, independent semantic systems. Several studies have addressed this question. For example, Schwanenflugel and Rey (1986) used a cross-language priming task in which Spanish-English bilinguals saw the prime word "body" and immediately afterwards had to say whether the following item, either "brazo" (arm) or "arm", was a word or not. The authors found that whether the prime and the following word (the target) were in the same or in different languages had no effect on the amount of priming, and they concluded that concepts in the bilingual individual are represented by a language neutral conceptual system. In a more recent study, Fox (1996) used flanker words to prime targets and found an equal level of negative priming for monolingual and bilingual word pairs. She also concluded that mental representations of words in a bilingual's two languages are integrated within a shared representational system. Although both studies were carefully conducted and produced reliable data, it is difficult to tease apart in the results obtained what is due to the representational issue and what is caused by the language mode variable. The bilinguals were probably not in a monolingual mode when they were tested. Participants knew they were being tested as bilinguals and they saw words in the two languages. Because of this, they had probably activated both their languages (consciously or unconsciously) and were thus in a bilingual mode. (The same argument can be made about masked priming studies if considerable care is not taken to put participants in a monolingual mode.) If both languages are active, bilinguals are then in a position to react as quickly to targets in the language of the prime (or flanker word) as to targets in the other language (all other things being equal). No claim is being made here concerning the substantive issue of shared as opposed to separate semantic stores or, more concretely, which language(s) is / are primed in within- and between-language experimental studies. The only point being put forward is that the language mode variable can certainly influence, and maybe sometimes even account for, the results obtained. (The same is probably true of studies examining selective versus non-selective processing in bilinguals, as will be seen later).

Another domain of research which has not always controlled for language mode sufficiently concerns simultaneous language acquisition in bilingual children. It has been proposed by some researchers (Volterra and Taeschner, 1978; Redlinger and Park, 1980, among others) that children who acquire two languages simultaneously go through an early fusion stage in which the languages are in fact one system (one lexicon, one grammar, etc.). They then slowly differentiate their languages, first separating their lexicons and then their grammar. Evidence for this has come from the observation of language mixing in very young bilingual children and from the fact that there is a gradual reduction of mixing as the child grows older. This position has been criticized by a number of researchers (e.g., Meisel, 1989; Genesee, 1989, among others) and one of the points made each time (in addition to the fact that translation equivalents may not be known in the other language) is that the children were often in a bilingual mode, i.e. the caretakers were usually bilingual themselves and were probably overheard using both languages, separately or in a mixed form, by the children, if not actually mixing their languages with them (see Goodz, 1989). In addition, the context in which the recordings were made for the studies probably induced language mixing. If one examines the procedure followed by Redlinger and Park (1980) and Vihman (1985), for example, it is clear that the recording context was rarely (if ever) monolingual. In the first study, the investigator spoke the same languages as two of the bilingual children and, in addition, the children's parents appear to have been present, and in the second study, the person doing the taping was the mother of the child (Raivo) and she was herself bilingual. In both cases, therefore, the children were in a bilingual context which induced a bilingual mode and hence language mixing. It is interesting to note that Lanza (1992) shows clear differences in mixing behavior for the same child when interacting with two different adults, one of whom prefers a monolingual interaction and one who accepts language mixing. (See Genesee, Boivin and Nicoladis, 1996, for a similar type of study where the adult interlocutors were two monolinguals, one in each language, and one bilingual.)

A final domain in which language mode is a crucial variable is language pathology. For example, in the domain of bilingual aphasia, several case studies have been published of patients who appear to mix languages inappropriately. Perecman (1984), for instance, states that the language of her patient (H.B.) was strongly marked by language mixing. The author writes that H.B. shifted from one language to another during the course of a single conversation and within the same utterance. However, we learn in the same paper that language mixing was particularly pronounced when the investigator (or investigators, it is unclear if there were one or two) shifted from one language to another within the same conversation or task, and we are actually given an extract from a dialogue in which the investigator switches languages! As was stated in a response to Perecman's paper (Grosjean, 1985b), it is interesting to speculate how much language switching H.B. would have produced had the investigator been totally monolingual. It seems only appropriate that a bilingual aphasic who is in a bilingual context, and who is faced with production problems, should use language mixing as a strategy to enhance communication (as would normal bilinguals). Another example comes from language production in bilinguals who suffer from dementia. Hyltenstam (1991), for instance, presents formally elicited data gathered from Finnish-Swedish patients recorded in what he states is a monolingual interaction, with a native speaker of each language, as well as in a bilingual interaction. The Swedish interactant was indeed monolingual but the Finnish one was also a speaker of Swedish, as we learn later in the paper. It is not surprising therefore to find in the Finnish productions language patterns ranging from monolingual Finnish utterances to mixed Finnish-Swedish utterances. It should be noted that mixing also took place in the Swedish monolingual interactions, but these can clearly be attributed to the patients' dementia. One cannot say the same thing concerning mixing in the Finnish interactions.

To conclude, failure to control for the bilingual mode factor produces at best very variable data due to the fact that participants are probably situated at various points along the monolingual-bilingual continuum, and at worst ambiguous data given the confound between this factor and the variable under study.

Tentative solutions

Language mode is a variable to be studied independently (one will need to investigate ways of determining the bilingual's position on the continuum, among other things) but it is also a variable to control for. In what follows I will concentrate on this latter aspect as failure to control for language mode has important implications for the way in which findings are interpreted. Because of lack of space, I will only consider how bilinguals can be put either in a strict monolingual mode or in a totally bilingual mode. As concerns the monolingual mode, two inappropriate approaches have been tried. The first is to put the participants in a "language set" (also called erroneously by some a "language mode") by giving them instructions in one language, getting them to do preliminary tasks in that language, occasionally presenting reminders in that language, giving them monolingual stimuli, etc. What this does is to activate a particular base language (the variable depicted on the vertical axis in Figure 1) but, as indicated earlier, it in no way guarantees a particular position on the monolingual-bilingual mode continuum (the variable on the horizontal axis).[2] The second approach, which has been used a lot with bilingual children, second language learners and aphasic or demented patients, has been to hide the experimenter's or interviewer's bilingualism. This is a very dangerous strategy as subtle cues such as facial expression and body language can give away the interlocutor's comprehension of the other language. In addition, it will not prevent occasional slip-ups such as responding in the "wrong" language or showing in one's response that what has been said in that language has been understood.

The solution to the monolingual mode problem is unfortunately not quite as easy as one would like it to be. For interview situations, if the researcher is interested in observing how a bilingual can produce just one language (something a bilingual often has to do), then the interviewer must be completely monolingual in that language (and not feign to be). In addition, the situation must be monolingual and there must not be any other person present who knows the other language. For more experimental situations, the difficulty is how to prevent the bilingual from activating, to some extent at least, the other language. If interest is shown in the participant's bilingualism, if he or she is tested in a laboratory that works on bilingualism, if the experimenter is bilingual or if the participant sees or hears stimuli from both languages, then any one of these factors is sufficient to put the participant in a bilingual mode and hence activate the two languages, albeit to differing degrees. Such questions as the independence or interdependence of the bilingual's language systems or the "automatic" influence of one language on the other (selective versus non-selective processing) cannot be studied adequately if this is so, even if precautions such as masking primes are taken (e.g., Bijeljac-Babic, Biardeau & Grainger, 1997). One possibility that comes to mind appears to be to intermix bilingual participants in with monolingual participants in a monolingual experiment (for example, a study that is part of a course requirement) and once the experiment is done, and after the fact only, so as to avoid the Rosenthal effect, to go back into the list of participants and extract the bilinguals. In addition, care will have to be taken that the stimuli presented do not give the aim away. Of course, one can also make the bilingual mode an independent variable and use two or more intermediary levels of the continuum (e.g., Grosjean, 1997) but there is no guarantee that the most monolingual level will be monolingual enough to make claims about non-selective processing or interdependent representations.

As concerns the bilingual endpoint of the language mode continuum, care will have to be taken that the participants are totally comfortable producing, or listening to, mixed language. This can be done by having bilingual experimenters or interviewers who belong to the same bilingual community as the participants and, if possible, who know them well. They should interact with the participants in mixed language and the situation should be conducive to mixed language (no monolinguals present, a relaxed non-normative atmosphere, etc.).

Stimuli

Issue

Stimuli used in bilingual studies, such as syllables, words, phrases, and sentences, differ in a number of ways within and between languages. For example, words can differ on graphic form, frequency of graphic form, frequency and density of graphic form neighbors, phonetic form, frequency of phonetic form, frequency and density of phonetic form neighbors, syntactic categories and frequency of these categories, meanings of the various syntactic forms, concreteness-abstractness, animacy, etc. For instance, if one takes French "pays" (country) and English "pays", two homographs taken from a study conducted by Beauvillain and Grainger (1987), one notices that although both graphic forms are quite

[2] Interestingly, and with hindsight, the participants who were tested in Soares and Grosjean's (1984) study, "Bilinguals in a monolingual and a bilingual speech mode: The effect on lexical access," were never in a totally monolingual mode. This is because they knew the study dealt with bilingualism and they were accustomed to code switch with one of the experimenters. Instructions in each of the two languages and practice sentences in these languages did help to establish the base language (or language set) in the "monolingual" parts of the study. This, added to the fact that the stimuli were in only one language, probably pushed the participants towards the monolingual end point of the continuum. Whether they actually reached that monolingual endpoint is doubtful, however.

frequent, English "pays" probably has more graphic form neighbors than French "pays". As for the phonetic form, the two are quite different, as English /peɪz/ contains a diphthong and a terminal consonant, whereas French /pei/ has two vowels and no final consonant. The phonetic form frequency is probably quite similar in the two languages but the English form has more neighbors than the French form. As concerns syntactic categories, English "pays" is an inflected verb and a very rarely found noun in its plural form. As for French "pays", it is only a noun and it is far more frequent than the English noun. Moving on to meaning, the English verb form of "pays" has four meanings and the noun form has two meanings. The French noun "pays" has three meanings and they are all different from the English noun meanings. Finally, there is a certain diversity as to concreteness and animacy of the various French and English meanings. Thus, as can be seen from this apparently simple case, stimuli will differ considerably from one another.

Problems

Three problems surround stimuli in bilingual studies: differences in the stimuli used across studies, differences in stimuli used within studies, and factors that need to be controlled for in stimulus selection. As concerns differences in stimuli used across studies, what are often thought to be similar stimuli are unfortunately not always that similar. For example, much work has been done with cognates, defined by Crystal (1991) as linguistic forms that are historically derived from the same source as other language forms. When one compares how different researchers define the concept, one finds very large differences. For example, concerning the graphemic form of cognates, de Groot (1995) says it is similar, Caramazza and Brones (1979) say it is identical, Sánchez-Casas, Davis and García-Albea (1992) talk of a large degree of overlap, and Beauvillain and Grainger (1987) say it is the same. As concerns meaning, the labels used respectively are: similar, same, large degree of overlap, similar. Finally, with respect to phonology, De Groot says it is similar, Caramazza and Brones state that it is different (!), and the two other studies do not give any information on this factor. Because of the problem of understanding what is meant by "similar," "same" and "large degree of overlap," and based on the fact that words often have several meanings with different frequencies, among other things, it is no surprise that differences are found across studies (especially if the tasks used call on all the linguistic aspects of cognates, including phonology). In fact, Votaw (1992) shows the complexity of the issue in a six-cell table in which she presents three levels of shared form and three levels of shared meaning. Even though she does not refer to phonological form and to multi-meaning cognates, the table is useful for observing which cells are covered by the different studies that have used cognates. What has just been said about cognates also pertains to other "similar" stimuli across studies.

Concerning differences in stimuli within studies, the issue is one of variability. An example comes from the homographs used by Beauvillain and Grainger (1987). We have already seen that English "pays" and French "pays" share the noun category (although the English word is very much more frequent as a verb) and that as nouns the meanings are different in the two languages. When we compare this pair with another pair that was used in the same study, English "lame" and French "lame" (blade), we find another pattern of differences. English "lame" is an adjective and a verb (also a very rare noun) whereas French "lame" is only a noun. The cause of this variability is quite understandable (there are only a small set of homographs to choose from in the two languages), but if variability within a study is too large, it can reduce the effect that is sought or actually make it disappear.

As for factors that need to be controlled for during stimulus preparation, several have been mentioned in recent years, making studies which do not control for them somewhat problematic. For example, concreteness is an important variable both in neurolinguistics and psycholinguistics. In the former domain, Zatorre (1989) reports that concrete nouns are processed more bilaterally than abstract nouns. In psycholinguistics, de Groot (1992) has shown that concrete words are translated faster than abstract words. She also states that cognates and infrequent words are more likely to be translated by means of the word-word association route. Sholl (1995) has shown that animacy has clear effects on word translation: animate concepts are translated more rapidly than inanimate concepts. As for Grainger and Beauvillain (1987), they put forward the orthographical uniqueness of a word as a factor. In a lexical decision task, they showed a cost for language mixing in word lists; mixed lists produced longer reaction times than pure lists. The cost disappeared, however, when the words in each language were orthographically unique to that language. Finally, in research on spoken word recognition of code-switches and borrowings, a number of factors have been found to play a role: phonotactics and language phonetics (Grosjean, 1988; Li, 1996), interlanguage neighbor proximity (Grosjean, 1988) and sentential context (Li, 1996). Not controlling for such factors (at least the more important ones) can lead to weak effects or no effects, to different or contradictory results across studies, and to the difficulty of replicating published studies.

Tentative solutions

At least four well-established solutions known to most researchers in psycholinguistics can be used to solve or lessen the stimuli problem. The first but also the hardest is to control for as many linguistic factors as possible when choosing stimuli. The second is to replicate the results using a new set of stimuli, and the third is to use stimuli as their own control when possible (although one must avoid repetition effects across conditions). Finally, the fourth, and probably the most appropriate for cross-study comparisons, is simply to reuse the stimuli that have appeared in an already published study so as to replicate the results or to show that some specific independent variable can modify the outcome of the experiment.

A long-term solution to the problem would be for the field to start putting together normalized stimuli for pairs of languages, such as lists of cognates and homographs controlled on a number of variables, word frequency counts and word association lists obtained from bilingual groups, etc. This kind of information already exists in monolingual research and it provides many advantages, not the least being that the experimenter can spend more time on other aspects of the study.

Tasks

Issue

Experimental tasks used to study bilinguals range from those used in production studies (reading lists or continuous text aloud, retelling stories, naming pictures under various conditions, giving word associations, etc.), to those in perception and comprehension studies (free recall, syllable identification and discrimination, Stroop tests, eye tracking, word priming, lexical decision, translation, etc.), all the way to those in hemispheric lateralization studies (dichotic listening, hemifield presentation, concurrent activity tasks, etc.).

Problems

Some problems are common to monolingual and bilingual research such as those that relate to strategic versus automatic processes involved in the task, the metalinguistic nature of the task, its processing locus, the allocation of attention during the task, etc. There is also much debate around such questions as the size of the SOA (stimulus onset asynchrony), the blocking or not of stimuli, the proportion of filler items, etc. I will concentrate however on three specific problems. The first concerns how certain tasks activate both the bilingual's languages and hence create a confound between the bilingual mode the participant is in and the variable under study. The second deals with the question of what certain tasks are tapping into, and the third concerns which aspects of the results depend on the task itself and which on the variable being studied.

As concerns the first problem, it is clear that such tasks as the bilingual Stroop test, bilingual word priming, bilingual association production, bilingual category matching, word translation, and so on, all activate both languages in the bilingual. In the bilingual Stroop test, one cannot perceive the word "red" written in green and respond "vert" (green in French) without having both languages activated. In the bilingual category matching task, one cannot see the name of a category in one language (e.g., "furniture") and then an instance of that category in another language (e.g., "silla" (chair in Spanish)), without activating both languages. This becomes a very real problem when the question being studied pertains to such issues as selective versus non-selective processing, the independence or the interdependence of the bilingual's language systems, or one versus two lexicons. If one is interested in these issues, one should be careful not to activate the other language by using a task that does just that. When this occurs, it becomes difficult to disentangle what is due to normal bilingual representation and processing, and what is due to the bilingual language mode induced by the task.

For example, Beauvillain and Grainger (1987) wanted to find evidence for the presence or absence of language-selective access of interlexical homographs during visual word perception. To do this, in the first experiment they presented pairs of words in two conditions. In the related condition, the first word (the context word) was a homograph in English and French (e.g., "coin" which means corner in French) and it was followed by a test word (e.g., "money") that could be primed by its English meaning but not its French meaning. In the unrelated condition, the context word was only an English word (not a homograph) and the test word had no relationship to it. The participants were told that the first word would always be a French word and they were never informed of the presence of homographs (the pairs were mixed in with filler pairs). They were asked to do a lexical decision on the second item and were informed that it would be an English word or non word. The authors hypothesized that selective access would be confirmed if the context word in the related condition ("coin") were found not to facilitate the test word ("money"); if there was facilitation, however, then non-selective access would be shown. The results showed that facilitation was in fact obtained, that is, that reaction times were faster in the related than in the unrelated condition. This was replicated in a second experiment and the authors concluded that lexical access in bilinguals is not initially language-selective. The problem, of course, is that despite the instructions which were meant to force participants to ignore the meaning of the homograph in the other language, the bilinguals needed their two languages to do the task, i.e. read the context word in French and then decide whether the second word was an English word or not. To do this, they had to put themselves in a bilingual language mode and activate both their lexicons. (It should be noted that as they were tested as bilinguals, they were probably already in a bilingual mode before the experiment even started.) It is no surprise therefore that a result indicating non-selective processing was obtained (the same comment can be made about another well known study which examined the same question, that of Altenberg and Cairns, 1983). Recently, Dijkstra, van Jaarsveld and ten Brinke (1998) have shown that interlingual homographs may be recognized faster than, slower than, or as fast as monolingual control words depending on task requirements and language intermixing. Even though they did not account for their findings in terms of language mode, it is clear that both these variables affect the mode and hence the results obtained. What one can conclude from this is that, whenever possible, tasks or conditions that activate both languages should not be used to study issues such as selective versus non-selective processing, or the independence versus the interdependence of the bilingual's language systems.

The second problem that concerns tasks is that it is difficult to know what tasks are tapping into: language processing, language representation or both? It is interesting to note that most monolingual studies that use priming tasks, lexical decision, or the Stroop test are basically aimed at understanding processing, i.e., how words are accessed in the lexicon. The findings that have come out of this research have mainly been used to build processing models and not representational models. However, probably because of an early interest in bilingual language representation, these same tasks are often used to study representation in bilinguals. Unless one espouses a view that equates processing with representation (something that becomes very difficult to defend at higher language levels), one should try to come to grips with this second, highly delicate, problem. Unfortunately, the field is hesitant about the issue and we find researchers using identical tasks to tap into representation and processing. For example, Beauvillain and Grainger (1987) used priming with lexical decision to get at the selective access issue, whereas Schwanenflugel and Rey (1986) used this same task (with minor procedural differences) to get at the representational issue. If a task is indeed reflecting representation, then we need to know which level of representation it is reflecting. For example, in lexical representation research, we have to know which of the following four levels is being tapped into: the lexeme level, the lemma level, the conceptual level or the encyclopedic level (which is outside the lexicon).

The third problem concerns which aspects of the results depend on the specific processing demands of the task itself and which on the variable being studied. Many conflicting results in the literature, in particular those concerning the one versus two lexicons issue, can be accounted for by this problem. It will be recalled that in the 60s and 70s an extensive debate took place around whether bilinguals have one language-independent store or whether they have two language-dependent stores. Much evidence was collected for each hypothesis, but little by little researchers started realizing that there was a confound between the tasks used to study the question and the question itself. Kolers and Gonzalez (1980) were among the first to state that two different issues had become confused in the study of bilingual memory, the issue of representation, its commonness across languages or its means dependency, and the way the issue is tested. They suggested that the bilingual's linguistic representations are independent or dependent to the degree that particular skills are utilized in a given context or task. Scarborough, Gerard and Cortese (1984) stated practically the same thing when they wrote that a bilingual might appear to have a separate or an integrated memory system depending upon how task demands control encoding or retrieval strategies (see also Durgunoglu and Roediger, 1987). Since then the focus has shifted away from the one versus two lexicons question to how the bilingual's lexical representation might be organized (see for example Potter et al., 1984; Kroll and Stewart, 1994; de Groot, 1992), but the problem of what the task is doing has not disappeared completely, as can be seen in discussions by Fox (1996) and Kroll and de Groot (1997), among others. The task effect is also present in neurolinguistics where it has been shown that orthographic comparisons yield consistent left visual field advantages while phonological and syntactic judgments give right visual field advantages (Vaid, 1983; Vaid, 1987; Zatorre, 1989).

Tentative solutions

The first problem mentioned, the fact that certain tasks activate both the bilingual's languages, is very difficult to solve if one is interested in issues such as selective processing or the independent nature of language representation in bilinguals. If that is the case, one must make sure that the task is not artefactually activating the bilingual's two languages and/or processing systems. The task must be monolingual in nature and must not involve processes such as cross language priming, perception in one language and production in the other, etc. If the question of interest is different, such as whether distinct groups of bilinguals behave differently when perceiving or producing language, then the dual language activation nature of the task should simply be controlled for.

The other two problems (what it is that tasks are reflecting and which aspects of the results are task specific) can be addressed by having a very good understanding of the tasks used in bilingualism research: what issues can be studied with them, which variables can be tested, what the dependent measures are, the advantages and problems of the tasks, and so on. It would be important one day to develop a guide to bilingual research paradigms along the lines of the one proposed by Grosjean and Frauenfelder (1997) for spoken word recognition paradigms. Finally, several paradigms can be used to obtain converging evidence, but one must keep in mind that similar effects, revealed by similar values of a dependent measure, may not always reflect similar processing routes and similar underlying representations.

Models

Issue

One of the main aims of research on bilingualism, whether descriptive, theoretical or experimental, is to develop models of how the bilingual's languages are acquired, represented and processed. Since research started in the field, researchers have met this aim with proposals such as the coordinate, compound, subordinate distinction, the one versus two lexicons hypotheses, the switch or monitor proposals, various models of lexical representation, ventures to describe written and spoken word recognition in the bilingual, and the fused versus separate language development models of simultaneous language acquisition. By their very existence, these theoretical contributions have been a real asset to the field in that they attempt to step back from data to give a general description of a phenomenon. In addition, they allow other researchers to confirm or invalidate certain predictions and hence propose variants or new models. Their advantages therefore far outweigh the problems, as will be seen below.

Problems

A first problem that is slowly disappearing is that some models still have a monolingual view of the bilingual individual. Instead of accepting that bilinguals are specific speaker-hearers who through the contact and interaction of two or more languages are distinct from monolinguals (Grosjean, 1985a; Cook, 1992), some researchers still use a monolingual yardstick to describe aspects of bilingual behavior and representation. Earlier work on the input and output switches (reviewed in Grosjean, 1982) was based in part on the notion that bilinguals had one language switched on, and the other switched off, but never the two switched on at the same time. And yet it is now recognized that in a bilingual language mode, both languages are active and the bilingual can produce mixed language utterances at the same rate as monolingual utterances (and, of course, decode them at that rate). This monolingual viewpoint can still be found in certain areas where it is expected that "dominant" bilinguals will behave in large part like monolinguals in their dominant language. Of course, this might be the case in some instances but one should be ready to accept bilingual specificities when they appear.

A second problem concerns the discrete classifications that are found in the field. For example, Weinreich's (1966) coordinate, compound, subordinate trichotomy and Ervin and Osgood's (1954) coordinate, compound dichotomy, triggered much research. But contradictory findings and theoretical considerations have led various researchers to move away from these distinctions and hypothesize that within the very same bilingual, some words in the two lexicons will have a coordinate relationship, others a compound relationship and still others a subordinate relationship, especially if the languages were acquired in different cultural settings and at different times. Recent work on lexical representation in bilinguals appears to defend such a position (see various chapters in de Groot and Kroll, 1997). The same kind of discrete classification problem can be found in the long debate that has surrounded the number of lexicons the bilingual possesses (reviewed by Grosjean, 1982). Paradis's subset hypothesis (1981, 1986) was instrumental in helping researchers view this question in a different light, and recent proposals of lexical organization such as the word association model and the concept mediation model (Potter et al., 1984), the revised hierarchical model (Kroll and Stewart, 1994) and the conceptual feature model (De Groot, 1992), have also contributed to an improved understanding of the organization of the bilingual's lexical representations. It should be noted though that some researchers still propose that distinct groups of bilinguals are best characterized by just one of these models (or variants of it). It is only recently that de Groot (1995), based on an extensive review of the literature, comes to the conclusion that *the* bilingual memory does not exist. The memory of every individual is likely to contain structures of various types and these structures will occur in different proportions across bilinguals. This will depend on factors such as level of proficiency of the languages known, the characteristics of the words, the strategy used to learn them, the context in which the languages are used, the age at which a language was acquired, and so on. In sum, one should be extremely wary of discrete classifications that do not do full justice to the representational and processing complexity found within the individual bilingual.

A third problem is that some models may not contain all the necessary components or levels needed. An example comes from recent work on lexical representation where most of the models proposed (see above) contain only two levels: a lexeme (or form) level and a conceptual (or meaning) level. And yet there is quite a bit of evidence in the literature that the lexicon contains a third level, the lemma level, that is situated between the lexeme and the conceptual level. Lemmas contain morphological and syntactic information about the word (Jescheniak and Levelt, 1994; Myers-Scotton and Jake, 1995). Just recently Kroll and de Groot (1997) have proposed to take this level into account and have presented the general outline of a distributed lexical/conceptual feature model of lexical representation in the bilingual that contains this level. At some point their model will probably have to take into account a fourth level (world knowledge) at least to explain the underlying operations that take place when participants are involved in paradigms that include nonlinguistic operations (such as picture naming). Paradis (1995) states, as he has done repeatedly, that one of the major problems in the field has been the failure to distinguish between the meaning of words and nonlinguistic representations. Based on research in neurolinguistics, he states that we must distinguish between the lexical meaning of words, which is a part of the speaker's linguistic competence, and conceptual representations which are outside implicit linguistic competence. (Note here that he uses the expression "lexical meaning" for what corresponds to the conceptual level in most models and "conceptual representation" for nonlinguistic, world knowledge.) He adds that the conceptual system, where messages are elaborated before they are verbalized in the course of the encoding process, and where a mental representation is attained at the end of the decoding process, remains independent and isolable from the bilingual's language systems. It would be interesting to know whether tasks such as word repetition, word translation and picture naming, for example, require access to this nonlinguistic level. Some must (e.g., picture naming), whereas others may not have to.

A fourth problem is that the field has too few global models that give a general picture of bilingual competence, bilingual production and perception, as well as bilingual language acquisition. For example, until de Bot's (1992) attempt at adapting Levelt's (1989) "Speaking" model to the bilingual, there was no general overall view of how the bilingual speaker goes from a prelinguistic message to actual overt speech. Even though de Bot's model still needs to give a clear account of how language choice is conducted, how the language mode is chosen and the impact it has on processing, how code-switches and borrowings are actually produced, how interferences occur, and so on, it has the very real quality of dealing with the complete production process and hence of encouraging debate in the field (e.g., de Bot and Schreuder, 1993, Poulisse and Bongaerts, 1994, Poulisse, 1997). This is true also of Green's (1986) resources model of production for normal and brain-damaged bilinguals. In the domain of perception and comprehension, no model as broad as Marslen-Wilson and Tyler's (1987) interactive model or Forster's (1979) modular model of language processing has been proposed. However, headway is being made by two computational models that are relatively broad: a bilingual model of visual word recognition (BIA; Grainger and Dijkstra, 1992; Dijkstra and van Heuven, in press), and a model of spoken word recognition in bilinguals (BIMOLA; Grosjean, 1988; Léwy and Grosjean, in preparation).

A final problem, which is admittedly in partial contradiction to the previous one, is that models are not always detailed or explicit enough. For example, Myers-Scotton (1993) has proposed a model, the Matrix Language Frame (MLF) Model, which states that a number of hierarchies, hypotheses and principles govern the structuring of sentences containing code-switches. The model has attracted the attention and the interest of linguists and psycholinguists but, like other important models, it has also raised many questions. For example, Bentahila (1995) states that it is not specific enough on such things as what constitutes a matrix language, the difference the model makes between an extensive embedded language (EL) island and a change of matrix language, what a system morpheme is, and so on. For Bentahila, models must be explicit and their validity depends on clear definitions which are externally verifiable without circularity.[3]

Tentative solutions

If there is one issue for which solutions can only be tentative, it is the one which deals with models. This is by far the most delicate and complex issue raised so far and what follows is only one researcher's view point. First, and from what has been said, it is clear that any model will have to take into account the full complexity of the bilingual speaker-hearer as illustrated in the first two sections of this paper (participants and language mode). For example, bilinguals should not be viewed as two monolinguals in one person or be classified once and for all in discrete linguistic or psycholinguistic categories. Second, it is crucial that general models be proposed. The field is in dire need of general theories of the bilingual speaker-hearer as well as of models of bilingual language acquisition and processing. Third, models must contain all the necessary components or levels needed and they must be as explicit as possible so that they can be put to the test. Fourth, it is important that cross-fertilization takes place between the various domains of bilingualism. A theoretical linguistics of bilingualism that attempts to account for the bilingual's competence, a developmental psycholinguistics that models how children acquire their two languages simultaneously or successively, a neurolinguistics of bilingualism that accounts for normal and pathological brain behavior, and a psycholinguistics that models processing in bilinguals can each bring a lot to the other domains and receive a lot from them. Finally, bilingual models will have to use, after being adapted, the new approaches and the new theories that are constantly being developed in the various fields of cognitive science primarily to study monolinguals. In return, these fields will be enriched by what is learned about bilinguals.

Concluding remark

Dealing with the methodological and conceptual issues that have been presented in this paper will take time, work and some inventiveness. The outcome, however, will be clearer and less ambiguous results as well as models that take into account the full complexity of the bilingual individual.

[3] It should be noted that Myers Scotton (pc) reports that many issues raised by Bentahila are discussed and clarified in the "Afterword" of the 1997 paperback version of her book, *Duel ling Languages* (Myers Scotton, 1993).

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