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L'effet du bilinguisme sur la mémoire de travail : comparaisons avec des monolingues et étude du changement de langue dans des tâches d'empan complexe

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RESUME . : . SUMMARY

Le but de cette thèse était d'étudier l'effet du bilinguisme et du changement de langues dans des tâches de mémoire de travail. La recherche sur le bilinguisme et la cognition a mis en évidence que les deux langues d'un bilingue étaient toujours activées (e.g., Hoshino & Kroll, 2008). Selon le modèle de l'inhibition de Green (1998), un bilingue qui souhaite s'exprimer dans une langue doit désactiver l'autre langue en utilisant un mécanisme de contrôle appelé l'inhibition. Bialystok et ses collègues (e.g., Bialystok, Craik, Klein, & Viswanathan, 2004; Bialystok & Martin, 2004; Bialystok & Senman, 2004) ont émis l'hypothèse que ce mécanisme était le même que celui utilisé pour le contrôle de l'attention de manière générale. Le contrôle de l'attention est assuré par des fonctions exécutives, dont les principales sont l'inhibition, le shifting et l'updating (Miyake et al., 2000). Ainsi, Bialystok et al. (2004) ont mis en évidence de meilleurs résultats de bilingues comparés à des monolingues sur une tâche mesurant l'inhibition. Néanmoins, ces résultats n'ont pu être répliqués lorsque le statut socio-économique de participants issus d'une même culture a été mesuré (Morton & Harper, 2007). D'autres chercheurs ont trouvé une supériorité des bilingues dans des tâches mesurant d'autres fonctions exécutives (e.g., Bonifacci, Giombini, Bellocchi, & Contento, 2010; Carlson & Meltzoff, 2008; Costa, Hernández, & Sebastián-Gallés, 2008; Engel de Abreu, Cruz-Santos, Tourinho, Martin, & Bialystok, 2012).

Dans le premier chapitre de cette thèse, nous avons comparé des bilingues et des monolingues sur une tâche de mémoire de travail, dont le fonctionnement requiert l'utilisation de fonctions exécutives (e.g., Baddeley, Della Sala, Robbins, & Baddeley, 1996; Miyake & Shah, 1999). Nous avons mesuré et pris en compte le statut socio-économique des participants. En effet, le statut socio-économique corrèle avec les performances de contrôle exécutif (e.g., Farah et al., 2006; Mezzacappa, 2004) et la capacité de mémoire de travail (e.g., Lee, Kawachi, Berkman, & Grodstein, 2003). Nous avons fait passer une tâche de mémoire de travail à des étudiants universitaires et des apprentis. Concernant le statut socio-économique, nous avons mesuré chez les premiers un indice significativement plus élevé. Les résultats à la tâche de mémoire de travail n'étaient pas significativement différents chez les étudiants universitaires. En revanche, les apprentis bilingues ont obtenu un score significativement plus élevé que les apprentis monolingues. Nous en avons conclu que le bilinguisme avait un effet positif sur la capacité de mémoire de travail pour des participants au niveau socio-économique modeste.

Les résultats similaires des étudiants universitaires monolingues et bilingues, ayant été sélectionnés pour leurs bonnes capacités cognitives, correspondent au lien positif entre statut socio-économique et capacité de mémoire de travail mis en évidence par Lee et al. (2003).

Dans les Chapitres II et III, nous nous sommes intéressés au coût cognitif engendré par le changement de langues durant une tâche de mémoire de travail chez des bilingues. Dans le Chapitre II, les participants devaient effectuer une tâche d'empan complexe mesurant la capacité de mémoire de travail. Cette tâche consistait à mémoriser dans l'ordre de présentation des séries d'items, dont la nature pouvait varier selon l'expérience. Il pouvait s'agir de chiffres ou de mots. Entre la présentation de chaque item, les participants devaient effectuer oralement une tâche concurrente, qui consistait à nommer des items apparaissant à l'écran. Nous avons également fait varier la nature de ces items (formes, chiffres ou couleurs) dans les différentes expériences menées. Les participants devaient compléter plusieurs conditions linguistiques. Des conditions dans lesquelles la tâche de rappel et la tâche concurrente étaient dans une même langue (le langage dominant, L1 *vs* la deuxième langue, L2), ainsi que des conditions dans lesquelles ils effectuaient la tâche de rappel dans une langue et la tâche concurrente dans l'autre. La nature des items à mémoriser a influencé la performance de rappel. Ainsi, lorsque les items à mémoriser étaient des chiffres, le rappel était meilleur dans les conditions comportant une seule langue. La performance était néanmoins similaire lorsque le rappel était en L1 comparé à L2. Lorsqu'il s'agissait de mémoriser des mots, le rappel était meilleur lorsque la tâche était entièrement en L1 comparé à la tâche entièrement en L2. En revanche, il n'y avait pas de différence significative de rappel entre les conditions comportant une et deux langues. Nous avons expliqué ces différences par la stratégie d'encodage possible selon la nature des items à mémoriser. Dans le Chapitre III, les participants ont effectué un reading span (Daneman & Carpenter, 1980). Cette tâche consiste à lire une série de phrases et à mémoriser le dernier mot de chaque phrase à rappeler à la fin d'une série. Nous avons créé un reading span multilingue, dans lequel les participants pouvaient avoir à lire et mémoriser des contenus dans une ou deux langues selon les conditions, cela parmi trois langues possibles : l'allemand (L1) et le français (L2), appris avant l'âge de 10 ans et l'anglais (L3), appris après l'âge de 10 ans. Les résultats ont montré que le rappel des mots était plus élevé lorsque la série de phrases était entièrement en L1, comparé aux conditions qui comportaient deux langues. Il n'y avait pas de différence significative entre les conditions entièrement en L2 ou en L3 et les conditions à deux langues L1L2 ou L1L3. Nous proposons d'expliquer ces résultats différents de ceux du Chapitre II par la nature différente de la tâche concurrente, i.e. la lecture d'une phrase entière, les intrusions lexicales des mots de la phrase à lire étant plus importantes.

Dans le quatrième et dernier chapitre, nous avons mené une étude descriptive des bilingues de l'Université de Fribourg, dont sont issus un bon nombre des participants de nos expériences. Nous nous sommes intéressés à l'acquisition et l'usage de leurs langues. Pour ce faire, nous avons utilisé le *Language Experience and Proficiency Questionnaire* (LEAP-Q ; Marian, Blumenfeld, & Kaushanskaya, 2007). Ce questionnaire a permis d'établir deux profils distincts de bilingues. En effet, une analyse statistique a mis en évidence que la nature de l'utilisation actuelle de leurs deux langues pouvait diviser les bilingues en deux groupes distincts. Premièrement, un groupe qui parle une langue dans son cadre privé et une autre à l'extérieur. Deuxièmement, un groupe qui parle les deux langues dans chaque environnement qu'il fréquente.

Summary

The aim of this thesis was to study the effect of bilingualism and language switching on working memory capacity. Research in bilingualism and cognition highlighted that both languages from a bilingual individual are always activated (e.g., Hoshino & Kroll, 2008). According to the Inhibition Control model (Green, 1998), a bilingual person has to inhibit the language not required in order to speak in the wished language. Bialystok and her colleagues (e.g., Bialystok, Craik, Klein, & Viswanathan, 2004; Bialystok & Martin, 2004; Bialystok & Senman, 2004) proposed that this inhibition mechanism was the same used in attentional control. The later is handled by executive functions, the main ones being inhibition, shifting and updating (Miyake et al., 2000). Thus, Bialystok et al. (2004) found a better performance in bilinguals compared to monolinguals in a task measuring inhibition. However, these results were not replicated when socioeconomic status was measured (Morton & Harper, 2007). Other researchers found a bilingual advantage in tasks measuring executive functions (e.g., Bonifacci, Giombini, Bellocchi, & Contento, 2010; Carlson & Meltzoff, 2008; Costa, Hernández, & Sebastián-Gallés, 2008; Engel de Abreu, Cruz-Santos, Tourinho, Martin, & Bialystok, 2012).

In the first chapter of this thesis, we compared bilinguals with monolinguals on a working memory task, as working memory requires the use of executive functions (e.g., Baddeley, Della Sala, Robbins, & Baddeley, 1996; Miyake & Shah, 1999). We measured the socioeconomic status of participants. Indeed, socioeconomic status correlates with executive control performances (e.g., Farah et al., 2006; Mezzacappa, 2004) and working memory capacity (e.g., Lee, Kawachi, Berkman, & Grodstein, 2003). College and apprenticeship students performed a working memory task. Concerning socioeconomic status, college students significantly scored higher than apprenticeship students. Results from the working memory tasks were similar in college students. However, concerning apprenticeship students, the bilinguals performed significantly better than their monolingual peers. We concluded that bilingualism had a positive effect on working memory capacity for participants from a modest socioeconomic status. The similar results from monolingual and bilingual college students correspond to the positive link between socioeconomic status and working memory capacity highlighted by Lee et al. (2003).

In Chapters II and III, we investigated the cognitive cost caused by the language switching within a working memory task in bilinguals. In Chapter II, participants performed a complex span task measuring working memory capacity. This task consisted of recalling a series of items in the order of presentation. The nature of the items, digits or words, varied according to the experiment. Between the presentation of each item to maintain, participants performed a concurrent task orally, consisting of naming items that appeared on the screen. We also varied the nature of the items (shapes, digits or colors) in the different experiences we carried. Participants completed several linguistic conditions. There were conditions in which the maintenance and concurrent task were in the same language (the dominant language, L1 *vs* the second language, L2). There were also conditions in which the maintenance task was in a language and the concurrent task in the other, and vice-versa. The nature of the items influenced the recall performance. Thus, when digits had to be maintained, the recall was better in one-language conditions. However, performance was similar when recall was in L1 compared to L2. When participants had to recall words, recall was better in L1 compared to L2. Though, there was no significant difference between one-language and two-language conditions. We explained this difference by the possible strategy of encoding according the nature of the items to maintain. In Chapter III, participants performed a reading span task (Daneman & Carpenter, 1980). This task consists of reading a series of sentences and maintaining the last word of each sentence to recall at the end of a series. We designed a multilingual reading span, in which participants read and maintained in one or two languages, in three possible languages according to conditions: German (L1), French (L2), both learned before the age of 10, and English, learned after the age of 10. Results showed a higher recall when sentences were entirely in L1, compared to two-language conditions. There was no significant difference between conditions entirely in L2 and L3 and two-language conditions L1L2 and L1L3. We proposed that results were different from experiments from the Chapter II because of the different nature of the concurrent task, i.e. reading an entire sentence, lexical intrusions of words of the sentences to read being more important.

In Chapter IV, we carried a descriptive study of bilinguals from the Université de Fribourg. We were interested in the acquisition and use of their languages. We used the Language Experience and Proficiency Questionnaire (LEAP-Q ;Marian, Blumenfeld, & Kaushanskaya, 2007). This validated questionnaire allowed classifying participants in two bilingual profiles. Indeed, a statistical analysis highlighted that the nature of the use of both languages could divide bilinguals in two distinct categories. First, a group speaking one language at home and the other in their outside environment. Second, a group speaking both languages in each environment.

INTRODUCTION

INTRODUCTION

Peu de gens nous contrediront quand nous affirmons que parler deux langues est une richesse. Deux langues, cela veut dire deux mondes linguistiques, avec toutes leurs particularités, mais aussi deux mondes en soi, car chaque langue est associée à sa propre culture. Ou, serions-nous tentés d'affirmer, ses propres cultures, tant le concept de culture définit la multitude et le fourmillement d'habitudes de vie, de traditions, de signes caractéristiques. Dans cette thèse, nous n'allons pas directement nous pencher sur ces thèmes, nous allons plutôt investiguer, observer, essayer de comprendre l'effet que le bilinguisme peut avoir sur des processus cognitifs, plus précisément sur la mémoire de travail. Afin d'aborder une brève définition de la mémoire de travail avec une personne qui n'en aurait jamais entendu parler, on pourrait faire une analogie avec cette fameuse idée émise dans « Le Bourgeois Gentilhomme » de Molière, selon laquelle Monsieur Jourdain ferait de la prose sans le savoir. Chaque individu utilise constamment sa mémoire de travail, il s'agit d'une activité centrale chez l'être humain. La mémoire de travail, comme nous le verrons plus précisément tout au long de ce travail, est un système qui permet de traiter et de maintenir temporairement de l'information. Etudier l'effet du bilinguisme sur ce système nous paraît ainsi d'un intérêt singulier.

Le bilinguisme

Le bilinguisme est souvent perçu comme une particularité. Pourtant, on estime que plus de la moitié de la population mondiale est bilingue (Grosjean, 2010). Le bilinguisme n'est ni limité à des catégories sociales, ni à des groupes d'âge. Le bilinguisme n'a pas attendu la globalisation pour être un phénomène présent aux quatre coins du globe. Comment pourrait-on définir le bilinguisme en quelques mots, sans en donner une définition exhaustive? Deux définitions historiques mettent bien en évidence la difficulté de qualifier le bilinguisme. Selon Bloomfield (1935), « Le bilinguisme est le fait de maîtriser une deuxième langue aussi bien que sa langue maternelle ». Pour Macnamara (1967), « Un bilingue est une personne qui possède dans une langue autre que sa langue maternelle une compétence de base dans au moins une de ces quatre habiletés langagières: compréhension orale, conversation, lecture et écriture ». Il s'agit ici de deux définitions fort différentes. Actuellement, le débat est toujours ouvert et les définitions varient. Est-ce qu'apprendre deux langues dès le plus jeune âge signifie être bilingue, si on ne pratique plus du tout une des deux langues depuis des décennies ? Est-ce qu'une langue apprise tardivement mais pratiquée quotidiennement en plus d'une langue maternelle permettrait à un individu de se considérer comme bilingue ?

Selon les chercheurs, différents critères d'âges et de fréquences sont considérés.

Lorsque nous aborderons le bilinguisme dans ce travail, nous ferons la distinction entre les bilingues précoces et tardifs. Cette distinction est communément acceptée dans les recherches de cette dernière décennie, comme le montre la revue de Hilchey et Klein (2011). Un bilingue précoce est un individu qui a appris deux langues avant l'âge de 10 ans et les pratique de manière hebdomadaire au minimum. Un bilingue tardif est un individu qui a appris une deuxième langue après l'âge de 10 ans et qui la pratique également au moins de manière hebdomadaire.

Le monde occidental actuel semble alors considérer un nombre croissant d'individus de bilingues tardifs, s'ils ne sont pas bilingues précoces, ayant appris deux langues avant l'âge de 10 ans. En effet, l'anglais est devenu une langue de référence dans bon nombre de professions. De plus, les loisirs cinématographiques ou télévisuels offrent fréquemment la possibilité de visionner des contenus dans leur langue originale. Qu'est-ce que cela implique au niveau des processus cognitifs d'être bilingue ? Quels sont les mécanismes en jeu lorsqu'un bilingue s'exprime dans une langue, puis change de langue ? Est-ce que le fait de changer régulièrement de langue entraîne-t-il la flexibilité intellectuelle de manière générale ?

Tout au long de notre exposé nous utiliserons les dénominations L1 et L2 pour mentionner les deux langues des bilingues. L1 est la langue qui est la plus dominante entre les deux langues parlées. Car, même si l'on parle parfois de bilingues maîtrisant parfaitement leurs deux langues, il y en a toujours une qui est au moins légèrement mieux maîtrisée que l'autre. Peut-être connaissez vous de parfaits bilingues ? Avez-vous déjà observé, s'ils parlent une troisième langue apprise tardivement, l'accent que cette personne présente en parlant cette langue ? Il s'agit de l'accent de la langue dominante. Ou demandez à un bilingue de compter à voix haute le plus rapidement possible le nombre d'objets présents sur une table. La langue qu'il utilisera sera sa langue dominante.

Le bilingue dans son environnement quotidien

Une personne bilingue, dans son environnement quotidien, va devoir changer de langue durant la journée, peut-être même à une haute fréquence si cette personne évolue dans un environnement bilingue. Ou alors elle va parler une langue dans son foyer et une autre langue dans un autre environnement. Dans cette section, nous allons voir quels sont les processus cognitifs en jeu et leurs conséquences lorsqu'un individu change de langue.

Recherches et modèles

Un élément abordé de manière récurrente dans la recherche sur le bilinguisme de ce début de XXIème siècle est la plasticité au niveau neuronal et cognitif (Kroll & Bialystok, 2013). De nombreuses recherches neuropsychologiques ont montré que la plasticité était encore potentiellement très importante aux niveaux neuronal et cognitif et ceci tout au long de la vie adulte, et qu'elle ne s'arrêtait donc pas à la fin de l'adolescence. Selon Kroll et Bialystok (2013), le bilinguisme fait partie des processus qui mènent à ces changements neuronaux et cognitifs. La raison invoquée par ces auteurs est que les deux langues d'un bilingue restent toujours actives « à un certain degré ». Nous allons vous exposer des études qui prouvent que ces langues sont toujours activées, afin de démontrer que changer de langue est un processus coûteux cognitivement. Cela même pour des individus maîtrisant parfaitement leur deuxième langue. Ainsi, lorsque de parfaits bilingues effectueront des tâches cognitives en devant alterner les langues à l'intérieur même d'un essai, nous verrons dans nos recherches que ce changement de langue prétéritera la performance à ces tâches.

Parmi les recherches prouvant que les deux langues d'un bilingue sont toujours activées, l'étude de Hoshino et Kroll (2008) incluant des bilingues espagnol-anglais et des bilingues japonais-anglais conclut à une activation de la L1 lors d'une tâche ne demandant que l'utilisation de la L2, qui est l'anglais pour les deux groupes. Cette langue a été acquise en moyenne à l'âge de 10 ans. Le matériel consistait en des dessins en noir et blanc. L'avantage de l'utilisation de dessins permet une influence moins importante des similarités orthographiques pour les bilingues espagnol-anglais. Parmi ces dessins, la moitié représentait des mots qui possédaient des cognates (i.e. des mots apparentés) entre les deux langues d'un participant. Ainsi, un exemple de cognate à la fois en anglais, espagnol et japonais est le mot guitare. Il se dit *guitar* en anglais, *guitarra* en espagnol et *gi.ta.a* en japonais (Tableau 1).

Tableau 1 : Exemples d'items représentés par des dessins par type de cognate selon les langues (Hoshino & Kroll, 2008)

Examples of materials by cognate type and cognate status

Cognate type	Cognate			Noncognate		
	English	Spanish	Japanese	English	Spanish	Japanese
English, Spanish, and Japanese	*guitar*	*guitarra*	*ギター (gi.ta.a)*	glasses	gafas	メガネ (me.ga.ne)
English and Spanish	*camel*	*camello*	ラクダ (ra.ku.da)	clown	payaso	ピエロ (pi.e.ro)
English and Japanese	*shirt*	camisa	*シャツ (sha.tsu)*	sheep	oveja	ヒツジ (hi.tsu.ji)

Note. Cognates are italicized.

Les participants devaient donner le nom de l'image montrée, le plus rapidement et le plus précisément possible en anglais, leur L2. Les auteurs ont mesuré la vitesse de réponse ainsi que la précision. Concernant la vitesse, les bilingues espagnol-anglais étaient plus rapides lorsque les dessins possédaient des cognates en anglais, espagnol et japonais, ainsi qu'en anglais et espagnol (

Tableau 2). Il y a donc une facilitation dans la performance lors de la présence de cognates entre leur L1 et L2. Ainsi, ils étaient plus lents à répondre pour les dessins possédant des cognates en anglais et japonais. Les bilingues japonais-anglais, quant à eux, obtenaient des scores plus rapides pour les dessins qui possédaient des cognates en anglais, espagnol et japonais, ainsi qu'en anglais et japonais. A nouveau, il y a donc une facilitation dans la performance lors de la présence de cognates entre leurs L1 et L2. Ainsi, ils étaient plus lents à répondre pour les dessins possédant des cognates en anglais et en espagnol.

Tableau 2: Tableau récapitulatif de l'étude de Hoshino et Kroll (2008): résultats sur la vitesse de réponse selon le type de cognate

Vitesse		
Type de cognate	**Bilingues espagnol-anglais**	**Bilingues japonais-anglais**
Anglais-espagnol-japonais	Plus rapides lors de dessins possédant des cognates.	Plus rapides lors de dessins possédant des cognates.
Anglais-espagnol	Plus rapides lors de dessins possédant des cognates.	Pas de différence significative entre les dessins possédant et ne possédant pas de cognates.
Anglais-japonais	Pas de différence significative entre les dessins possédant et ne possédant pas de cognates.	Plus rapides lors de dessins possédant des cognates.

Concernant la précision des réponses, le même pattern de résultats que celui concernant la vitesse a été trouvé. Ces résultats sur la vitesse et la précision conduisent Hoshino et Kroll (2008) à conclure que les deux langues sont activées lorsqu'on demande à un participant d'effectuer une tâche en L2, qui comporte également toutes les instructions en L2. Les résultats montrent également que le partage d'un système d'écriture commun, ou non, n'a pas d'influence dans cette expérience. Ainsi, la facilitation a lieu de manière similaire pour les bilingues espagnol-anglais lors de cognates en espagnol-anglais que pour les bilingues japonais-anglais lors de cognates en japonais-anglais. Dijkstra, Van Jaarsveld et Brinke (1998) avaient également montré que des bilingues étaient plus rapides à juger si une série de lettres formait un mot lorsque les mots en question partageaient des cognates entre leurs deux langues. Cette activation des deux langues a même été trouvée chez des lecteurs sourds (Morford, Wilkinson, Villwock, Piñar, & Kroll, 2011). Leur L1 était la langue des signes américaine et leur L2 l'anglais. Pour cette population, lorsqu'ils lisaient en anglais, leur langage des signes était activé.

D'autres études montrent plus exhaustivement que cette activation conjointe des deux langues serait également présente pour des langues qui ne partagent pas le même système d'écriture. Ainsi, Thierry et Wu (2007) ont testé à l'aide d'une étude ERP (Event-Related Potential, *Potentiel évoqué*) des étudiants anglais monolingues et des étudiants bilingues chinois-anglais qui possédaient l'anglais comme L2 tardive. Cette étude ajoute de plus des évidences neurologiques aux données comportementales. Egalement, un groupe de contrôle de monolingues chinois a effectué la même tâche, traduite en chinois. On leur présentait des paires de mots en anglais (ou en chinois pour le groupe contrôle). Les participants devaient décider si les 2 mots avaient un lien ou non au niveau de leur signification. La moitié des paires comportaient ce lien (e.g., *wood-carpenter*, i.e., bois-charpentier) et l'autre non (e.g., *train-ham*, i.e., train-jambon). Egalement, la moitié des paires partageait un idéogramme en chinois. Le design expérimental était donc un design factoriel 2 x 2 complètement équilibré, avec un facteur apparent (la similarité de signification) et un facteur caché (un idéogramme chinois en commun entre les 2 mots) (Tableau 3).

Tableau 3: Exemple de paires de mot pour chaque condition (Thierry & Wu, 2007) (Wu, n.d.)

Wood – Carpenter 木头 – 木匠 ***mu tou – mu jiang***	**Ham – Train** 火腿 – 火车 ***huo tui – huo che***
Doctor – Nurse 医生 – 病人 ***yi sheng – bing ren***	**Rabbit – Pen** 兔子 – 钢笔 ***tu zi – gang bi***

Ainsi, un effet significatif de facilité provoqué par la répétition d'un même idéogramme entre la paire de mots, alors que les mots sont présentés en anglais, montrerait que le chinois était activé lors de cette tâche en anglais. Les auteurs ont rapporté à la fois les résultats comportementaux et les résultats de leurs mesures ERP.

Les résultats comportementaux ont montré chez tous les groupes que les réponses étaient plus rapides lorsque les paires de mots partageaient une similarité sémantique. Evidemment pour les monolingues anglais, il n'y avait aucun effet significatif mesuré pour des mots qui partageaient un idéogramme chinois. Pour les bilingues chinois-anglais, il n'y avait pas non plus d'effet significatif. Concernant les monolingues chinois, on a mesuré une interaction entre la similarité sémantique des mots des paires et le partage d'un idéogramme chinois dans la même paire. Des analyses post-hoc ont révélé que les participants mettaient plus de temps à juger un mot qui ne partageait pas de similarité de signification, mais qui cependant partageait un idéogramme.

Les résultats ERP (Tableau 4) ont montré chez les monolingues anglais un effet de la similarité sémantique entre deux mots d'une même paire. En effet, l'amplitude moyenne était réduite de manière significative entre 300 ms et 500 ms, la fenêtre attribuée à la composante N400, cette dernière étant liée aux processus d'intégration sémantique. Comme on pouvait s'y attendre, la présence de l'idéogramme chinois commun à deux mots d'une paire n'a eu aucun effet sur la composante N400. Concernant les bilingues chinois-anglais, l'effet de similarité sémantique était également significatif, mais de manière moins importante que chez les monolingues anglophones. Résultat important, la présence d'un idéogramme chinois commun dans une paire a provoqué un effet significatif sur la composante N400. A noter que cet effet n'interagissait pas avec la similarité sémantique. Ces résultats montrent que la langue chinoise est activée chez les participants bilingues chinois-anglais qui effectuent une tâche contenant exclusivement des items en anglais. Enfin, on a mesuré chez les monolingues chinois un effet similaire aux bilingues chinois-anglais et aux monolingues anglais concernant la similarité de signification. L'effet lié à la présence d'un idéogramme commun entre les mots d'une même paire est similaire à celui mesuré chez les bilingues chinois-anglais.

Tableau 4: Récapitulation des résultats des groupes linguistiques selon les facteurs "similarité sémantique" et "présence d'un idéogramme chinois commun" (Thierry & Wu, 2007).

	Monolingues anglais	**Bilingues chinois-anglais**	**Monolingues chinois**
Similarité sémantique entre 2 mots d'une même paire (facteur apparent)	Effet significatif sur la composante N400.	Effet significatif sur la composante N400.	Effet significatif sur la composante N400.
Présence d'un idéogramme chinois entre 2 mots d'une même paire (facteur caché)	Pas d'effet sur la composante N400.	Effet significatif sur la composante N400.	Effet significatif sur la composante N400.

L'expérience a ensuite été conduite à l'identique, à l'exception de la modalité de présentation des items, qui était auditive et non plus écrite. Les résultats ont montré des effets similaires, prouvant que ces effets ne sont pas tributaires d'une seule modalité sensorielle.

Si les deux langues restent activées, on suppose alors l'existence d'un mécanisme qui permet d'activer et de désactiver une langue donnée selon le besoin. Ce mécanisme va être très important pour nos recherches, puisqu'il sera susceptible d'engendrer des coûts cognitifs lorsque des bilingues devront changer de langue à l'intérieur même d'un essai d'une tâche cognitive. Par ailleurs, une partie de la littérature considère que ce mécanisme est à l'origine d'un avantage des bilingues sur les monolingues dans des tâches cognitives non-verbales. Nous verrons que cet avantage porte à controverse, puisqu'un nombre croissant d'études ne le rapporte pas. Nous nous intéresserons également à cette question lors de la deuxième partie expérimentale dans laquelle nous comparerons les groupes linguistiques (monolingues vs bilingues) en fonction de leur statut socio-économique (élevé vs moyen inférieur).

L'hypothèse de l'existence d'un mécanisme activateur et désactivateur de langues est examinée et largement évoquée dans la littérature depuis un article de Green (1998) qui propose que l'inhibition est le mécanisme qui permet la désactivation d'une langue. David W. Green pose la base de sa proposition sur le modèle de production langagière de Levelt (1989) concernant les lemmes, expression de linguistique qui s'apparente à la notion de « mot » dans la vie courante. D'après ce modèle, chaque concept lexical est associé à un lemme. Ce dernier possède alors les propriétés syntaxiques nécessaires pour qu'un individu puisse créer des phrases. Chaque lemme fait office en quelque sorte d'*étiquette de langage*. La sélection syntaxique est alors le fruit de la compétition entre les lemmes possibles. Selon Green (1998), chez un bilingue, pour un même mot, il y a un lemme associé en L1 et un autre en L2. Son modèle se base également sur l'hypothèse selon laquelle les deux langues d'un bilingue sont activées lorsque ce dernier parle une de ces langues. L'inhibition est alors vue comme une réponse à un stimulus. C'est à dire qu'inhiber signifie dans ce cas déployer son attention afin de prohiber la seconde langue pour n'utiliser que la première dans un contexte donné. Plus précisément, le modèle de l'inhibition fait l'hypothèse qu'un bilingue est amené à choisir un lemme conformément au langage dans lequel il souhaite s'exprimer. Il inhibe alors le lemme du langage qu'il ne souhaite pas utiliser. Dans cette optique, changer de langue à une fréquence importante peut s'avérer coûteux en temps et en charge cognitive. En effet, changer de langue veut dire inhiber tous les lemmes de la langue dans laquelle on ne souhaite pas s'exprimer à un moment donné. Depuis, on a adopté une vision plus large pour expliquer l'activation et la désactivation d'une langue. On estime que les fonctions exécutives en général – et non l'inhibition seule – permettent cette opération. Le modèle de Green a néanmoins inspiré toute une série de recherches sur les fonctions exécutives et le bilinguisme. Nous développerons cela de manière exhaustive dans le chapitre 1.3. Nous verrons que Costa et ses collègues (Costa, Hernández, Costa-Faidella, & Sebastián-Gallés, 2009; Costa et al., 2008) privilégient le monitoring à l'inhibition pour expliquer le mécanisme d'activation et de désactivation d'une langue. Le monitoring est une fonction exécutive qui permet de déterminer s'il y a conflit et dans ce cas d'agir en conséquence.

Cette première partie nous montre donc que l'activation permanente des deux langues a un coût, non seulement pour s'exprimer dans une langue, mais également pour changer de langue. Nous étudierons dans le Chapitre II les coûts cognitifs provoqués par le changement de langue dans une tâche de mémoire de travail. Les mécanismes en jeu chez les bilingues ont aussi été investigués par le biais des IRMf (Imagerie par Résonnance Magnétique fonctionnelle). C'est ce que nous allons parcourir dans le sous-chapitre suivant. En observant les zones du cerveau qui s'activent, la recherche a pu confirmer des hypothèses et lancer de nouvelles pistes.

Evidences neuropsychologiques

La neuroimagerie et les techniques de neuropsychologie ont servi à l'avancement des connaissances sur le bilinguisme durant ces vingt dernières années. Comme le précise Abutalebi (2008) dans sa revue de littérature, les techniques d'IRMf ont permis d'améliorer les connaissances sur l'activité cérébrale dans le domaine du langage de deux manières. Elles ont d'une part confirmé des théories et des explications scientifiques. Elles ont d'autre part permis de nouvelles découvertes. Leur avantage est de pouvoir mettre en évidence avec précision les réseaux neuronaux en action lors de processus cognitifs opérés par un bilingue.

Par sa revue de données de neuroimagerie, Abutalebi (2008) compare les données issues de tâches de production de mots et de grammaire chez des bilingues maîtrisant peu leur L2 par rapport à des bilingues maîtrisant leur L2 aussi bien que leur L1. Les réseaux neuronaux activés de la zone préfrontale sont les mêmes pour ces deux groupes, mais chez les bilingues maîtrisant peu leur L2 ils sont plus activés. Ainsi, plusieurs aires associées au contrôle cognitif, tels les BA 9, 46 et 47 sont plus activées. Cependant, pour le deuxième groupe de bilingues maîtrisant la L2 autant que leur L1, les différences de magnitude d'activation de ces zones précédemment observées lors de l'utilisation de la L2 disparaissent. Cela témoigne que le coût cognitif engendré par l'utilisation d'une L2 peu maîtrisée, est plus important que celui qui résulte de l'utilisation de la L1, par définition totalement maîtrisée.

Bien que les études abordées dans cette revue de littérature utilisent parfois des paradigmes et des modalités bien différents, elles ont en commun le fait qu'elles montrent toutes l'activation du cortex préfrontal, du cortex cingulaire antérieur et du gyrus supramarginal. Toutes ces zones sont associées au contrôle cognitif. Comme les zones mises en évidence lors de l'utilisation de la L2 sont communes à celles associées au contrôle cognitif, des chercheurs ont fait l'hypothèse que les bilingues pouvaient être meilleurs que les monolingues dans des tâches demandant l'utilisation du contrôle cognitif (e.g., Bialystok, Craik, Klein, & Viswanathan, 2004; Bialystok, Craik, & Luk, 2008; Bialystok, Martin, & Viswanathan, 2005; Costa et al., 2009, 2008; Emmorey, Luk, Pyers, & Bialystok, 2008; Luo, Craik, Moreno, & Bialystok, 2013). C'est le sujet que nous développerons dans le prochain sous-chapitre. Nous présenterons d'abord ce que sont les fonctions exécutives et l'avancée des recherches dans ce domaine. Nous aborderons ensuite les recherches qui s'intéressent à l'avantage des bilingues. Nous verrons ultérieurement que cet avantage est actuellement discuté, ce qui nous amènera plus tard à une recherche dans laquelle nous avons comparé des monolingues et des bilingues.

Switching des langues et switching lors de tâches non-verbales: un seul et même mécanisme?

Comme nous l'avons vu précédemment, Green (1998) a proposé que l'inhibition, une fonction exécutive également utilisée dans le contrôle attentionnel, permettait de désactiver chez un bilingue la langue non souhaitée. Ce mécanisme n'étant pas limité au changement de langue mais à un nombre d'activités plus large, l'hypothèse suivante a été développée dans la littérature : les bilingues, bien entraînés à contrôler les langues, pourraient être meilleurs dans des tâches cognitives faisant appel à l'inhibition. Les recherches en neuroimagerie ont montré que les aires cérébrales activées lors du changement de langue sont celles associées au contrôle cognitif de manière générale (Abutalebi & Green, 2007; Bialystok, Craik, & Luk, 2012; Kroll & Bialystok, 2013; Luk, Green, Abutalebi, & Grady, 2012). En d'autres termes, il n'y a pas de zone(s) spécifique(s) consacrée(s) au changement de langue. Cette dernière activité fait partie d'un ensemble plus large d'activités cognitives. Ces nouveaux apports ont conforté les chercheurs dans leur investigation d'un avantage bilingue. Dans ce chapitre, nous verrons que les fonctions exécutives sont les outils du contrôle exécutif. Chaque fonction exécutive a au final le même but: diriger l'attention. La difficulté suivante va alors se présenter : si les bilingues ont un avantage, sur quelle fonction exécutive se manifeste-t-elle ? Nous verrons que Bialystok et ses collègues (e.g., Bialystok et al., 2004) ont proposé que les bilingues avaient de meilleures capacités d'inhibition. L'équipe de Costa (e.g., Costa et al., 2008) a proposé un avantage au niveau du monitoring. Il est important de présenter les diverses recherches et les controverses qu'elles ont ensuite provoquées pour comprendre notre démarche expérimentale. En effet, nous testerons des monolingues et des bilingues à l'aide de tâches de mémoire de travail. Pour exécuter ces dernières, un individu utilise notamment ses fonctions exécutives.

Contrôle exécutif et fonctions exécutives

Le contrôle exécutif est un sujet de recherche prépondérant dans la littérature en psychologie cognitive actuelle. Miyake et Friedman (2012) décrivent le contrôle exécutif comme la capacité de contrôler ses impulsions et ses envies au niveau cognitif. Plus précisément, il s'agit de l'aptitude à guider ses capacités cognitives. Il ne s'agit pas d'une entité unique, mais d'un ensemble de fonctions exécutives (Miyake et al., 2000). Les trois fonctions exécutives principales seraient le shifting, l'updating et l'inhibition.

Le shifting, aussi appelé dans la littérature « attention switching » ou « task switching », permet de déplacer son attention d'une tâche sur une autre. Une tâche est abandonnée et toute l'attention est canalisée sur une autre tâche. Cette fonction exécutive est contrôlée principalement par le lobe frontal, y compris le gyrus cingulaire antérieur, aussi appelé réseau attentionnel antérieur. L'updating se déroule en deux étapes. Tout d'abord, il consiste à contrôler les informations venant de l'environnement, à les sélectionner et à les coder, de manière à ce qu'elles soient utiles à la tâche souhaitée. Ensuite, l'updating permet de faire sortir de l'attention les informations n'étant plus nécessaires contenues en mémoire de travail et de les remplacer par les nouvelles informations entrantes fraîchement codées. Cette fonction exécutive est contrôlée principalement par le cortex préfrontal, spécialement sa partie dorsolatérale. L'inhibition, quant à elle, sert à éliminer de manière volontaire des réponses dominantes, automatiques ou prépotentes. Le mot inhibition étant largement utilisé dans la langue courante et dans d'autres sous-domaines de la psychologie, il est important de souligner l'aspect *volontaire* de sa nature. Il ne s'agit pas ici d'un mécanisme automatique non-souhaité. A noter également que cette inhibition n'est pas réactive, mais qu'elle se situe en amont du processus attentionnel. C'est à dire que l'inhibition est le mécanisme qui permet à un individu de pointer son attention sur un élément précis et ensuite d'agir en conséquence. Selon le modèle de l'inhibition de Green (1998) dans le domaine du bilinguisme, faisons l'hypothèse qu'un bilingue français/allemand doive s'exprimer en allemand. Pour ce faire, il va d'abord devoir inhiber la langue française. C'est seulement à ce moment-là qu'il pourra effectuer l'action requise par la tâche demandée, c'est à dire s'exprimer en allemand.

Des analyses factorielles montrent que les fonctions exécutives possèdent à la fois de la variance commune et de la variance propre à chaque fonction exécutive. De la variance commune, car ces fonctions sont toutes des outils qui oeuvrent pour la même finalité : déployer l'attention de manière adéquate. Dans ce but, elles ont certaines caractéristiques communes. Ainsi, ces analyses factorielles indiquent que les trois principales fonctions exécutives corrèlent entre elles à un certain degré (Figure 1). De la diversité, car elles relèvent chacune d'un processus différent.

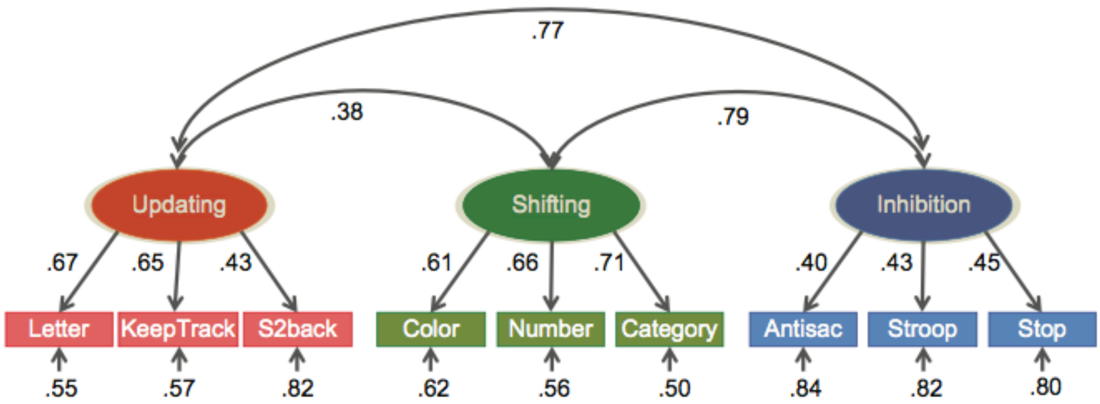


Figure 1: Corrélations entre les trois principales fonctions exécutives, ainsi que les corrélations des fonctions exécutives avec les tâches qui les évaluent (Miyake & Friedman, 2012)

L'inhibition et l'updating corrèlent à .77, l'inhibition et le shifting à .79 et l'updating et le shifting à .38. Pour Miyake et Friedman (2012), ces corrélations montrent l'unité des fonctions : elles ont de commun le fait qu'elles maintiennent les buts d'une tâche et qu'elles utilisent des informations spécifiques de ces tâches qui permettent ce maintien. Tandis que le restant ne corrélant pas témoigne de la flexibilité dont fait preuve chaque fonction exécutive. Chaque fonction exécutive possède une part de fonctionnement qui lui est propre, qui a été défini pour chaque fonction principale au début de ce sous-chapitre.

Selon le modèle de Green (1998), la langue qu'un bilingue ne souhaite pas utiliser est inhibée pour permettre de s'exprimer dans la langue requise. Ce modèle a mené Bialystok et al. (2004) à évaluer l'inhibition chez des monolingues et des bilingues dans une tâche cognitive non-verbale, la tâche de Simon. Si les bilingues utilisent plus cette fonction exécutive que les monolingues par l'exercice de leur activité langagière, ils pourraient être meilleurs que les monolingues dans la tâche de Simon requérant de l'inhibition. Nous allons détailler les recherches de Bialystok et ses collègues dans le sous-chapitre suivant.

L'inhibition : les recherches de Bialystok et collaborateurs

Bialystok et ses collègues ont effectué depuis la fin des années 1990 un nombre important d'études qui comparent les monolingues et les bilingues. Bon nombre de leurs études ont mesuré et comparé la capacité d'inhibition chez ces deux populations. Ainsi, Bialystok et al. (2004) ont mené trois expériences chez des adultes et des personnes âgées. Ils ont voulu étudier si le fait d'être monolingue ou bilingue a un effet sur l'inhibition dans ces deux populations d'âge différent. Par exemple, dans la première étude, des participants adultes, âgés de 30 à 54 ans et des participants adultes plus âgés, de 60 à 88 ans, ont été comparés. Dans chaque groupe, la moitié des individus était monolingue et résidait au Canada. L'autre moitié était bilingue précoce tamoul-anglais et habitait en Inde. Les participants effectuaient une tâche de Simon (Simon & Wolf, 1963) sur ordinateur (Figure 2). Dans cette tâche, un carré bleu ou rouge apparaissait à gauche ou à droite de l'écran. Le participant devait appuyer sur une touche à gauche lorsque le carré était bleu et à droite lorsqu'il était rouge, cela indépendamment du côté de présentation du carré. Pour répondre correctement, les participants devaient alors *inhiber* l'information spatiale (présentation à gauche ou à droite de l'écran) pour se focaliser sur la couleur du carré. Cependant, ils devaient appuyer sur une touche à gauche et à droite, action qui possède une analogie avec l'emplacement de présentation du carré. Cela rend la tentation naturelle d'appuyer sur une touche selon l'emplacement du carré. Or, il s'agit ici de répondre concernant la couleur d'un carré. Un essai qui demande de répondre par la touche de gauche alors que l'item est placé à gauche s'appelle congruent et un essai qui demande de répondre par la touche de droite alors que l'item est placé à gauche s'appelle incongruent.

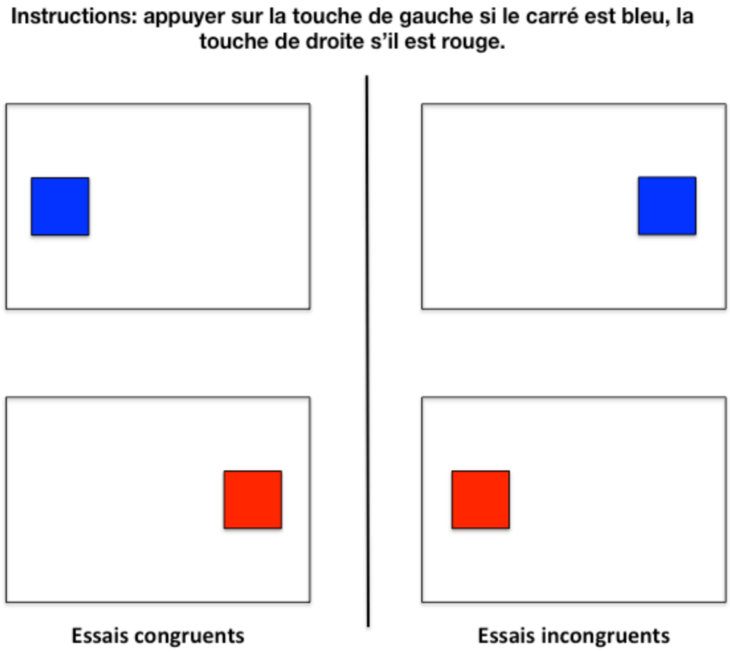


Figure 2: Les quatre types possibles d'essais de la tâche de Simon (Bialystok et al., 2004)

Les analyses concernant la vitesse ont montré que les essais congruents étaient exécutés plus rapidement que les essais incongruents, ce qui est propre à l'effet Simon. Ainsi, les essais qui ne requéraient pas d'inhiber une information étaient résolus plus rapidement. Les bilingues étaient plus rapides que les monolingues. Les jeunes adultes étaient également plus rapides que les personnes âgées. L'interaction entre la congruence et le type linguistique des participants était significative. En effet, la magnitude de la différence des temps entre les essais congruents et incongruents était plus importante chez les monolingues que les bilingues. En outre, il y avait une interaction entre la congruence et le groupe d'âge des participants. La magnitude de la différence des temps entre les essais congruents et incongruents était plus importante chez les personnes âgées que chez les adultes. Néanmoins, il n'y avait pas d'interaction entre la congruence, le type linguistique des participants et le groupe d'âge des participants. En d'autres termes, le groupe d'adultes plus âgés montrait des différences de performance plus importantes que les adultes plus jeunes entre les essais congruents et incongruents, autant chez les monolingues que les bilingues. A partir de ces expériences, Bialystok et ses collègues concluent que le bilinguisme stimule l'inhibition et offre un avantage important aux bilingues dans les domaines d'application de cette fonction exécutive. Cet avantage est présent même chez une population adulte et vieillissante. Néanmoins, les bilingues sont plus rapides que le monolingues lors de tous les types d'essais.

Ils le sont aussi bien pour les essais incongruents que les essais congruents. Costa et son équipe font alors l'hypothèse qu'un avantage bilingue ne se situerait pas au niveau de l'inhibition, mais du monitoring. Si l'avantage se trouvait au niveau de l'inhibition, les bilingues seraient plus rapides uniquement pour les essais incongruents. C'est seulement lors de ces derniers qu'il faut utiliser l'inhibition. Un essai congruent ne contient pas de conflit à résoudre. En revanche, le monitoring permet à un individu de décider ou non s'il y a conflit et d'agir en conséquence. L'utilisation du monitoring pourrait expliquer que les bilingues sont également plus rapides à répondre aux essais congruents. Dans le prochain sous-chapitre, nous allons présenter les recherches de l'équipe de Costa.

Monitoring : les recherches de Costa et collaborateurs

Costa et ses collègues ont fréquemment utilisé la tâche de flanker afin de comparer les monolingues et les bilingues. Cette tâche se compose d'une flèche centrale présentée sur un écran d'ordinateur. Cette flèche peut pointer à gauche ou à droite. Le participant doit indiquer en appuyant sur une touche de quel côté pointe cette flèche centrale. Cette dernière est flanquée (d'où le nom de la tâche en anglais, *flanker*) de deux flèches de chaque côté, pointant toutes dans le même sens. Si elles pointent dans le même sens que la flèche centrale, on dit que l'essai est congruent (Figure 3). Si elles pointent dans le sens opposé de la flèche centrale, l'essai est incongruent.

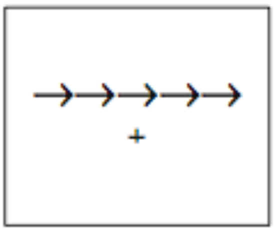


Figure 3: Essai congruent de la tâche de flanker (Costa et al., 2009)

Typiquement, dans cette tâche, les participants ont des réponses plus rapides pour les essais congruents que pour les essais incongruents. Dans les essais congruents, ils n'ont pas besoin de résoudre de conflit, i.e. ils n'ont pas besoin d'isoler l'information de direction de la flèche centrale allant dans le sens contraire de toutes les autres flèches. Costa et al. (2008) ont également trouvé que les bilingues étaient plus rapides que les monolingues à résoudre les essais à la fois congruents et incongruents. Ils en concluent que les bilingues ont un meilleur monitoring que les monolingues. Ils parlent de monitoring, car selon eux la tâche implique de décider s'il y a conflit ou non et ensuite de répondre à l'essai. Costa et al. (2008) expliquent que les bilingues sont meilleurs dans cette fonction exécutive, qu'ils sont spécialement performants pour gérer des essais qui peuvent contenir un conflit ou non, car dans leur quotidien les bilingues ont constamment besoin de gérer le besoin de changer de langue ou non. Dans une recherche ultérieure, Costa et al. (2009) ont voulu étudier précisément l'utilisation du monitoring chez les monolingues et les bilingues.

Pour ce faire, ils ont créé des conditions qui demandaient un monitoring différencié. L'avantage des bilingues devait alors être spécialement marqué pour les conditions de haut monitoring et peu, voire non présent, dans les conditions de bas monitoring. Afin de varier le monitoring, ils ont fait varier le pourcentage d'essais congruents et incongruents de la tâche de flanker dans une série. Ainsi, si la série présente des essais en quasi-totalité de même nature (soit entièrement congruent ou incongruent), ils ont fait l'hypothèse que le participant n'aurait que peu besoin du monitoring. Au contraire, si 50% d'essais congruents et 50% d'essais incongruents étaient présentés dans une série, ils ont fait l'hypothèse que le monitoring serait très sollicité. Dans les conditions de bas monitoring, il n'y avait pas de différence de vitesse de réponse entre les monolingues et les bilingues. En revanche, dans les conditions de haut monitoring, les bilingues répondaient plus rapidement que les monolingues. Ils ont donc conclu que l'avantage bilingue pouvait être présent seulement dans des conditions très exigeantes cognitivement. Dans les séries contenant une majorité d'essais de même nature - soit une majorité d'essais congruents ou au contraire d'incongruents - le monitoring ne serait que peu engagé. En conséquence, les bilingues n'ont pas été plus efficients que les monolingues dans ce type de séries. Mais lorsque la nature de l'essai suivant est hautement incertaine, le monitoring serait particulièrement sollicité. La rapidité plus importante des bilingues dans ce type de séries s'expliquerait par une maîtrise particulièrement étendue du monitoring.

Toutefois, un problème important autant pour les études de l'équipe de Costa que pour celles de Bialystok est la difficulté à répliquer leurs résultats. Afin de pouvoir conclure à un avantage bilingue, une expérience comprenant la même méthodologie et le même type de participants doit montrer des résultats similaires. Nous verrons dans le sous-chapitre suivant par la revue de Hilchey et Klein (2011) que la réplication de ces résultats est rare.

Des effets portant à controverse

La revue de Hilchey et Klein (2011)

Hilchey et Klein (2011) ont fait une méta-analyse de toutes les recherches sur l'avantage potentiel des bilingues au niveau du contrôle exécutif. Ils se focalisent sur les études qui ont utilisé soit la tâche de Simon ou la tâche de flanker. Comme le montre la Figure 4, Hilchey et Klein (2011) ont recensé les études comparant les monolingues avec les bilingues sur la tâche de Simon composée d'items présentés sous forme de flèche, la tâche de flanker et la tâche de Simon. Les points situés sur la ligne 0 indiquent les études qui ne trouvent pas de différence significative de vitesse entre les monolingues et les bilingues. Les points situés au-dessus de cette ligne désignent les études qui obtiennent des scores plus rapides pour les bilingues comparés aux monolingues. Enfin, les points en-dessous de la ligne 0 représentent les études dans lesquelles les monolingues sont plus rapides que les bilingues. Hilchey et Klein ont classé toutes les études selon l'âge des participants. Ainsi, l'abscisse de ce graphique représente les âges moyens des participants.

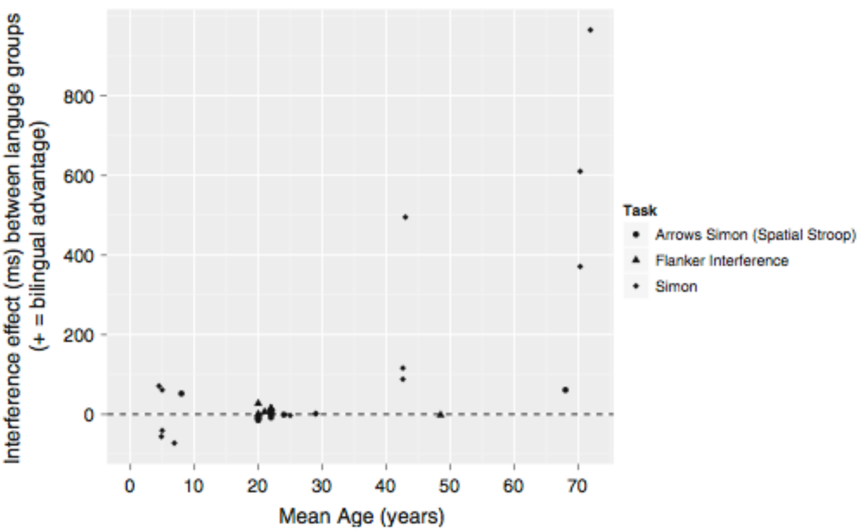


Figure 4: Magnitude des interférences entre monolingues et bilingues sur les tâche de Simon (flèches), flanker et Simon selon l'âge moyen (Hilchey & Klein, 2011)

Cette figure témoigne de plusieurs faits qui remettent en perspective certaines hypothèses. Tout d'abord, concernant les populations jeunes et adultes de moins de 40 ans, seul un nombre limité de recherches relève des différences entre les monolingues et bilingues. Parmi les études témoignant d'une meilleure performance des bilingues comparée au monolingues (e.g., Bialystok et al., 2004 ; Costa et al., 2009), les bilingues sont meilleurs dans tous les types d'essais, même ceux qui ne contiennent pas de conflit à résoudre. L'équipe de Bialystok prédisait un avantage pour les essais incongruents uniquement, là où justement il y avait un conflit à résoudre. Leur hypothèse se basait sur un avantage des bilingues à résoudre ces conflits plus rapidement et plus précisément, étant donné qu'ils auraient un avantage en inhibition. Costa et al. (2009) proposent que cet avantage pour les essais congruents et incongruents, aussi appelé avantage global, est le résultat d'un meilleur monitoring chez les bilingues, comme nous l'avons vu au sous-chapitre 0.3.3.

Ensuite, quatre études ont investigué les effets de l'âge, qui ont montré un avantage des bilingues âgés sur les monolingues âgés concernant la rapidité et la précision de la réponse (i.e, Bialystok et al., 2004 ; Bialystok et al., 2005; Bialystok et al., 2008; Emmorey et al., 2008). Hilchey et Klein (2011) tiennent à préciser qu'ils notent quelques anomalies dans les résultats de ces études. L'effet Simon chez les monolingues âgés se situe entre 1000 ms et 1800 ms (Bialystok et al., 2004; Bialystok et al., 2005). Rappelons que l'effet Simon est la différence de score entre les essais congruents et incongruents. Or, l'effet Simon se situe habituellement aux alentours de 70 ms chez les personnes âgées (Kubo-Kawai & Kawai, 2010, cité dans Hilchey & Klein, 2011 ; Van der Lubbe & Verleger, 2002, cité dans Hilchey & Klein, 2011). La performance extrêmement mauvaise des monolingues dans ces deux études fait conclure Bialystok et ses collègues à un avantage des bilingues sur les monolingues.

Un autre problème important dans les recherches évaluées par Hilchey et Klein (2011) est l'hétérogénéité des participants bilingues au niveau des langues parlées, de leur ethnie et de leur milieu socio-économique ainsi que culturel. Ainsi, dans la première étude de Bialystok et al. (2004), les monolingues étaient Canadiens nés à cet endroit, tandis que les bilingues étaient nés et avaient grandi en Inde. Comment être sûr qu'une différence mesurée ne serait pas due au milieu socio-économique et culturel plutôt qu'à un avantage bilingue ? Il aurait fallu tester des participants bilingues qui provenaient du même milieu que les monolingues. Hilchey et Klein (2011) ne sont pas les premiers à pointer cette faiblesse expérimentale. En effet, Morton et Harper (2007) avaient émis des doutes sur le choix des participants de cette même étude devenue populaire dans la littérature. Ils ont alors décidé de la répliquer, mais en prenant des enfants monolingues anglophones et des bilingues anglais-français ayant grandi au Canada dans la même région. De plus, ils ont mesuré et pris en compte le statut socio-économique, ce qui n'était nullement le cas dans l'étude de Bialystok et al. (2004) et la quasi-totalité des études de cette équipe. Des enfants monolingues et bilingues entre 6 et 7 ans ont effectué une tâche de Simon identique à la tâche de l'Expérience 1 de Bialystok et al. (2004). Bialystok et ses collègues relevaient des réponses plus précises et rapides des bilingues comparées aux monolingues. En revanche, les résultats de la réplication de Morton et Harper (2007) ont montré des performances similaires entre les monolingues et les bilingues. Ils retrouvent néanmoins l'effet Simon : tous les participants étaient plus lents et moins précis lorsqu'ils devaient répondre aux essais incongruents comparés aux essais congruents. Morton et Harper (2007) notent que leur étude était la première à comparer avec la tâche de Simon des enfants monolingues et bilingues provenant exactement du même milieu.

Après avoir abordé le choix de la population, nous allons nous pencher sur les tâches évaluant les fonctions exécutives utilisées dans ces études. Ainsi, les différentes tâches évaluant l'inhibition devraient corréler entre elles. Signe de fiabilité, ces corrélations montreraient que toutes ces études évaluent exactement la même habilité. Or, comme nous le verrons dans le sous-chapitre suivant, elles ne corrèlent pas entre elles. Il s'agit là d'un problème de taille : si une tâche utilisée pour la comparaison entre monolingues et bilingues n'est pas adéquate, toute conclusion issue des résultats de cette tâche ne peut être qu'hâtive.

Les recherches de Paap et Greenberg (2013)

D'autres chercheurs sont sceptiques face un avantage des bilingues dans les fonctions exécutives. Ainsi, Paap et Greenberg (2013) questionnent notamment les tâches utilisées pour évaluer les participants sur les fonctions exécutives. Ils notent que les recherches évaluant l'inhibition utilisent différentes tâches selon les études. Le problème est que les trois principales tâches utilisées – les tâches de Simon, flanker et Stroop – ne corrèlent pas entre elles. En effet, une étude de Stins, Polderman, Boomsma et de Geus (2005, cité dans Paap & Greenberg, 2013) ne trouve que des corrélations non significatives entre ces trois tâches et toutes inférieures à .20. Paap et Greenberg ont donc décidé de mener trois études qui utilisent tout un panel de tâches testant l'inhibition. Leurs recherches ont utilisé les tâches de Simon, de switching couleur-forme, d'anti-saccade et de flanker. De plus, les participants ont rempli un questionnaire d'usage de langues, un exercice sur les homographes et les matrices de Raven. Les participants étaient de jeunes étudiants en psychologie comprenant des monolingues anglophones et des bilingues précoces. Ces derniers avaient pour deuxième langue un panel de 30 langues. Tous utilisaient les deux langues régulièrement, pour la plupart tous les jours.

Concernant la tâche de Simon, les monolingues et les bilingues effectuaient tous deux la tâche avec une grande précision, résultant d'un score moyen de 98% de réponses correctes. Comme précédemment abordé, l'hypothèse concernant la tâche de Simon était la suivante : si les bilingues possédaient une meilleure capacité d'inhibition, ils auraient dû être plus rapides que les monolingues à répondre aux essais incongruents. Or, les résultats n'ont montré aucun avantage des bilingues. Ils n'étaient pas plus rapides que les monolingues. Les effets attendus d'une tâche de Simon étaient néanmoins observés : les participants étaient plus rapides pour exécuter des essais congruents que des essais incongruents. La tâche de switching couleur-forme se présentait de la manière suivante pour un participant : selon l'instruction, il devait soit juger la couleur, soit la forme d'une figure présentée, le plus précisément et le plus rapidement possible. Si les bilingues avaient une meilleure capacité d'inhibition, ils devaient être plus rapides que les monolingues pour les conditions mixtes. Or, aucune différence significative entre monolingues et bilingues n'a été mesurée. Les auteurs mentionnent que ces résultats ne peuvent pas être dus à de trop petites différences de coûts entre les conditions contrôle et les conditions mixtes, ces différences étant importantes et dépassant 200 ms. Statistiquement, si les résultats des conditions mixtes étaient très proches des résultats des conditions contrôle, l'analyse aurait pu ne pas déceler de différence significative entre monolingues et bilingues alors qu'elle existait, créant alors un faux négatif.

La tâche anti-saccade était proche de celle utilisée par Kane, Bleckly, Conway et Engle (2001). Un distracteur clignotait à deux reprises avant l'apparition d'un stimulus à juger. Le distracteur apparaissait du côté opposé duquel le stimulus à juger était présenté. Ensuite le stimulus apparaissait, il s'agissait soit d'un « B », d'un « P » ou d'un « R ». Le participant devait appuyer le plus rapidement et précisément possible sur la touche qui correspondait au bon stimulus. Si les bilingues possédaient une meilleure capacité d'inhibition, ils devaient être plus rapides que les monolingues à répondre. Or, ce n'est pas le cas, les monolingues et les bilingues ont obtenu des scores similaires.

La tâche de flanker était similaire à celle utilisée par Costa et al. (2008) (Figure 3). On s'attendait à ce que les bilingues soient plus rapides que les monolingues à la fois dans les essais congruents et incongruents. Les résultats de l'étude de Costa et al. (2008) allaient dans cette direction et avaient fait pencher les auteurs pour un avantage des bilingues sur la fonction exécutive du monitoring. Contrairement à l'étude de Costa et de ses collègues, aucune différence significative n'a été trouvée entre les monolingues et les bilingues.

Face à ces comparaisons qui n'ont montré aucune différence entre monolingues et bilingues, Paap et Greenberg (2013) se sont interrogés sur les causes possibles des différences entre les groupes monolingues et bilingues dans les études que nous avons abordées précédemment. Premièrement, ils mentionnent les erreurs de type I, qui sont en statistique de faux positifs. En d'autres termes, le test statistique fait état d'un effet qui n'existe pas en réalité. Ensuite, ils abordent les facteurs démographiques cachés, déjà mentionnés par Morton et Harper (2007) et Hilchey et Klein (2011). Des milieux socio-économiques ou des milieux socio-culturels différents peuvent provoquer des résultats différents dans ces tâches cognitives. L'influence de ces facteurs est très probablement plus complexe qu'il n'y paraît. C'est pourquoi les participants à nos expériences répondront à des critères prédéfinis et rempliront un questionnaire socio-économique. De cette manière, nous contrôlerons autant que possible ces facteurs démographiques. Dans les prochains chapitres, nous exposerons les raisons de ce choix. Pour commencer, nous allons présenter ce qu'est la mémoire de travail et faire état de l'avancement des recherches dans ce domaine.

Mémoire de travail et bilinguisme

Les recherches de psychologie cognitive concernant le bilinguisme ont, comme nous l'avons vu, porté sur les fonctions exécutives. Comme nous le verrons dans ce chapitre, la mémoire de travail fait appel aux fonctions exécutives. Dans nos recherches, nous prendrons un angle un peu différent en évaluant les bilingues à l'aide de tâches de mémoire de travail. C'est pourquoi nous allons préalablement nous pencher sur ce domaine actuellement très important de la psychologie cognitive.

La mémoire de travail

La mémoire de travail est un système qui permet d'effectuer du traitement et du maintien temporaire d'informations. Il y a une tradition en psychologie qui assimile la fonction exécutive d'actualisation (*updating)* à la mémoire de travail. Nous utiliserons le terme mémoire de travail comme un système à part entière, tel qu'abordé par Baddeley et Hitch (1974). Plus précisément, il s'agit donc d'un « système à capacité limitée qui permet le stockage temporaire et la manipulation de l'information nécessaire aux tâches complexes comme la compréhension, l'apprentissage et le raisonnement » (Baddeley, 2000).

La mémoire de travail est au coeur de l'activité contrôlée de l'individu. En outre, il y a un lien entre la mémoire de travail et l'intelligence fluide (Kane, Hambrick, & Conway, 2005). En effet, ces auteurs reportent de hautes corrélations dans une dizaine d'études entre des mesures de mémoire de travail et des épreuves testant l'intelligence fluide, comme des opérations mathématiques, les matrices de Raven ou le test de Cattell. Plusieurs modèles proposent d'expliquer le fonctionnement de la mémoire de travail. Nous allons voir les principaux modèles.

Recherches et développement de modèles

Dans cette section, nous avons sélectionné les principaux modèles de mémoire de travail. Notre choix s'est principalement porté sur les modèles qui s'intéressent au focus attentionnel, celui-ci étant particulièrement lié aux fonctions exécutives, puisque ces dernières permettent à un individu de déployer son attention sur des contenus particuliers.

1. Le modèle à multi-composantes de Baddeley

Le terme mémoire de travail était déjà utilisé, notamment par Attkinson et Schiffrin (1968, cité dans Baddeley, 2012), pour définir le stockage à court terme. Pour la première version de leur modèle, Baddeley et Hitch (1974) voulaient proposer un système aussi simple que possible, mais qui pouvait s'appliquer à autant d'activités cognitives que possible. C'est un modèle à multi-composantes, par opposition à unitaire.

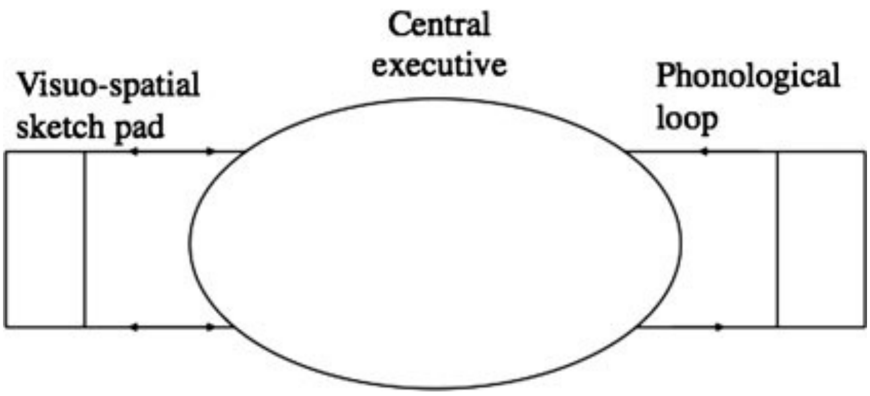


Figure 5: Modèle de mémoire de travail (Baddeley, 1986)

Le central exécutif (*central executive*) est en charge du contrôle attentionnel (Figure 5). Il s'occupe de coordonner les différents processus du modèle et de gérer les processus attentionnels et stratégiques. Le stockage temporaire est géré par un calepin visuo-spatial (*visuo-spatial sketch pad*) si la modalité est visuelle et/ou spatiale. Cette unité permet de stocker et de manipuler des informations visuelles, telles des formes, des couleurs, des emplacements. Le stockage est géré par une boucle phonologique (*phonological loop*) si la modalité est auditive. Cette unité permet de stocker à court terme et de manière limitée des contenus auditifs. Ainsi, elle permet de répéter en boucle ces contenus afin de les maintenir. Chacune de ces composantes possède des capacités limitées. Elles sont considérées comme des systèmes esclaves, gérés par le central exécutif.

La boucle phonologique et le calepin visuo-spatial ne prenant pas en charge toutes les modalités sensorielles, Baddeley a ajouté des années plus tard une quatrième composante au modèle, le buffer épisodique (*episodic buffer*) (Baddeley, 2000) (Figure 6). Ce dernier permet de mémoriser des contenus de diverses modalités. Il fait un lien entre diverses informations pouvant utiliser diverses modalités qui forment une unité. Cette unité peut être par exemple – afin d'illustrer ce propos – un événement ou un épisode vécu par un sujet. Le buffer épisodique, tout comme la boucle phonologique et le calepin visuo-spatial, possède des capacités limitées.

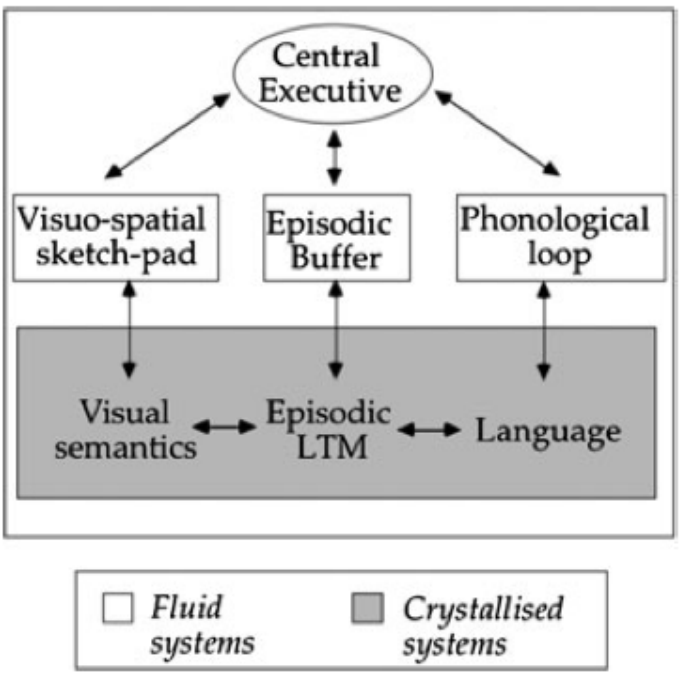


Figure 6: Modèle de mémoire de travail avec l'addition du buffer épisodique (Baddeley, 2000)

2. Le modèle d'Engle

Engle ne considère pas la mémoire de travail comme un système à multi-composantes mais comme un système unitaire. D'après le modèle d'Engle, la mémoire de travail est composée d'un central exécutif (Figure 7). Elle permet d'activer des traces contenues en mémoire à long terme, de les maintenir et d'inhiber les éléments non-nécessaires. Dans cette logique, la mémoire à court terme est composée des traces volontairement activées. Ces dernières sont sujettes à disparaître par le déclin ou l'interférence. Seule une infime partie est amenée à être spécialement activée par un processus effectué par le central exécutif, qui place les traces sélectionnées dans le focus attentionnel. Pour ce faire, il y a différentes stratégies et procédures qui permettent de maintenir cette activation. Par exemple, la répétition phonologique, abordée dans le modèle de Baddeley, est une stratégie possible. Ce modèle met en évidence l'importance prépondérante des mécanismes attentionnels qui permettent de maintenir l'activation de traces. Ils s'adaptent à la fois à la modalité sensorielle de la trace mnésique, mais aussi à la difficulté de la tâche et l'intensité nécessaire pour le maintien. Un autre apport important de ce modèle est la présence de mécanismes qui permettent d'inhiber les informations qui créent des interférences et contribueraient au départ de traces mémorielles du focus attentionnel. La mémoire à court terme et la mémoire de travail sont deux concepts différents, mais qui sont néanmoins particulièrement apparentés (Engle, Tuholski, Laughlin, & Conway, 1999). En effet, ces auteurs mentionnent une part de variance commune entre ces deux concepts, mettant en évidence certains mécanismes communs. Par exemple, lors d'une tâche verbale, le regroupement de mots par similitude verbale ou sémantique est une stratégie commune à ces deux types de mémoire. En revanche, une partie des procédures sera unique à chaque type de mémoire. Ainsi, les mécanismes de contrôle attentionnel sont spécifiques à la mémoire de travail.

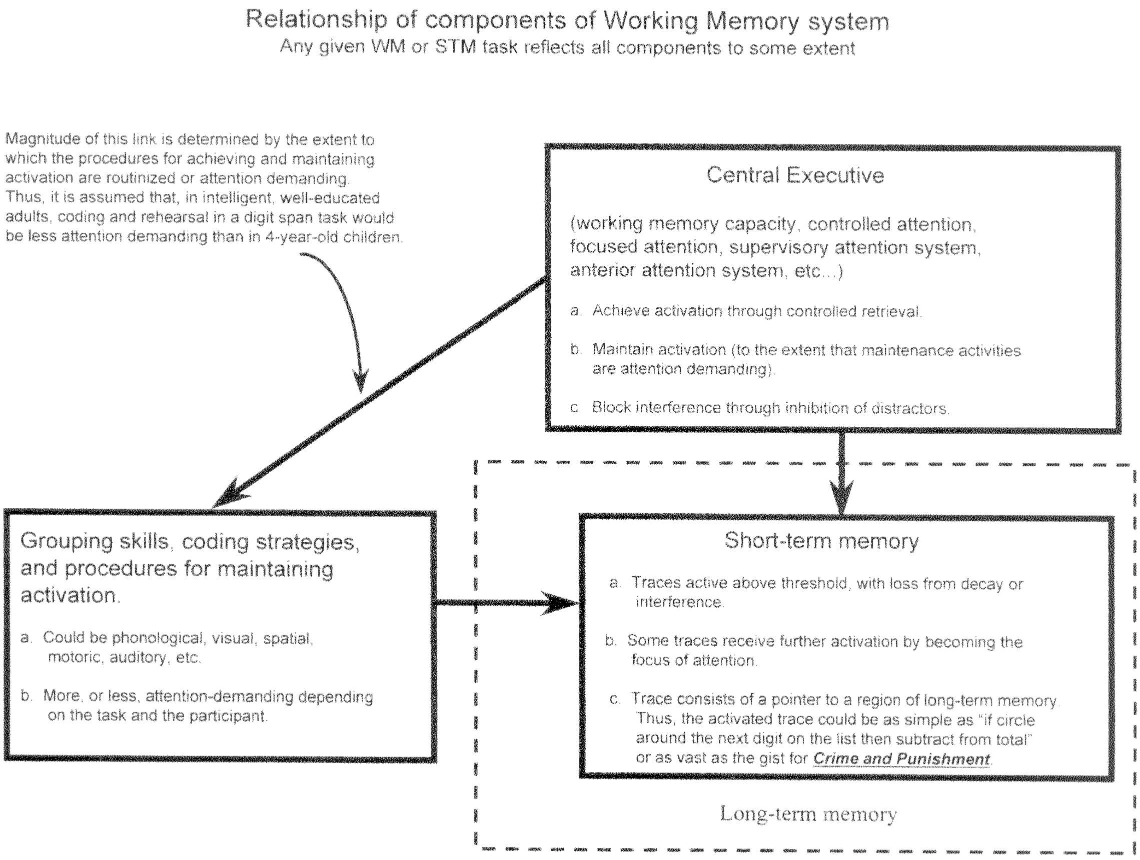


Figure 1. Relationship of the various components of working memory (WM) that are relevant to a measurement model (STM = short-term memory).

Figure 7: Modèle de mémoire de travail (Engle et al., 1999)

3. Le modèle de Cowan

Tout comme celui d'Engle, le modèle de Cowan propose que les traces présentes en mémoire de travail ne sont pas contenues dans des buffers, mais uniquement contenues dans le focus attentionnel à un moment donné (Cowan, 2005). Son modèle prend la forme d'un système emboîté, à la manière de poupées russes. A l'opposé du modèle à multi-composantes qui considère que la mémoire de travail est une structure indépendante de la mémoire à long terme, la mémoire de travail est dans ce modèle la partie active de la mémoire à long terme. Les traces contenues en mémoire à long terme peuvent alors posséder divers niveaux d'activation. De plus, à l'opposé du modèle d'Engle, celui de Cowan considère la mémoire à court terme comme un sous-ensemble de la mémoire de travail.

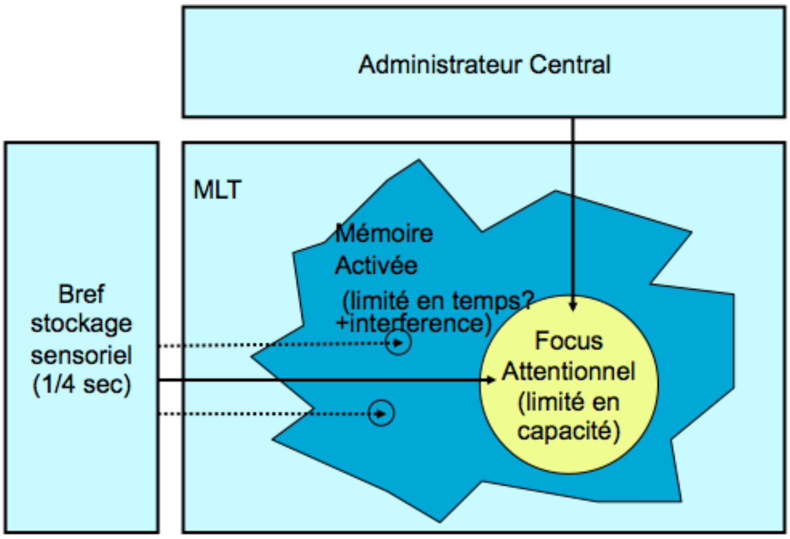


Figure 8: Modèle de mémoire de travail de Cowan (2005).

Le focus attentionnel est le cœur de ce modèle (Figure 8). Il est dirigé et contrôlé par l'administrateur central. Afin de placer un élément dans le focus attentionnel, il doit préalablement être acheminé en mémoire activée (qui correspond à la mémoire à court terme). Le focus attentionnel est limité de trois à cinq items chez un jeune adulte. Cette dernière permet un bref stockage de quelques centaines de millisecondes. Si l'élément n'est pas placé dans le focus attentionnel avant la fin de ce délai, il sort de la mémoire activée. En guise d'exemple, afin d'illustrer ce système emboîté, suivons un stimulus présenté à un individu qui sera pertinent pour une tâche qu'il souhaite effectuer (Cowan, 1988). Ce stimulus va entrer dans l'unité de stockage sensoriel pendant une très brève durée (l'élément gauche de la Figure 8). Pendant ce temps, des traces mnésiques de la mémoire à long terme sont activées. Il en résultera le codage du stimulus. A ce moment, ce processus n'est pas encore conscient pour l'individu. Si ce stimulus est pertinent pour l'individu, il entrera dans le focus attentionnel par l'action de l'administrateur central. A partir de là, l'individu pourra manipuler ce stimulus et activer des informations nécessaires contenues en mémoire à long terme. Dans ce cas de figure, le focus attentionnel a été déployé de manière volontaire par l'administrateur central. Il y a également la possibilité d'un déploiement involontaire de l'administrateur central provoqué par un stimulus perturbant comme un bruit. Dans ce cas, ce stimulus perturbant créerait une interférence. Comme le focus attentionnel est limité entre trois et cinq items, ce stimulus perturbateur prendrait la place d'un item pertinent pour l'individu et serait susceptible de diminuer la performance de l'individu dans la tâche qu'il est train d'effectuer.

4. Le modèle de partage temporel des ressources

Le modèle de partage temporel des ressources (*Time-Based Resource-Sharing model, i.e. TBRS)* se base sur quatre postulats (Camos & Barrouillet, 2014). Premièrement, le postulat de base de ce modèle est que les deux fonctions de la mémoire de travail – le traitement et le maintien – se partagent l'attention, une ressource très limitée. Deuxièmement, le traitement et le maintien s'effectuent l'un après l'autre, de manière séquentielle. Comme l'attention ne peut être portée que sur un seul contenu à la fois, un sujet doit alterner entre traitement et maintien. Troisièmement, le contenu qui est placé dans le focus de l'attention bénéficie d'activation. Néanmoins, lorsqu'il quitte ce focus, les traces mnésiques déclinent avec le temps. Afin de pallier à ce déclin, un contenu devra être réactivé par la suite afin d'être maintenu. Ce processus s'appelle le rafraîchissement attentionnel. Quatrièmement, le partage de l'attention se fait par un switching rapide et continuel entre traitement et maintien. Cela implique une nouvelle conception de la charge cognitive au sein d'une tâche de mémoire de travail. Il est communément accepté que la nature du traitement a une influence importante sur la charge cognitive (Barrouillet & Camos, 2010). En revanche, l'idée selon laquelle elle est prépondérante dans le maintien est novatrice. Le coût cognitif dans le TBRS est égal à la durée de la capture attentionnelle, divisée par le temps total alloué. Plus la tâche de traitement demande de temps par rapport au temps total disponible, plus le coût cognitif sera important. Si cette tâche a une longue durée de capture attentionnelle, le fort coût cognitif engendré prétéritera la performance de maintien.

Afin d'illustrer le fonctionnement de ce modèle, prenons une variante d'une tâche communément utilisée pour évaluer la mémoire de travail, la *complex span task*. On présente à un participant des séries de six consonnes qu'il doit mémoriser. Entre chaque présentation de consonnes, il doit juger de la parité de quatre chiffres présentés séquentiellement, en appuyant sur une touche (Figure 9). A la fin d'une série de six consonnes et conséquemment de 24 chiffres, il doit rappeler les lettres mémorisées dans leur ordre d'apparition.

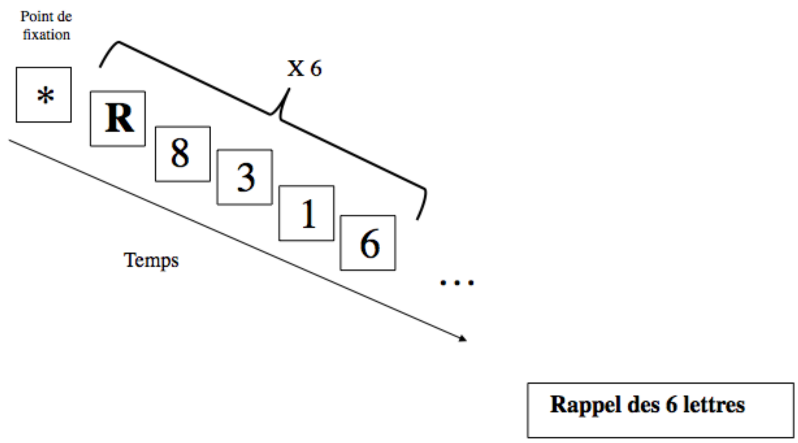
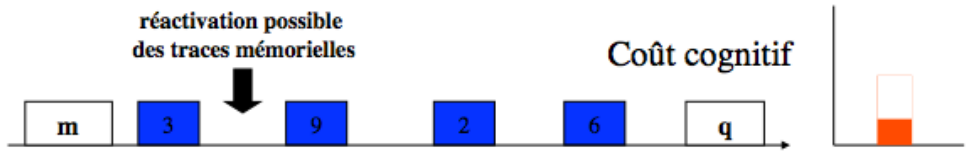


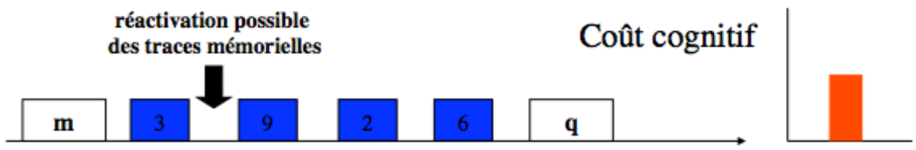
Figure 9: Exemple d'un essai de tâche d'empan complexe. Les lettres en gras représentent la tâche principale et les chiffres la tâche concurrente.

La vitesse de présentation des lettres est constante, tandis que la présentation des chiffres présente trois modalités : une vitesse lente, une vitesse moyenne et une vitesse rapide. Le participant va donc lire et mémoriser la première lettre. Il effectue ensuite la tâche de parité, à quatre reprises. Entre chacune des épreuves de parité, il aura l'occasion de replacer le contenu à mémoriser dans le focus attentionnel, afin de réactiver en mémoire la série de lettres (Figure 10).

Vitesse lente



Vitesse moyenne



Vitesse rapide

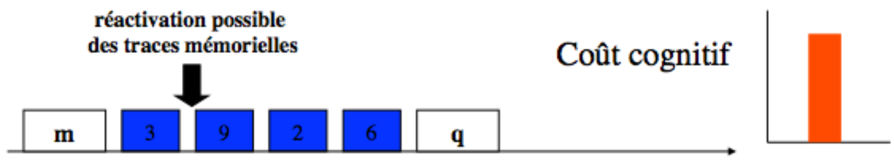


Figure 10: Réactivation possible des traces mémorielles lors de la tâche d'empan complexe.

Plus le participant a de temps entre chaque tâche de parité, plus son rappel sera bon. En effet, il bénéficiera de plus de temps pour réactiver en mémoire la série de lettres présentée. La difficulté de la tâche concurrente n'a pas d'importance en soi, c'est la durée qu'occupe cette tâche qui est prépondérante. Ce modèle montre aussi qu'on ne peut pas séparer dans la mémoire de travail l'aspect mémoire de l'aspect travail (Barrouillet & Camos, 2010). Les deux sont liés et l'administrateur central présenté dans les modèles précédents ne s'occupe pas que du traitement, mais également du maintien en mémoire de travail. Lors d'activités de maintien, l'administrateur central va garder des items actifs ou rafraîchir des items en les faisant entrer à nouveau dans le focus attentionnel.

La capacité de mémoire de travail chez les bilingues

Comme nous l'avons vu, la recherche en psychologie cognitive s'intéressant à un potentiel avantage bilingue au niveau cognitif a été traitée par le biais de l'évaluation de fonctions exécutives. Certaines recherches se penchent sur l'inhibition (e.g., Bialystok et al., 2004), d'autres sur le monitoring (e.g., Costa et al., 2008). Pour nos recherches, nous allons opter pour une approche plus globale en évaluant la capacité de mémoire de travail chez les bilingues. En effet, les tâches de mémoire de travail requièrent l'utilisation de fonctions exécutives (e.g., Baddeley, Della Sala, Robbins, & Baddeley, 1996; Barrouillet & Camos, 2010; Friedman & Miyake, 2004). Comme le mentionnaient Paap et Greenberg (2013), les différentes tâches existantes pour mesurer une fonction exécutive comme l'inhibition ne corrèlent pas entre elles. C'est pourquoi ils ont testé leurs participants à l'aide d'une batterie de tests pour chaque fonction exécutive. L'idée de ce présent travail est d'adopter un angle de vue différent des recherches publiées sur le sujet et d'utiliser des tâches d'empan complexe afin d'évaluer les bilingues. Les tâches d'empan complexe permettent de prendre en compte la vision dynamique de la mémoire de travail et de tous les processus qui lui sont associés. En effet, comme le montrent Barrouillet et Camos (2010), la mémoire de travail fait appel à des fonctions exécutives non seulement pour le traitement, mais également pour le maintien. Le choix de ce type de tâches pour nos recherches nous paraît donc idéal afin d'évaluer de la manière la plus complète possible le contrôle exécutif de bilingues. Comme le rappelaient Redick et al. (2012) à l'aide d'évidences psychométriques, la tâche d'empan complexe est la mesure étalon de la mémoire de travail. Ils mentionnent que les tâches d'empan complexe prédisent les performances de bon nombre de tâches mesurant le contrôle attentionnel, comme la tâche de Stroop, la tâche anti-saccade ou la tâche de flanker. De plus, elles ont une excellente fiabilité, comme en témoignent les retests effectués par ces auteurs. En outre, ils précisent que la mémoire de travail est le meilleur prédicteur des performances cognitives. A notre connaissance, aucune recherche sur le bilinguisme utilisant la tâche présentée dans la Figure 9 n'a encore été entreprise. Certes, Bonifacci, Giombini, Bellocchi et Contento (2010) ont utilisé des tâches de mémoire de travail, mais des tâches plus spécifiques et impliquant une charge cognitive moins importante qu'une tâche d'empan complexe. Ainsi, la tâche principale de leur étude était une tâche d'anticipation. Les participants observaient et apprenaient l'ordre d'apparition de séries de quatre rectangles de couleur. Ensuite, durant la tâche d'anticipation, le participant devait appuyer sur une touche pour indiquer quel serait le rectangle qui allait apparaître ensuite dans la séquence.

La partie centrale de ce travail est composée de quatre chapitres. Dans le premier chapitre, nous avons comparé des monolingues à des bilingues sur une tâche d'empan complexe. Nous avons voulu savoir si les bilingues obtenaient de meilleures performances que les monolingues. Nous avons contrôlé le statut socio-économique des participants en le mesurant à l'aide d'un test. Les participants sélectionnés sont d'une part des étudiants de l'Université de Fribourg et d'autre part des apprentis d'un âge similaire se formant dans des métiers manuels. Quatre groupes expérimentaux ont ainsi pris part à l'étude : des apprentis monolingues et bilingues, ainsi que des étudiants universitaires monolingues et bilingues. Le deuxième chapitre s'intéresse au changement de langue dans une tâche d'empan complexe chez les bilingues. Nous avons voulu étudier de quelle manière le changement de langue augmentait le coût cognitif dans une tâche de mémoire de travail. Les bilingues effectuaient cette tâche dans quatre conditions différentes. Ils devaient effectuer des essais entièrement en L1 ou en L2, à la fois pour le maintien et le traitement. Ils complétaient également des conditions dites « mixtes ». Dans celles-ci, ils effectuaient le maintien en L1, le traitement en L2 et vice-versa. Nous avons mené plusieurs expériences de ce type, dont nous avons fait varier le type de stimuli et les paramètres temporels. Dans le troisième chapitre, nous avons ensuite testé des bilingues précoces avec une tâche qui requiert également un changement de langue. Mais nous avons voulu tester cela d'une manière plus proche du changement s'opérant quotidiennement dans un environnement bilingue. Pour ce faire, nous avons utilisé une tâche de Reading Span. Il s'agissait de lire des séries de phrases et de se souvenir du dernier mot de celles-ci. Cette tâche était effectuée en trois langues. La L1 des participants était l'allemand. La L2, le français, devait avoir été acquise avant l'âge de 10 ans. La troisième langue était l'anglais, une langue à laquelle les étudiants étaient régulièrement confrontés. Les participants devaient avoir appris cette langue après l'âge de 10 ans et ne pas la maîtriser parfaitement. En utilisant une troisième langue apprise tardivement, nous avons comparé les performances des participants avec les deux langues apprises précocement. La tâche de Reading Span comportait alors 5 conditions. Dans les conditions simples, les phrases à lire étaient soit entièrement en L1 ou en L2. Il existait également deux types de conditions mixtes : soit une phrase sur deux était en L1 et la deuxième était en L2, soit une phrase sur deux était en L1 et la deuxième était en L3. Le type de participants que nous avons testé dans le cadre de ce travail de thèse est principalement composé d'étudiants bilingues de l'Université de Fribourg. Dans le quatrième et dernier chapitre, nous avons donc soumis à des bilingues français-allemand/allemand-français de l'université le questionnaire LEAP-Q (*Language Experience and Proficiency Questionnaire*), (Marian et al., 2007). Cet outil standardisé permet d'obtenir un important nombre d'informations sur l'acquisition des langues du participant et la nature de sa pratique actuelle de ces langues. Cela nous a permis de dresser deux profils bilingues.

La partie expérimentale de ce travail propose donc d'apporter de nouvelles contributions à l'étude des liens entre le bilinguisme et la cognition. D'une part, concernant un potentiel avantage au niveau du contrôle exécutif chez les bilingues comparés aux monolingues. En outre, nous verrons si le statut socio-économique joue un rôle important dans cette relation. D'autre part, au sujet du changement de langue à l'intérieur même d'un essai d'une tâche de mémoire de travail, nous verrons si le coût cognitif engendré par ce changement de langue chez des bilingues précoces est important. Un parfait bilingue évoluant dans un environnement dans lequel il doit fréquemment changer de langue fait-il face à des coûts cognitifs significativement plus importants qu'un monolingue ? Les résultats des expériences menées dans cette partie nous permettrons de répondre à cette question. Nous mettrons en évidence un certain nombre d'implications que nous développerons dans la conclusion de ce travail.

CHAPTER ONE : A bilingual advantage in working memory capacity only for young adults with a lower socioeconomic status

A bilingual advantage in working memory capacity only for young adults with a lower socioeconomic status

A bilingual person in its everyday life has to select the appropriate language to use in a specific context. This individual has to switch between two languages, highlighting one and suppressing the other. In recent years, research investigated the mechanism involved when switching between languages. Especially, the question was to determine whether this mechanism was common to other non-verbal tasks. If it is the case, bilinguals could benefit from some cognitive advantages - the so-called bilingual advantage - specifically in executive control by experiencing frequent language switching. The aim of our study was to assess working memory difference in bilinguals and monolinguals young adults. In three experiments, we measured socioeconomic status (SES). If bilinguals had better executive control than monolinguals, they should outperform monolinguals in working memory. We compared monolingual, early and late bilingual students on working memory capacity. The three groups had a similar high SES and showed similar high scores on working memory. In a similar experiment, we then contrasted monolinguals and early bilinguals apprenticeship students with a lower SES. In this population, bilinguals had better recall performance than monolinguals. These results suggest that SES has an influence on the so-called bilingual advantage, bilingual participants with a low SES benefiting from an advantage on working memory.

Keywords: bilingualism, language switching, executive control, executive functions, working memory, socioeconomic status.

Introduction

A bilingual person interacting in its everyday environment has to select the appropriate language to use at the right time. Hence, this person has to switch between two languages, highlighting one and suppressing the other. In recent years, research has widely investigated the mechanisms involved when switching languages. A recurring view in recent research is that this frequent language switching improves executive control in non-verbal tasks (e.g., Bialystok, Craik, Green, & Gollan, 2009; Carlson & Meltzoff, 2008; Martin-Rhee & Bialystok, 2008; Morales, Gómez-Ariza, & Bajo, 2013). Indeed, fMRI studies confirm that the frontal executive control systems are the same used when switching languages as the ones used in non-verbal tasks necessitating executive control (Luk et al., 2012). The aim of this study was to compare monolingual and bilingual young adults on working memory capacity, which requires executive control (Miyake & Shah, 1999). Among three experiments, we controlled language proficiency and socioeconomic status.

Executive control

Executive control allows to exert one's attention on a task (Miyake & Friedman, 2012). According to Miyake et al. (2000), executive control is not a single entity but is composed of several executive functions. They are “general purpose control mechanisms that modulate the operation of various cognitive subprocesses and thereby regulate the dynamics of human cognition” (Miyake et al., 2000, p. 50) . Inhibition, updating and shifting are the main ones. Inhibition allows suppressing dominant and automatic responses. Updating selects pertinent information for a task and replaces old irrelevant information. Shifting allows switching between several tasks. Executive functions are frequently associated to the prefrontal cortex of the brain (see Introduction for further information related to executive functions).

The so-called bilingual advantage

The first researches in cognitive psychology investigating possible bilingual advantages on non-verbal tasks stemmed from the inhibition model (Green, 1998). In this model, inhibition, one of the main executive functions, would allow bilinguals to switch between their two languages. The inhibition model is based on the assumption that the languages of a bilingual person are always both activated. The language a bilingual individual does not want to use to express himself is then suppressed by inhibition control. Green (1998) proposes that this mechanism is the same used for controlling attention.

Following the inhibition model (Green, 1998), Bialystok, Craik, Klein and Viswanathan (2004) propose that bilinguals should outperform monolinguals on non-verbal tasks, because inhibition would be more developed in bilinguals. To test this hypothesis, Bialystok and colleagues frequently used the Simon task which evaluates inhibitory capacity (i.e, Bialystok, 2006; Bialystok et al., 2005, 2004; Bialystok, Craik, & Luk, 2008; Bialystok, Martin, & Viswanathan, 2005; Martin-Rhee & Bialystok, 2008). A typical computerized Simon task consists of showing arrows on the left or the right of a screen. Arrows can point left or right. If an arrow points left, participants have to press a key on the left of the keyboard. In the opposite case, participants have to press another key on the right of the keyboard. By varying the side of the screen an arrow is presented and the side it is pointing, two types of trials, called congruent and incongruent, are generated. On congruent trials, an arrow points the same side it is presented on screen. However, on incongruent trials there’s a conflict, an arrow points one side and is presented on the other side of the screen. One has to inhibit the information about the location of the arrow on the screen. All participants are slower on the incongruent trials. This is what is called the Simon effect. Bialystok et al. (2004) administered a Simon task to young and older adults, monolinguals and bilinguals. Simon effect was larger among monolinguals than bilinguals, because bilinguals gave faster answers on incongruent

trials. The authors concluded that bilinguals had a more efficient inhibition control, which allowed them to suppress more easily the information about the location of the arrow, and made them produce a faster answer. However, bilinguals were also unexpectedly faster on congruent trials. It was the case for the three experiments of this study. To explain this unexpected result, Bialystok and colleagues proposed that in this type of task, participants have to keep the rule in mind during the entire experiment (Bialystok et al., 2009). Participants have to confront each trial to the rule and decide if they need to inhibit some info from this trial. In this case, they would be more efficient than monolinguals in inhibition and monitoring. To prove this assumption, Bialystok, Craik and Ryan (2006) created experiments containing only congruent or incongruent trials. This time no significant difference between monolinguals and bilinguals was found. For this series of experiments, no monitoring was required as only one type of trials (congruent or incongruent) was presented during the experiment. Costa, Hernández, Costa-Faidella and Sebastián-Gallés (2009) argue that a better monitoring in bilinguals is the prime reason they have an advantage over monolinguals on non-verbal tasks. These authors assessed monolingual and bilingual young adults a flanker task with low and high monitoring conditions. This computerized task consists of indicating on which side points a center arrow that is flanked by other arrows pointing either on the same direction (congruent trial) vs. the opposite direction (incongruent trial) (
Figure 11). Low monitoring series were composed of 92% congruent trials and 8% incongruent trials (Experiment 1). Hence, most of the time, participants had to give the same answer. High monitoring series were composed of 50% congruent trials and 50% incongruent trials (Experiment 2). In the low monitoring trials, both monolinguals and bilinguals were faster to respond and made fewer errors in congruent than incongruent trials. There was no significant difference between monolinguals and bilinguals on incongruent trials. In high monitoring trials, both groups were faster and made fewer errors in congruent trials. Importantly, bilinguals were faster than monolinguals in congruent and incongruent trials. Thus, bilinguals were faster than monolinguals on high monitoring conditions, showing their superiority in monitoring. However, the authors argued that it is not due to a better capacity of conflict resolution, since the low monitoring conditions also comprised of some conflicts to resolve (i.e. incongruent trials).

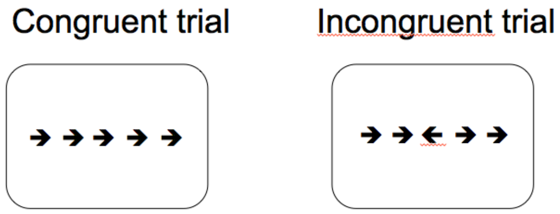


Figure 11: Congruent and incongruent trials in the Flanker task.

Other studies showing a bilingual advantage include a study by Prior and Macwhinney (2010), showing smaller switching costs on a task-switching paradigm on young adults, a study on kindergarten Spanish-English bilinguals showing a better inhibition in bilinguals (Carlson & Meltzoff, 2008), or a higher executive control and episodic memory on old bilinguals (Schroeder & Marian, 2012). These studies tested early bilinguals.

In terms of late bilingualism, Tao, Marzecová, Taft, Asanowicz and Wodniecka (2011) compared monolingual, early and late bilingual young adults on alerting, orienting and executive control. Early bilinguals learned their L2 until the age of six and late bilinguals learned their L2 at twelve years old or later. The authors mentioned that, to their knowledge, no study on the bilingual advantage had been conducted on late bilingual young adults so far. A flanker task was used to compare participants on executive control. Early bilinguals showed a better performance than monolinguals on incongruent and congruent trials. However, late bilinguals outperformed monolinguals only on incongruent trials. The authors concluded that both groups were better than monolinguals on conflict resolution (to be used in incongruent trials), but only early bilinguals showed an advantage on monitoring.

Evidence in neuroimaging studies could have make the authors predict that late bilinguals, whose L2 was weaker, would perform even better than early bilinguals. Indeed, some neuroimaging studies showed that for a weaker L2, brain areas in charge of general cognitive control were more activated (Abutalebi, 2008; Abutalebi & Green, 2007; Golestani et al., 2006; Hernandez, Hofmann, & Kotz, 2007; Sakai, Miura, Narafu, & Muraishi, 2004; Wartenburger et al., 2003). Thus, this accentuated activation might have benefited non-verbal cognitive activities requiring the use of the same brain areas.

Bilingualism and socioeconomic status

An important issue in studies about the bilingual advantage is that they often failed to be replicated (Hilchey & Klein, 2011). Morton and Harper (2007) point out that socioeconomic status (SES) in studies with children was not correctly controlled. In their study, they selected only English-French bilingual children from six to seven years old with a SES comparable to an English monolingual group. Children completed a Simon task, equivalent to Bialystok et al. (exp. 1, 2004). Bilingual and monolingual children obtained equal performances in the Simon task. Then, the authors compared SES with the Simon task result. They found that a higher SES corresponded to a better performance on the Simon task. Indeed, bilingual participants from Bialystok and colleagues were mostly immigrants with various languages and SES. As Morton and Harper stated, their findings were notable, because their study was the first to control as accurately as possible ethnicity and SES with children. Bialystok (2009) explained the difference by highlighting that Morton and Harper participants were one year and a half older than the five years old from the study made in her laboratory. She mentioned that it was an important difference in developmental time. More recently, Engel de Abreu, Cruz-Santos, Tourinho, Martin and Bialystok (2012) found a bilingual advantage on executive control with children from three to four years old from the same ethnicity with a low SES. Blom, Küntay, Messer, Verhagen and Leseman (2014) compared low SES bilinguals with high SES monolinguals from five and six years old on working memory capacity. There is a link between executive control and working memory that we will explain further in a forthcoming section. They found no bilingual advantage. Longitudinal studies on general population showed that SES correlated positively with working memory capacity (Lee et al., 2003; Noble, McCandliss, & Farah, 2007) and executive control (Farah et al., 2006; Mezzacappa, 2004; Noble, Norman, & Farah, 2005), and that working memory performance was stable all along adolescence (Hackman et al., 2014). Thus, it would be interesting to compare monolingual and bilingual young adults with a low or a high SES on working memory to get a complete picture on the joint effects of language and socioeconomic status.

Failures to show a bilingual advantage

Several recent studies failed to show a bilingual advantage on executive functions (Gathercole et al., 2014), inhibition (Kirk, Fiala, Scott-Brown, & Kempe, 2014; Paap & Liu, 2014), inhibition, switching and monitoring (Paap & Greenberg, 2013), and working memory (Ratiu & Azuma, 2015).

Nonetheless, another important issue from studies showing a bilingual advantage, i.e. the publication bias, is addressed by de Bruin, Treccani and Della Sala (2015). They investigated more than a hundred abstracts from conferences from 1999 to 2012 on bilingualism and executive control. Data that showed a bilingual advantage was published 68% of the time. However, data that showed no bilingual advantage or even a bilingual disadvantage was published only 29% of the time. Studies finding no bilingual advantage shared similar designs, tasks and number of participants as studies showing a bilingual advantage. This publication bias could be generated at several stages of the publication process, starting with the authors, then the reviewers and the editors.

Executive control and working memory

Executive control shares a relation with working memory. The later is described as a system that allows to actively maintain and treat information during limited periods of time. The first model of working memory (Baddeley, 1986; Baddeley & Hitch, 1974) is composed of a central executive, a phonological loop and a visual sketchpad. The central executive is in charge of attention control, allowing but not limited to maintain task goals, to handle strategic and attention processes. Temporary storage is handled by the phonological loop for verbal information and the visual sketchpad for visual information. Thus, in this model, the central executive is handling executive control tasks (Baddeley, Della Sala, Robbins, & Baddeley, 1996). Other influent models of working memory also include a central executive or an attentional control mechanism analogous to this component (Barrouillet & Camos, 2010; Cowan, 1988; Engle, Tuholski, Laughlin, & Conway, 1999; Miyake & Shah, 1999). Consequently, working memory capacity is importantly linked with executive control. McCabe, Roediger, McDaniel, Balota and Hambrick (2010) investigated the relationship between executive functioning and working memory in an adult life span sample. They found a very strong correlation (r= .97) between these two constructs. Therefore, comparing monolinguals and bilinguals on working memory capacity would be pertinent and different from studies investigating one executive function at a time.

The present study

The aim of this study was to measure working memory capacity on monolingual and bilingual young adults, controlling and varying SES. In the first experiment, we compared monolinguals and early bilinguals with a high SES. In the second experiment, we measured working memory capacity on late bilinguals with a high SES and compared them with participants from the first experiment. In a final experiment, we measured working memory capacity on monolinguals and bilinguals with a low SES. Bilingual participants from the first experiment spoke German and also Swiss-German dialect. Considering it as a first language utterly different than German is a matter of debate, as Swiss-German shares many roots with German. Also, there is no grammar and written form of Swiss-German. We propose to consider German as a prolongation of Swiss-German dialect in their learning during their childhood. Anyhow, about multilingualism compared to bilingualism, Bialystok, Craik, Green and Gollan (2009) conclude in their review there is so far no clear evidence that multilingualism has greater benefits than bilingualism. Furthermore, Bialystok, Craik and Luk (2012) make a distinction between individuals who learned a new language by necessity compared to individuals who learned a new language by interest. The later involves motivational processes that may influence positively cognitive performance. In our case, Swiss-German bilinguals learned German at school by necessity.

Our predictions were the following. For the first and second experiments, we predicted that monolinguals, early and late bilinguals would be similar in working memory capacity. Both groups were college students with a high SES. As SES is positively correlated with working memory capacity (Lee et al., 2003), the strong effect of SES on the working memory performance should overcome the possible effect of bilingualism. If the effect of SES was not as strong as we predicted, we should find a bilingual advantage for at least the early bilinguals. In this case, it would be less likely – but still possible - to find a late bilingual advantage, according to Tao et al (2011) results. Again, late bilinguals showed an advantage in inhibition, but not in monitoring, while early bilinguals showed an advantage in both executive functions, inhibition and monitoring. Miyake et al. (2000) consider that updating and monitoring working memory representations can be classified as “updating”, one of three more important executive functions detailed in their seminal paper. In this case, late bilinguals would be less likely to show an advantage in working memory, since they showed no advantage in monitoring in the study from Tao et al. (2011). Finally, for the third experiment comprising of low SES young adults, we predicted that early bilinguals would show a better working memory capacity than monolinguals. As research showed that a lower SES was corresponding to a lower working memory capacity (Lee et al., 2003; Noble et al., 2007) and executive control (Farah et al., 2006; Mezzacappa, 2004; Noble et al., 2005) in the general population, a bilingual advantage would likely enhance working memory capacity for bilinguals from a low SES.

Experiment 1

In the first Experiment, we assessed working memory capacity in monolingual and bilingual young adults. Individuals were college students from the Université de Fribourg. Participants completed a computer-paced complex span task. We measured language proficiency, languages spoken and SES. Our participants were studying in Fribourg, a bilingual city consisting of a French-speaking and a German-speaking population, the latter being frequently bilingual, speaking both languages fluently. This is an excellent opportunity to have participants fitting perfectly our experimental needs. For example, Morton and Harper (2007) pointed out that participants from Bialystok et al. (2004) originated from very different cultures and countries, likely influencing results. Individuals who participated in our study were from similar culture and environment.

To ensure an equivalent SES between our two experimental groups, French monolinguals and German-French bilinguals, participants filled a Swiss socioeconomic status test. If bilinguals have overall better executive functions, our hypothesis was that they should outperform monolinguals in the complex span task. As a complex span task involve a high cognitive demand - thus a large demand in executive control - a significantly higher recall performance from bilinguals would show a bilingual advantage in executive control.

Method

Participants

Fifty-nine undergraduate psychology students (14 males; mean age = 21.8 years; *SD* = 2.0 years) were recruited at the Université de Fribourg and received experiment credits for their participation. Monolinguals (N = 35; 7 males; 21.8 years, *SD* = 1.8 years) spoke fluently only French before the age of ten and bilinguals (N = 24; 7 males; 22.7 years; *SD* = 2.3 years) spoke French and German fluently before the age of ten.

It should be noted that most bilinguals were native French dominant speakers who learned German before the age of ten (N = 21). The remaining bilinguals were native German dominant speakers who learned French before the age of ten (N = 3). Most of them were then bread in a bilingual environment since early childhood.

Material and procedure

Participants were tested individually. First, they filled a questionnaire including a socioeconomic status test and a language test. Then, a computer-paced working memory span task was administered.

Socioeconomic status test (IPSE)

Adapted to the Swiss social structure, the “Indice de Position Socio-Economique“ (IPSE) is composed of an educational scale and an occupational scale (Genoud, 2005) (Appendix A). It is based on the Hollingshead Index of Social Position (Hollingshead, 1971). Education is divided in seven levels from “University and the like” (scored 1) to “less than obligatory school” (7). Occupations are distributed in seven levels from “Higher executives of large concerns, major professionals and the like” (1) to “Unskilled employees” (7). As participants were students, they were asked the occupation that scored the highest in the scale between their parents. Participants had to tick a box for each scale. The final score is computed as the ISP with the sum of the education score multiplied by four and the occupation score multiplied by seven, a weighting obtained after a multiple correlation and regression analysis (Hollingshead, 1971).

Language proficiency test

A C-test of each language was administered to each participant (Grotjahn, 1995, 2002). This test consists of completing blanks in a partially truncated text. This test is not a standardized test, but rather a method to test proficiency (Grotjahn, 2002). Very convenient because it allows testing proficiency in a short time, this method is well correlated with longer tests like TOEFL (Hastings, 2002). To create our C-tests, we chose newspaper articles, one for each language (Appendix B). The French article was from *La Liberté*, a Swiss daily newspaper, and the German article was from the *Weltexpress*, an online German daily newspaper. Both were of similar size and on the same topic, i.e. demonstrations in France against change of retirement age. The length of each article was around 100 words. The first and last sentence of each text was left in its entirety. Every second word of the remaining words was half-truncated. They were 34 blanks to fill and a maximum of 10 minutes was allowed to complete one text. This duration was chosen according to the time allowed in function of the number of items found in C-test literature (Grotjahn, 1995, 2002). Monolinguals only completed the French test and bilinguals filled both. Scores were the percentage of correct answers. Spelling mistakes counted as wrong answers.

Working memory span task

Participants completed a computer-paced complex span task programmed in E-Prime 2.0 (Schneider, Eschman, & Zuccoloto, 2007). They were asked to memorize series of 6 consonants in the order of presentation. All consonants were used except "w", because it is trisyllabic in French. Between the presentation of each consonant during 1000 ms, they had to judge the parity of 4 digits (from 1 to 9) displayed in Arabic form. Digits were presented at 3 different paces: 1600 ms (slow), 1200 ms (medium) or 800 ms (fast). An instruction screen explained that the parity task had to be done as fast as possible without sacrificing accuracy, because this task was as important as memorizing the letters. As working memory consists of active treatment and storage (e.g., Baddeley, 1986; Baddeley & Hitch, 1974), achievement in both tasks are equally emphasized. After a fixation point (an asterisk) presented on the screen for 1000 ms, participants had to read the first of the 6 consonants presented in random order, which was followed by a set of 4 digits also presented in random order, then appeared the second consonant and so on (Figure 12). Every item was presented on the center of the screen, in black on a white background. Digits were presented at the same pace within a trial. There were a total of 15 trials, i.e., 5 trials by pace. The pace order was also random. They had to press one of two keys to judge the parity, left for odd and right for even. When a trial was over, participants had to fill paper form with the consonants they memorized in order of presentation. Then, they reported it on the computer, letter by letter. Writing all the memorized letters on paper right after the trial allowed measuring their performance as precisely as possible, without interference from filling the letters on the computer. When this part was completed, a new trial was administered.

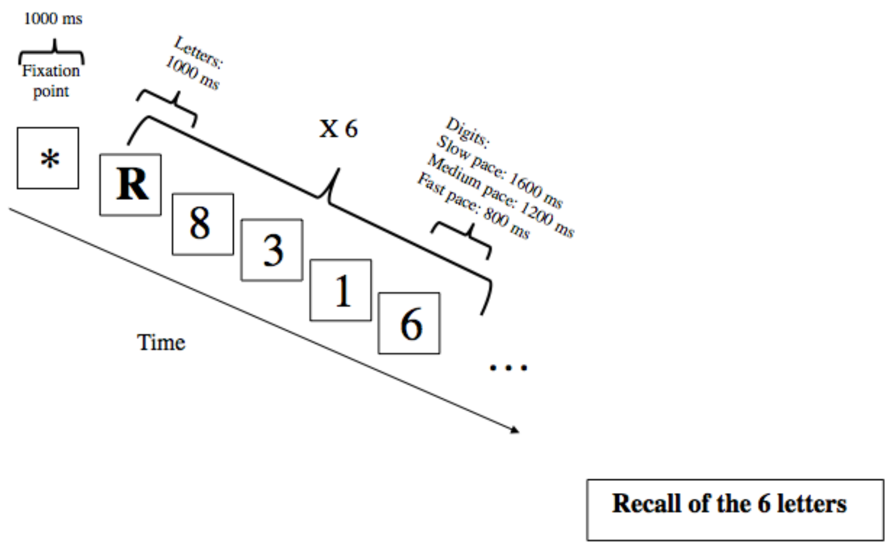


Figure 12: A trial from the working memory task.

Before the experimental trials, a training of three series was administered. During the training, if the parity was judged wrong, or if the participant did not answer before the end of presentation of the digit, a beep sound was played. Participants had to answer correctly at least 75% of the parity task, otherwise they were performed the training trials again. The aim of setting a minimal percentage of correct responses was to make sure that participants invested as much for the parity task as for the maintenance of memory items.

Results

Beforehand, we verified that our two groups were similar in different characteristics. Concerning age, monolinguals (21.8; *SD* = 1.7) and bilinguals (22.7; *SD = 2.3)* were not significantly different, $t(53) = 1.63$, $p > .10$. More importantly, as we wanted to compare groups with similar socioeconomic status (SES), monolinguals did not significantly differ in their SES (25.3; *SD* = 10.7) compared to bilinguals (26.4; *SD* = 8.3), $t < 1$. Next, we compared language proficiency level between groups, though the high score obtained by the bilinguals showed their proficiency in French. Monolinguals were significantly more proficient in the French C-test (94%; *SD* = 5%) than bilinguals (89%; *SD* = 8%), $t(56) = 3.07$, $p = .003$. Moreover, bilinguals were more proficient in French (89%; *SD* = 8%) than in German (81%; *SD* = 10%), $t(22) = 2.55$, $p = .02$, though both scores were very good, showing that they were proficient in both languages. Thus, monolinguals and bilinguals were similar in the non-linguistic measures conducted and bilinguals were very proficient in their two languages.

Concerning the working memory span task, we first checked that participants were paying enough attention to the concurrent task. All participants had at least 75% of correct responses in the parity task (86%; *SD*= 5). We performed a 2 (monolinguals vs. bilinguals) x 3 (paces) analyze of variance (ANOVA) on the percentage of correct parity judgment in a complete within-subject design. There was a pace effect on the percentage of correct responses, the faster the pace, the lower the percentage of correct responses, with 90% (*SD*= 5) for the slow, 88% (*SD*= 5) for the medium and 79% (*SD*= 9) for the fast pace, $F(2, 114) = 105.77$, $p < .001$ (Tableau 5). However, monolinguals (85%; *SD*= 5) and bilinguals (87%; *SD*= 6) did not differ on accuracy for the parity task, $F(1, 57) = 1.72$, $p > .20$, $p_{BIC}(H_0|D) = 0.76$. We used the Bayesian information criterion (BIC) to measure the degree of likelihood of the null hypothesis. The $p_{BIC}(H_0|D)$ calculates the probability the null hypothesis is true and its strength, compared to the alternative hypothesis (Wagenmakers, 2007). The classical *p*, testing null-hypothesis significance is not calculating strength. Thus, using the BIC in our case gives us this important additional information. From .75, the probability that the null hypothesis is conceived as a positive evidence and from .95, it is a strong evidence (Masson, 2011). Finally, there was no significant interaction between pace and group, $F<1$, $p_{BIC}(H_0|D) = 0.97$. We also compared response times on parity judgments with a similar ANOVA. The same pattern of findings emerged in response times as in accuracy. A faster pace induced lower reaction times, 640 ms (*SD*= 72) for the slow pace, 595 ms (*SD*= 55) for the medium and 521 ms (*SD*= 29) for the fast, $F(2, 114) = 221.99$, $p < .001$ (Tableau 5). Monolinguals and bilinguals did not differ in response times, $F < 1$, $p_{BIC}(H_0|D) = 0.83$, and no significant interaction between pace and group was found, $F < 1$, $p_{BIC}(H_0|D) = 0.98$.

Tableau 5: Percentage of correct responses (in bold) (and SD) and reaction times (ms) (and SD) for the parity judgment task in monolinguals, early and late bilinguals (Experiment 1 and 2), as a function of pace.

Pace	Slow	Medium	Fast
Monolinguals	**89.6 (3.7)**	**87.1 (3.9)**	**77.8 (8.6)**
	631 (70)	592 (58)	515 (32)
Early bilinguals	**90.4 (7)**	**89.2 (5.7)**	**80.6 (8.3)**
	649 (74)	598 (52)	527 (24)
Late bilinguals	**96.3 (2.2)**	**91.8 (5.6)**	**80.5 (8.9)**
	631 (82)	601 (64)	523 (39)

As monolinguals and bilinguals were similar on the parity task, we analyzed recall performance. We performed a 2 (monolinguals vs. bilinguals) x 3 (paces) ANOVA on the percentage of correct recall in a complete within-subject design. Whereas a typical pace effect was observed with reduced recall percentage when the pace increased, 86% (*SD*= 11) for the slow pace, 83% (*SD*= 13) for the medium and 66% (*SD*= 23) for the fast, $F(2, 114) = 37.35$, $p < .001$ (Figure 13), monolinguals (78%; *SD*= 14) and bilinguals (78%; *SD*= 12) had similar recall performance, $F < 1$, $p_{BIC}(H_0|D) = .88$. Furthermore, the pace x group interaction was not significant, $F < 1$, $p_{BIC}(H_0|D) = .98$.

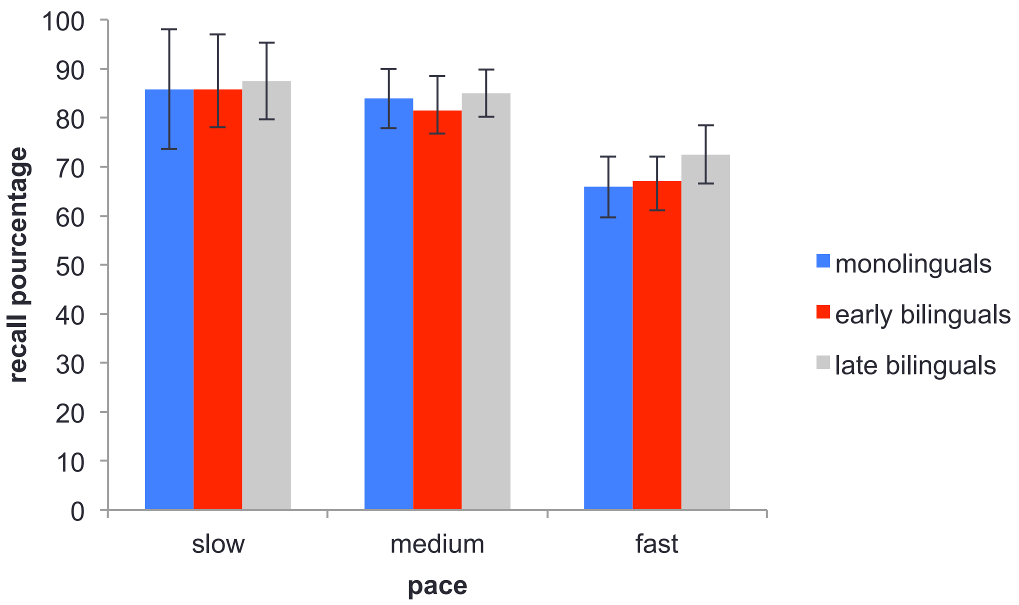


Figure 13: Percentage of recall in the working memory task (and SD) in monolinguals, early and late bilinguals (Experiments 1 and 2), as a fonction of pace.

Discussion

In this experiment, we assessed a working memory task on monolingual and bilingual participants. We were interested to find out if there was a bilingual advantage on working memory capacity in a population of college students from a high SES. As executive functions are involved in working memory (e.g., Baddeley et al., 1996; McCabe et al., 2010; Miyake & Shah, 1999), we administered participants a computer-paced complex span task measuring working memory capacity. If bilinguals have better executive functions, they should outperform monolinguals in working memory.

Although we did replicate the well known pace effect (e.g., Barrouillet & Camos, 2010), no significant difference between monolinguals and bilinguals was found. A Bayesian posterior probabilities analysis strongly supports a strong similarity of results between monolinguals and bilinguals. As working memory uses executive functioning, it is of interest to emphasize that bilinguals did not show any advantage over monolinguals. If a bilingual advantage is likely to be found on a highly demanding task (Costa et al., 2009), then we should have found a significant difference. Our results are in line with Lee et al. (2003), who showed there was a positive correlation between high SES individuals and working memory capacity. In fact, both monolinguals and bilinguals obtained an average of 78% of correct recall among the three paces. We suggest that some studies finding differences between monolinguals and bilinguals in executive functions (e.g., Bialystok et al., 2004; Carlson & Meltzoff, 2008) could be due to ethnic and SES differences.

To sum up, these results from this first experiment are adding weight to recent studies suggesting that there's not such a bilingual advantage when we speak about executive functions (Gathercole et al., 2014; Kirk et al., 2014; Paap & Greenberg, 2013; Ratiu & Azuma, 2015). Gathercole et al. (2014) tested participants from childhood to adulthood on executive functioning. Bilinguals were all proficient. No significant difference between groups was found on a card sort task, a Simon task or a metalinguistic task. Kirk et al. (2014) tested elderly people matched in SES on the Simon task. Monolinguals and bilinguals performed similarly. Paap and Greenberg (2013) did not find any bilingual effect on 15 indicators of executive functioning on young adults. Ratiu and Azuma (2015) tested working memory capacity on young adults using a backward digit span task, an operation span task and a symmetry span task. Bilinguals were proficient and learned both languages in their childhood. They found similar results between monolinguals and bilinguals. This last study is the closest to our first experiment. Both are measuring working memory, though our task is different than the three tasks from Ratiu and Azuma (2015). Nevertheless, both experiments did not find any bilingual advantage.

To test the effect of SES in tasks investing executive functioning, it would be interesting to perform the same experiment in a population of the same age and languages, but from a different SES. That was the aim of Experiment 3.

In this experiment, we also tested bilinguals who learned their second language before the age of 10. We were interested to replicate this experiment with late bilinguals. Tao et al. (2011) found that late bilinguals had an advantage over monolinguals on inhibition, but not on monitoring, as it was the case for early bilinguals. However, neuroimaging evidence showed more activation of brain areas involved in general cognitive control in bilinguals with a weaker L2 (Abutalebi, 2008; Abutalebi & Green, 2007; Golestani et al., 2006; Hernandez et al., 2007; Sakai et al., 2004; Wartenburger et al., 2003), suggesting that individuals with a weaker L2 could outperform balanced bilinguals as there executive control network is strongly activated. In the next experiment, we investigated this question with the same complex span task performed by late unbalanced bilinguals, i.e., participants with a weaker L2 learned after the age of 10.

Experiment 2

In the first experiment, we assessed working memory capacity in young adults. They were college students with a high SES. Our two groups consisted of monolinguals and early and balanced bilinguals who learned their two languages before the age of 10. Bilinguals had to use both languages on a daily basis. Monolinguals and early bilinguals performed similarly on the working memory task. In Experiment 2, we investigated whether late bilinguals with lower proficiency in second language (i.e., late unbalanced bilinguals) perform differently than early bilinguals working memory capacity. In his review, Abutalebi (2008) showed empirical evidence that less proficient bilinguals in L2, when they switch language, showed more activities than balanced bilinguals in brain areas associated with executive control (i.e., left prefrontal cortex, ACC and basal ganglia). Thus, it may appear that late unbalanced bilinguals are better in non-verbal tasks as well, because of the extensive use of these areas. However, Tao et al. (2011) showed a bilingual advantage for early bilinguals in inhibition and monitoring, whereas late bilinguals showed on advantage over monolinguals only in inhibition. As in Experiment 1, participants from Experiment 2 had a high SES. For this reason, there is a possibility to find the same pattern of results, even though participants were late bilinguals. Thus, to test this hypothesis, we assessed working memory capacity in late bilinguals, who learned their second frequently-used language after the age of 10.

Method

Participants

Sixteen undergraduate psychology students (1 male; mean age = 21.7 years; *SD* = 3.7 years) were recruited at the Université de Fribourg and received experiment credits. They were compared to the participants of Experiment 1.

It should be noted that late bilinguals were native German speakers who learned French after the age of 10. They considered themselves as middle proficient in French.

Materials and procedure

The material and procedure were the same as in Experiment 1.

Results

We first compared late bilinguals with participants from Experiment 1 on several characteristics. We performed a one-way ANOVA between monolinguals, early and late bilinguals on age, socioeconomic status and French proficiency. Monolinguals (21.79, *SD* = 1.75) were similar in age as early bilinguals (22.68, *SD* = 2.32) and late bilinguals (21.73, *SD* = 3.65), $F(2,67) = 1.06$, $p = .35$. However, monolinguals (25.3, *SD* = 10.7) were lower in socioeconomic status (the higher the score, the lower the status) than early bilinguals (26.4; *SD* = 8.3) and late bilinguals (19.2; *SD* = 6.1), $F(2,67) = 3.20$, $p = .05$, though the 3 groups were in the highest status (from 11 to 26). According to the C-test scores, monolinguals (94%; *SD* = 5) were more proficient in French than early bilinguals (81%; *SD* = 10) and late bilinguals (47%; *SD* = 10), $F(2,71) = 240.43$, $p < .001$. We run a t-test between early and late bilinguals on French C-test scores, i.e. their L2. Early bilinguals (81%; *SD* = 10) were more proficient than late bilinguals (47%; *SD* = 10), $t(37)= 14.64$, $p< .001$. As expected, late bilinguals were middle proficient in L2. Finally, we run a t-test between early and late bilinguals on German C-test scores, i.e. their L1. Early bilinguals (81%; *SD* = 10%) were less proficient than late bilinguals (90%; *SD* = 6%), $t(37) = 3.14$, $p= .003$. But both performances indicate a high proficiency. Thus, late bilinguals were similar in age and SES compared to participants from Experiment 1. As expected, late bilinguals were less proficient in L2 than early bilinguals and were unbalanced bilinguals.

For the working memory span task, all participants had at least 75% of correct responses in parity judgment (87%; *SD*= 5), showing they were paying enough attention to the concurrent task. We performed a 3 (monolinguals vs. early bilinguals vs. late bilinguals) x 3 (paces) ANOVA on parity judgment in a complete within-subject design. There was a pace effect on the percentage of correct responses, the faster the pace, the lower the percentage of correct responses, (92%, (*SD*= 5), for the slow, 89%, (*SD*= 5), for the medium and 80%, (*SD*= 9), for the fast pace), $F(2,144)= 147.34$, $p< 001$ (Tableau 5). Groups differed on accuracy of the parity judgment task, monolinguals (85%; *SD*= 5) being less accurate than early bilinguals (87%; *SD*= 6), and late bilinguals (90%; *SD*= 5) being the more accurate, $F(2,72) = 4.55$, $p = .01$. However there was no significant interaction between pace and group, $F(4,144) = 2.22$, $p = .07$, pBIC(H0|D)> .99. We used a similar ANOVA to compare response times in parity judgment task. A faster pace induced lower response times, (631 ms, (*SD*= 76), for the slow pace, 597 ms, (*SD*= 61), for the medium and 519 ms, (*SD*= 35), for the fast), $F(2,144) = 257.41$, $p < .001$ (Tableau 5). Groups did not differ in response times, $F < 1$, $p_{BIC}(H_0|D) = .98$, and no significant interaction was found between pace and group, $F < 1$, $p_{BIC}(H_0|D) > .99$.

To analyze recall performance, we performed a 3 (monolinguals vs. early bilinguals vs. late bilinguals) x 3 (paces) ANOVA on the percentage of correct recall in a complete within-subject design. As expected, a pace effect was observed, the faster the pace, the lower the recall percentage, 86% (*SD*=11) for the slow pace, 83% (*SD*=12) for the medium and 69% (*SD*=21) for the fast, $F(2,144) = 43.60$, $p < .001$, (Figure 13). However there was no difference between groups, $F < 1$, pBIC(H0|D) = .98, and no significant interaction between pace and group, $F < 1$, pBIC(H0|D) > .99. We then performed a 2 (early bilinguals vs. late bilinguals) x 3 (paces) ANOVA on the percentage of correct recall in a complete within-subject design. The faster the pace, the lower the recall percentage, 87% (*SD*=11) for the slow pace, 83% (*SD*=12) for the medium and 69% (*SD*=20) for the fast, $F(2,76)= 22.43$, $p< .001$, (Figure 3). There was no difference between groups, $F> 1$, pBIC(H0|D) = .97, and no significant interaction between pace and group, $F< 1$, pBIC(H0|D) = .80.

Discussion

In Experiment 2, we used the same working memory task as in Experiment 1 in middle proficiency late bilinguals. As neuroimaging studies showed (e.g., Abutalebi, 2008; Golestani et al., 2006; Sakai et al., 2004), late bilinguals with low to middle proficiency activate additional areas specific to general executive control compared to early proficient bilinguals when they have to switch language. Hence, it could show their advantage over monolinguals and early bilinguals in non-verbal task involving cognitive control. However, Tao et al. (2011) only found a bilingual advantage on inhibition in late bilinguals, though they found an advantage on inhibition and monitoring in early bilinguals. Our results did not show any bilingual advantage on working memory capacity for late bilinguals. Middle proficient late bilinguals performed similarly than monolinguals and proficient early bilinguals on the working memory task. The pace effect of the complex span task was present, the faster the pace, the lower the recall. But no difference between groups was observed. Bayesian posterior probabilities clearly confirmed these results. These findings reinforce the results of Experiment 1. When the two languages of bilingual participants with a high SES were identical, there was no difference in the complex span task.

Comparing Experiment 2 with the late bilinguals study by Tao et al. (2011), in addition to the fact that we used different tasks, participants were different in several characteristics that could explain the different results. Late bilinguals from the study of Tao et al. (2011) spoke two distant languages (i.e., Chinese as L1 and English as L2), were more or less balanced bilinguals and were raised in a different culture than Australian monolinguals. Indeed, they spent their childhood in China and arrived in Australia at the age of 12 or after. In our Experiment 2, late bilinguals spoke two less distant languages (i.e., German as L1 and French an L2), were unbalanced bilinguals, but were raised in a similar culture from Central Europe. Thus, the difference of bilinguals profiles, apart from the fact that they are both late bilinguals could explain the difference of patterns. For this study, we made sure that participants were from a similar culture to avoid any difference accountable to this variable.

Yet our results from Experiments 1 and 2 could be due to our specific population that scored high in SES and thus educational level. Findings could result from the high cognitive capacities of the students that participated in the study. College students have been selected during their school years for their good intellectual capacities. In Switzerland, student are pre-selected in the sixth grade and divided in three sections. Only one of the sections allows to go to high school. To enter college, students must have at least a high school diploma or an equivalent (both called a *maturité fédérale*). In 2013, only 34% of Swiss young people obtained a *maturité fédérale* (Office Fédéral de la Statistique, 2014). Thus, the process of selection to go to the university in Switzerland is rather rigorous. Furthermore, working memory capacity importantly correlates with fluid intelligence (Kane et al., 2005). Empirical evidence shows that fluid capacities are positively related to academic achievement (e.g., Johnston, Gradisar, Dohnt, Billows, & Mccappin, 2010; McGrew, 2005). Our population being on the high level of a number of cognitive capacities, among others fluid intelligence, any advantage due to bilingualism might have been invisible. This is why it is now important to replicate this design to a population with lower SES with the same age. This is what we did in Experiment 3. We tested some apprenticeship students with lower SES.

Experiment 3

In Experiments 1 and 2, we tested working memory capacity in college young adults, comparing monolinguals with early bilinguals and late bilinguals respectively. Groups were of high SES. We did not find any difference between monolinguals, early and late bilinguals. In Experiment 3, we tested apprenticeship young adults that had a significant lower SES and level of education.

According to empirical studies, a lower SES is associated with lower attentional, executive functioning and working memory capacities (e.g., Farah et al., 2006; Lee et al., 2003; Mezzacappa, 2004; Noble et al., 2007, 2005; Stevens, Lauinger, & Neville, 2009). By opposition of our two previous experiments testing high SES participants, a positive effect of bilingualism could be seen on working memory capacity in a population with a low SES, showing better results for bilinguals compared to monolinguals. Indeed, a study by Engel de Abreu et al. (2012) showed a better executive functioning on young bilingual children compared to young monolingual children, both with a low SES and a similar ethnicity. In order to test this assumption on working memory with young adults, in Experiment 3, the same complex span task as in the two previous experiments in apprenticeship young adults. Thus, we expected apprenticeship students to have a lower SES and lower performance in the French C-test measuring L1 proficiency. C-tests evaluate comprehension, spelling and grammar. We expected participants with a lower SES to have a lower school level as well. As French is not a transparent language and thus not easy to master completely in written form, results in the C-test should be lower for apprenticeship students. Concerning the complex span task, we predicted that early bilinguals would show a better working memory capacity than monolinguals, as we predicted a bilingual advantage for early bilinguals compared to monolinguals, both from a low SES.

Method

Participants

Fifty-seven apprenticeship students (41 males, mean age=18.8 years, *SD*=2.3 years) were recruited in an apprenticeship school in Fribourg and Bienne. Monolinguals (N=27; 20 males; 19.2 years, *SD*=2.1 years) spoke fluently French and bilinguals (N=30; 21 males; 18.4 years, *SD*=2.4 years) spoke French and another language. Among them, half spoke German (15), while the others spoke other languages (5 Portuguese, 2 Arab, 2 Italian, 2 Albanian, 2 Serbian, 1 Kosovar and 1 Finish). It was more difficult to find French-German early bilinguals, that is why we gave the possibility to French-another language early and proficient bilinguals to participate in the experiment, as long as they learned both languages before the age of 10. Furthermore, bilinguals were raised in Switzerland and thus shared a similar culture with monolinguals.

Materials and procedure

As in Experiment 1, the procedure was the same except for language proficiency. It was assessed in French only, as bilinguals spoke different second languages. We did not have the possibility to test them in every other second language they spoke, as we did not have proficient collaborators available for every language. We asked them if they learned both languages before the age of 10, were proficient in their L2 and used it on a regular basis, i.e. daily or at least weekly. If it was the case, we accepted them as early and proficient bilinguals.

Results

We compared participants on different characteristics. As in previous experiments, there was no difference in age, $t(55)= 1.32$, $p= .19$, socioeconomic status, $t < 1$, or French proficiency test, $t(55)= 1.94$, $p= .06$, between monolinguals and bilinguals.

We then compared participants from Experiment 1 (college students) to participants from this experiment on age, SES and French proficiency. For example, SES could have an influence on the working memory performance (e.g., Hackman et al., 2014; Lee et al., 2003; Mezzacappa, 2004). We performed 2 (apprenticeship vs. college students) x 2 (monolinguals vs bilinguals) ANOVAs on age, socioeconomic status and French proficiency in a complete between-subject design. Apprenticeship students (18.8, SD=2.3) were younger than college students (22.2, *SD*=2.0), $F(1,92)=49.64$, $p< .001$. There wasn't any difference between monolinguals and bilinguals on age, $F < 1$. There was not any significant interaction, $F(1,92)=2.63$, $p = .11$. As expected, socio-economic status, measured through IPSE test was lower in apprenticeship students (53.3, *SD*=11.7) than college students (25.8, *SD*=9.7), $F(1,93)=164.88$, $p< .001$. There was no significant difference between monolinguals and bilinguals, $F < 1$, and no significant interaction, $F < 1$. In French proficiency, apprenticeship students (78.9, *SD* = 13.9) had a lower percentage of correct responses than college students (92.4, *SD* = 7.1), $F(1,96) = 28.60$, $p < .001$. Monolinguals (89.3, *SD* = 10.5) had a better score than bilinguals (78.0, *SD*=13.4), though it was only a trend, $F(1,96) = 3.12$, $p = .08$. There was no significant interaction, $F(1,96) = 1.48$, $p = .23$.

As mentioned in the *Participants* section, we selected early and proficient bilinguals that spoke French as L1 and another language in L2, i.e. not German. Before including these participants in the results, we compared results from French-German bilinguals with French-other language bilinguals. The following analyses showed that these two groups were very similar in measures and performances. This was the reason why we decided to include them in the general analysis. To begin with, there was neither a difference in age between French-German and French-other language bilinguals, $F< 1$, nor a difference in socio-economic status according to the IPSE test, $F(1,29)= 1.49$, $p= .23$. However, bilinguals who spoke another language than German as L2 (82%; *SD*= 10) scored higher in the French C-test than French-German bilinguals (70%; *SD*= 18), $F(1,29)= 5.41$, $p= .03$.

Working memory task in apprenticeship students

We first analyzed working memory performance in apprenticeship monolinguals and bilinguals. We checked that participants were paying enough attention to the concurrent task. Apprenticeship students had more difficulties with the working memory task than college students. Thus, we lowered the threshold from 15%, compared to the college students study, choosing a threshold of 60%. If we kept the same criteria, there would have remained 19 monolinguals (instead of 27), and 24 bilinguals (instead of 30). Thus, we would have lost 30% of monolinguals and 20% of bilinguals, losing a total of 25% of participants. We performed a 2 (monolinguals vs. bilinguals) x 3 (paces) ANOVA on percentage of correct parity judgments in a complete within-subject design. There was a pace effect on the percentage of correct responses, the faster the pace, the lower the percentage of correct responses, (85%, (*SD*= 6), for the slow, 80%, (*SD*= 7), for the medium and 70%, (*SD*= 11), for the fast pace), $F(2, 110)= 117.50$, $p< .001$ (**Tableau 6**). Nevertheless, monolinguals (78%; *SD*= 7) did not significantly differ from bilinguals (80%; *SD*=7)), $F<1$, $p_{BIC}(H_0|D) = 0.85$. No significant interaction was found between pace and group, $F(2, 110)= 2.31$, $p= .10$, $p_{BIC}(H_0|D) = 0.95$. Concerning response times in the parity judgment task, we performed a similar ANOVA. As expected, we found the same pattern as we found for accuracy. The faster the pace, the lower the response times (685 ms (*SD*= 81) for the slow pace, 637 ms (*SD*= 64) for the medium and 533 ms (*SD*= 30) for the fast), $F(2,110)= 226.18$, $p< .001$ (**Tableau 6**). There was no difference between monolinguals and bilinguals, $F < 1$, $p_{BIC}(H_0|D) = 0.80$. There was no significant interaction between pace and group, $F< 1$, $p_{BIC}(H_0|D) = 0.97$.

Tableau 6: Percentage of correct responses (in bold) (and SD) and reaction times (ms) (and SD) for the parity judgment task in monolinguals and bilinguals, as a function of pace.

Pace	Slow	Medium	Fast
Monolinguals	**84.4 (5.2)**	**79.1 (6.7)**	**70.3 (10.0)**
	690 (70)	639 (63)	528 (33)
Bilinguals	**85.6 (6.6)**	**82.6 (6.9)**	**69.4 (11.5)**
	681 (91)	634 (66)	537 (27)

We performed a 2 (monolinguals vs. bilinguals) x 3 (paces) ANOVA on the percentage of correct recall in a complete within-subject design. As expected, when the pace is slower there is a better recall (74% (*SD*= 19) for the slow, 74% (*SD*= 19) for the medium and 65% (*SD*= 24) for the fast pace), $F(2,110)= 9.91$, $p< 001$ (Figure 14). Very importantly, contrary to our two previous experiments, bilinguals (76%; *SD*= 14) obtained a better recall percentage than monolinguals (66%; *SD*= 22), $F(1,55) = 4.28$, $p = .04$. Thus, it was the first time in this series of experiments that we observed a bilingual advantage. However, there was no significant interaction between pace and group, $F(2,110) = 1.01$, $p = .37$, $p_{BIC}(H_0|D) = 0.97$.

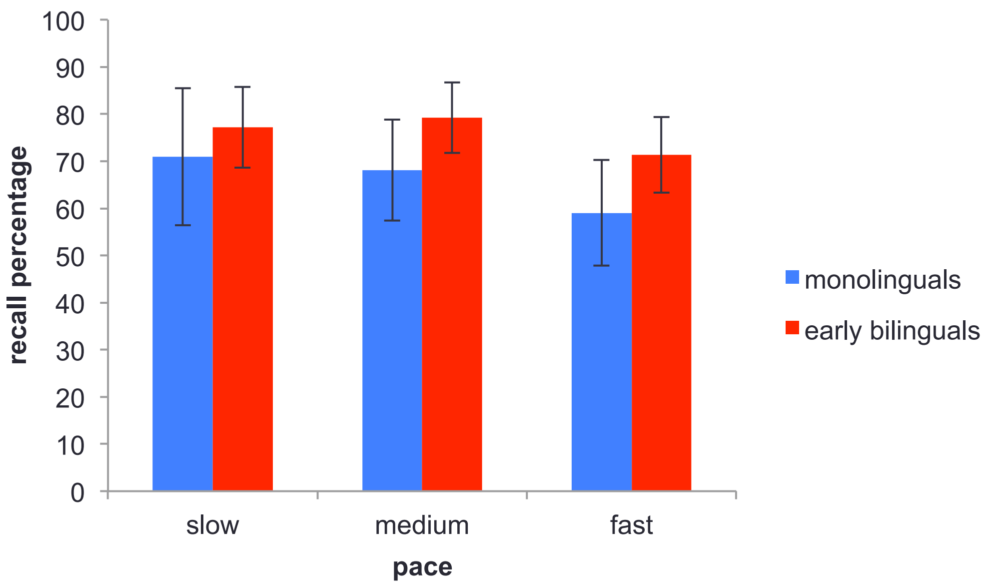


Figure 14: Percentage of recall in the working memory task (and SD) in monolinguals and bilinguals, as a fonction of pace.

French-German bilinguals vs. French-other language bilinguals

As we did for age, SES and C-test, we compared working memory performance between French-German bilinguals and bilinguals who spoke French as L1 and another language for L2. We carried a 2 (French-German vs. French-other language bilinguals) x 3 (paces) ANOVA on percentage of correct parity judgments in a complete within-subject design. As expected, the faster the pace, the lower the percentage of correct responses (86% (*SD*= 7) for the slow, 83% (*SD*= 7) for the medium and 69% (*SD*= 12) for the fast pace), $F(2,56) = 68.00$, $p < .001$. No difference was found between French-German (80%; *SD*= 8) and French-other language bilinguals (79%; *SD*= 7), $F< 1$, $p_{BIC}(H_0|D) = .83$. However, there was a significant interaction between groups and pace, $F(2,56)= 4.14$, $p= .02$, because French-German bilinguals (73%; *SD*= 12) were more accurate on the fast pace than French-other language bilinguals (66%; *SD*= 11), $t(14)= 1.49$, $p= .15$. An ANOVA on response times with the same design shows a pace effect, the faster the pace the faster the response (681 ms (SD= 91) for the slow, 634 ms (*SD*= 66) for the medium and 537 ms (*SD*=27) for the fast pace), $F(2,56) = 94.91$, $p < .001$. There was no difference between French-German (630 ms; *SD*= 62) and French-other language bilinguals (604 ms; *SD*= 53), $F(1,28)= 1.53$, $p= .23$, $p_{BIC}(H_0|D) = .71$. Finally, there was no significant interaction, $F< 1$, $p_{BIC}(H_0|D) = .91$.

Concerning the recall performance, we performed a 2 (French-German vs. French-other language bilinguals) x 3 (paces) ANOVA on the percentage of correct recall in a complete within-subject design. There was a difference of percentage recall between paces (77% (*SD*=16) for the slow, 79% (*SD*=15) for the medium and 71% (*SD*=17) for the fast pace), $F(2,56)=5.00$, $p=.01$. There was not any difference of recall percentage between French-German (76%; *SD*=12) and French-other language bilinguals (75%; *SD*=14), $F< 1$, $p_{BIC}(H_0|D) = .84$. There was no significant interaction between group and pace, $F(2,56)=1.28$, $p=.29$, $p_{BIC}(H_0|D) = .94$.

Discussion

In this last experiment, we tested apprenticeship students that have a lower SES than college students from Experiments 1 and 2. The lack of difference in recall in the complex span task between college monolinguals and bilinguals could be due to the fact that college students presented higher cognitive capacities in the general population, due to the selection process to enter university. As this population has a high SES and a high level of education, a possible bilingual advantage could be invisible because this high SES and level education allows them to get a very good working memory performance, as a high SES is positively correlated with a good working memory capacity (e.g., Lee et al., 2003; Noble et al., 2007).

In this experiment, apprenticeship bilinguals obtained a better recall percentage than their monolinguals peers. This is an important finding, because it was the first time within the present three experiments that we observed any difference between monolinguals and bilinguals on working memory capacity. There was no significant interaction. Bilinguals showed better scores than monolinguals in all three paces.

Our finding is in line with Engel de Abreu et al. (2012) results who found a bilingual advantage on low SES participants. However, Engel de Abreu et al. (2012) tested children on executive functioning, whereas we tested young adults on working memory capacity. However, our results concerning SES and bilingualism are different than Morton & Harper (2007) findings. They showed that SES had an influence on the results of their experiment, regardless of the fact of being monolingual or bilingual. Though theses authors tested inhibition with the Simon task on children, which again are a different investigation and a different population than our study.

Thus, our results show an influence of the SES. Interestingly, results from Experiment 3 contrast with our findings from Experiment 1 and 2, in which we found no difference between monolinguals and bilinguals with a high SES. According to Hackman et al. (2014), the impact of SES on working memory is stable during adolescence. Thus, a low SES resulting of a low working memory capacity would be stable. In this context, it is of interest to find a bilingual advantage, as empirical results (e.g., Lee et al., 2003; Noble et al., 2007) may have let us suppose that bilinguals participants would perform poorly in the working memory task, as they are from a low SES. It can open some perspectives in education for low SES bilinguals who have difficulties at school. We will discuss these perspectives in the General Discussion. Of course, when comparing our findings from this experiment with the two previous ones, we do not claim apprenticeship bilinguals performed similarly than college students. As a reminder, we had to lower the threshold of correct responses in the concurrent task (i.e., the parity judgment task), because the task was too difficult for this population. Recall performance was then not comparable with performance of the college students. We could only compare apprenticeship monolinguals and bilinguals, the later showing a significantly better performance than their monolingual peers.

General discussion

In the present study, we measured working memory capacity with a complex span task in monolingual and bilingual young adults. There is an important number of studies investigating a possible bilingual advantage on executive functioning (e.g., Bialystok et al., 2004, 2006; Carlson & Meltzoff, 2008; Costa et al., 2009; Costa, Hernández, & Sebastián-Gallés, 2008; Gathercole et al., 2014; Kirk et al., 2014; Martin-Rhee & Bialystok, 2008; Morton & Harper, 2007; Paap & Greenberg, 2013), which is not ubiquitously found. A possible problem is that other variables than bilingualism can influence results. For example, as pointed by Hilchey & Klein (2011), it is very important to control SES, because any difference measured between monolinguals and bilinguals could be influenced by a difference in SES between the two groups. That is why we controlled for age, SES and proficiency all along our three experiments. We evaluated working memory capacity, as other recent studies (Engel de Abreu, 2011; Engel de Abreu et al., 2012; Ratiu & Azuma, 2015), because there is a relation between working memory and executive functioning (e.g., Baddeley et al., 1996; Miyake & Shah, 1999). In the first experiment, we compared college students with a high SES from a similar culture. Bilinguals learned their second language early and were very proficient in L2. Thus, they were balanced bilinguals. We predicted that monolinguals and bilinguals would be similar in working memory capacity, as a high SES predicts a good working memory capacity (e.g., Lee et al., 2003). Our rationale was that the strength of the SES effect would overcome an effect of bilingualism. In the second experiment, we used the same complex span task from the previous experiment in unbalanced late bilinguals with a high SES and a similar culture. Bilinguals learned their L2 after the age of 10. Our hypothesis was the same as in Experiment 1, predicting a stronger effect of a high SES on working memory performance than a potential late bilingual advantage effect. In the third and last experiment, we tested participants with a significantly lower SES, apprenticeship students. Bilinguals were proficient in both languages and were early learners of their L2. Monolinguals and bilinguals were raised in Switzerland and shared a similar culture. This time, we predicted a better working memory capacity in bilinguals. As they were low in SES, we hypothesized that a bilingual advantage could be beneficial in the working memory task performance, as found in the study with low SES children by Engel de Abreu et al. (2012), compared to monolinguals who would score low in working memory, according to empirical research (Lee et al., 2003; Noble et al., 2007).

We only found a difference between monolinguals and bilinguals in apprenticeships students, who had a lower SES (Experiment 3). Bilinguals outperformed monolinguals in all three paces. They showed in average a working memory capacity 10% superior than monolinguals. Empirical research shows that a lower SES has unfavorable effects for cognitive development (Noble et al., 2005). Thus, it is particularly interesting to find a bilingual advantage in working memory capacity for this specific population. For high SES participants (i.e., college students), there was no significant difference in working memory performance between monolinguals and bilinguals, whether the bilingual group was composed of balanced and early bilinguals (Experiment 1) or unbalanced and late bilinguals (Experiment 2). Both experiments showed a high percentage of correct recall for monolinguals and bilinguals. In the two experiments, even in the fast pace (i.e., the highest cognitive load of the task), there is no difference between monolingual and bilingual college students. This finding is matching the assumption that a high SES was positively correlated with a high working memory capacity (Lee et al., 2003; Noble et al., 2007). Our results were analogous to the study of Ratiu & Azuma (2015), who tested working memory capacity in college students, but with a different set of tasks.

The results from this study opened up several points of discussion. First, we discussed the heterogeneity of bilingual non-linguistic characteristics in studies about the bilingual advantage, which could possibly have an impact on the results. We started to focus on culture and then on other activities that could enhance executive functioning. Second, we discussed the perspectives in education for bilingual children from a low SES having difficulties at school. The finding of a better working memory for bilinguals could be used in a remedial teaching program, acting on intrinsic motivation, self-esteem and self determination, using the self determination theory (Deci & Ryan, 1985, 2002).

The effect of culture

Bilingualism is one variable among the characteristics to describe an individual. This is not a supra-category. Being bilingual is not the only characteristic defining or influencing a person cognitively, it would be too restrictive. Notably, culture is a variable that can have a tremendous impact on an individual (Carlson, 2009), as we will develop later in this section. Some studies showing a bilingual advantage might as well measure cultural differences instead of bilingualism only, if culture is not controlled in the experiments. Concerning our study, we controlled as much as possible the culture variable. Each participant has been raised in a similar culture, in Switzerland (Experiment 1 and 3) or in Germany and Switzerland (Experiment 2), which are both cultures from Central Europe. There are clear evidences that largely different cultures have an impact on executive functioning (Carlson & Choi, 2009; Carlson, 2009; Glaser, 2000; Sabbagh, Xu, Carlson, Moses, & Lee, 2006). Yet, some influential studies showing a bilingual advantage compare participants from totally different cultures (e.g., Bialystok et al., 2004; Bialystok & DePape, 2009; Luk, De Sa, & Bialystok, 2011). Thus, Sabbagh et al. (2006) compared Chinese children with American children on executive functioning and theory of mind. The later is the understanding of different mental states, (e.g., beliefs, intents, knowledge) of oneself or someone else. Both groups were similar in their level of theory of mind reasoning, but Chinese children were superior in executive functioning measures. Likewise, Carlson and Choi (2009) compared Korean-English bilingual children living in the United States with American monolinguals on executive functioning. Bilingual children outperformed American monolinguals. However, the bilingual performance was similar as a third Korean monolingual group. If the design of the experiment did not comprise of a third group composed of Korean monolinguals, the conclusion would have probably supported a bilingual advantage. Though, the difference was due to an effect of culture. As Paap and Greenberg (2013) review, there are many variables, which have an important influence on the development of executive functioning that are culture dependent. They mentioned the different style of parenting and caregiving, teaching methods, discipline, and various emphases on self-control influenced by the culture. Matching participants on cultural background is then really essential in studies comparing bilinguals with monolinguals. Yet, one could argue that a bilingual is bicultural. Even if a bilingual is raised in a specific country, if one or both of his parents are immigrants, the individual shares two cultures. Such an argument shows how a delicate matter it is to select participants for a study about bilingualism. However, one could argue that an adult who has spent the majority of his life in a country, following the school education from this country has the culture from this place as his dominant culture. It would be ideal to select participants sharing a similar culture, though it is sometimes difficult to find participants that match the exact profile for a study. This was the case for the last part of the study. Finding French-German early bilinguals in apprenticeship students that were motivated to participate in our experiment proved to be more difficult than expected. Indeed, in Experiment 3, half of the participants shared the same culture and half where from a second generation of immigrants. As these two different characteristics did not influence the working memory performance, we could make the assumption that they all shared the Swiss culture as their dominant culture.

Activities enhancing executive functioning

As addressed earlier, culture and SES have an influence on studies measuring higher cognitive capacities (e.g., Carlson & Choi, 2009), but there are not the only variables influencing theses capacities. Research showed that a number of activities have a positive influence on executive functioning, including active video games experience (Anguera et al., 2013; Bavelier, Green, Pouget, & Schrater, 2012; Bialystok, 2006; Green, Sugarman, Medford, Klobusicky, & Bavelier, 2012; Strobach, Frensch, & Schubert, 2012), music training (e.g., Amer, Kalender, Hasher, Trehub, & Wong, 2013; Bialystok & DePape, 2009; Bugos, Perlstein, McCrae, Brophy, & Bedenbaugh, 2007; Moreno et al., 2011; Schellenberg, 2005), physical exercise involving discipline and self-control (Diamond & Lee, 2011), or non-computerized games (Diamond & Lee, 2011). Concerning video games, for example, Green et al. (2012) showed that action video game players had an advantage over non-players in a series of cognitive tasks requiring executive functioning, especially switching. To be considered as an active video game player (Experiment 1), individuals had to practice a minimum of five hours per week during the last six months. About musical training, Amer et al. (2013) tested musicians and non-musician, from a middle-age to older adult population matched on education. The musician group counted an average of twenty years of music practice. This group outperformed non-musicians on a number of executive control tasks, i.e., a visual span task measuring visual working memory, and also a Simon task and a reading with distraction task, both measuring inhibitory control. Finally, concerning physical activities, a review by Diamond and Lee (2011) interested in children from four to twelve years old showed that the regular practice of martial arts, aerobics, yoga, mindfulness enhanced executive functioning. The authors also review research about computerized and non-computerized games, showing that positive effects on executive control have also been found in such activities.

Of course, it is very difficult to control each of these factors having an influence on executive functioning. This could be a limit of our study. We could have added a questionnaire investigating these activities and used the information as covariates in our analyses. However, as Valian (2015) very interestingly pointed out, research did not yet propose an important specification concerning individuals practicing such activities in the long term, consequently benefiting from a lastingly executive functioning advantage: Do these individuals have different cognitive or personality characteristics from the start that could explain they did invest durably some time on this activity? In other words, these individuals might have some higher executive functioning required in such activities that motivated them to start or pursue these activities. If yes, this would mean that the practice of such activities would be the consequence of a better executive control from the start. Thus, controlling these variables in an experiment would be less relevant.

This can certainly not be the case for early bilingualism (or any situation in which a person becomes bilingual by necessity). Thus, for an early bilingual, the learning of two languages is rarely if ever a choice. A person can be an early bilingual, because a) his two parents have a different mother tongue, b) his parents immigrated in a country in which a different language is spoken, c) this person lives in an area in which a different language than their mother tongue is spoken. Put another way, in the case of early bilingualism, there is no relation between a higher executive control and the fact that an individual becomes a bilingual. Such a person becomes a bilingual by necessity.

We have discussed about the effect of some other variables than bilingualism that could influence the results of studies investigating the bilingual advantage on executive control. We will now develop another point of discussion, this time about the implication of the results from Experiment 3. As lower SES bilinguals had an advantage on working memory capacity compared to monolinguals, we proposed some remedial teaching for bilinguals with school difficulties. This teaching is based on their working memory advantage.

Implications concerning remedial teaching for bilinguals with school difficulties

Bilingual students, for example individuals from the population of apprenticeship students we tested, may encounter school difficulties, leading in worst cases in a spiral of failure. An apprenticeship consists mainly of working and learning in a company, though every week the student has to attend courses. These courses comprise of fundamental subjects (e.g., mathematics) and theoretical disciplines from the profession they are currently learning. Apprenticeship students could manage well the practical side of their training, but they could possibly have difficulties with the theoretical parts and the courses of the fundamental disciplines. In this section, we will propose a remedial teaching possibility, based on the appropriate use of working memory to enhance motivation and hopefully school results as a positive consequence. As found in Experiment 3, apprenticeship bilinguals had an advantage over monolinguals on working memory capacity. Thus, we will present the possibility of creating exercises in ascending complexity in the disciplines needed, based on their advantage on working memory. We will explain links between intrinsic motivation, self-efficacy and educational success, by presenting the self-determination theory (Deci & Ryan, 1985, 2002). Then, we will define how a remedial teaching program considering the working memory advantage of a bilingual can lead to a school results improvement.

Motivation is a key factor in learning and school achievement (e.g., Vianin, 2006; Viau, 1994). Motivation can be intrinsic or extrinsic. Intrinsic motivation is determined by internal rewards, such as the satisfaction and pleasure, whereas extrinsic motivation is determined by external rewards (Deci & Ryan, 1985). Intrinsic motivation is more stable and positive in the long term than extrinsic motivation, as it is a leading process in self-construction and self-achievement (Deci & Ryan, 2002). The self-determination theory (Deci & Ryan, 1985, 2002) is based on the assumption the every individual has a natural tendency towards self-construction, self-achievement, and the development of one’s potential. Though this tendency should not be taken as granted. The self-determination theory proposes that there are socio-contexts favorable to this tendency. Thus, the environment in which an individual is developing can facilitate or in the contrary can jeopardize the tendency towards self-achievement. In other words, the environment can influence an important part of developmental outcomes (Deci & Ryan, 2002). The authors propose that an optimal environment should help satisfy three basis needs: competence, relatedness (i.e., the feeling to belong in its environment and community) and autonomy. Thus, the self-determination theory is interested of the interplay between an extrinsic element like the environment and intrinsic motivation. This theory has implications in terms of educational environments (e.g., Ratelle & Duchesne, 2014; Ratelle, Larose, Guay, & Senécal, 2005; Sheldon & Krieger, 2007; Véronneau, Koestner, & Abela, 2005). A positive learning environment should tend toward the completion of educational goals. An optimal learning environment should be able to adapt itself for a student, allowing him to reach the necessary knowledge and skills, autonomy, self-determination and a feeling of competence. In the case of a student having difficulties and risking to fail, this environment should help him gain or regain trust in his potential. The self-determination theory proposes to tend to self-determined behaviors by using external regulations until they become intrinsic regulations (Deci & Ryan, 1985, 2002). In this case, a remedial teaching would be the external regulation. Such a teaching should tend towards intrinsic regulations, to allow the student to reach competence, relatedness and autonomy.

More specifically, we propose that the first goal of such a remedial teaching would be to make a student regain a self-perception of capability in school. As bilinguals with a low SES showed a significant better working memory capacity than their monolingual peers (Experiment 3), we propose to create a series of exercises of ascending difficulty tapping working memory capacity in the disciplines in which the students have difficulties. The method would additionally consist of congratulating the student for a good performance, acknowledging the benefits of being bilingual to resolve such exercises. Verbal rewards enhance intrinsic motivation in non-evaluative contexts (Deci, Koestner, & Ryan, 1999). Thus, it would be an integral part of the remedial program. Such exercises would help the student to reinforce his sentiment of competence and hopefully help him to reach self-achievement.

Conclusion

In our study, bilinguals showed a higher working memory capacity compared to monolinguals only in a low SES population. College students were similar in working memory capacity among the three groups we tested, monolinguals, early and late bilinguals. Importantly, finding a bilingual advantage on working memory capacity is particularly interesting, as it is well correlated with essential cognitive functions. As Redick et al. (2012) pointed out, working memory capacity is strongly related to fluid intelligence (Kane, Hambrick, & Conway, 2005; Oberauer, Schulze, Wilhelm, & Süss, 2005, in Redick et al., 2012) and particularly comprehension, reasoning and problem solving (Engle, 2002). Furthermore, finding this advantage only for lower SES bilinguals is very compelling. It would mean there is a cognitive advantage for a population crucially needing it. Further research could investigate the practical implications of such an advantage.

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Chapter two: The cognitive cost induced by the language switch in working memory span tasks

The cognitive cost induced by the language switch in working memory span tasks

Individuals living in a bilingual environment have to frequently switch languages. This study presented three experiments investigating the cost of the switch of languages in a working memory task in early and late bilinguals. Each task was composed of a storage task and a processing task. We varied the languages bilinguals had to use within trials, creating four language conditions. Thus, they were sometimes instructed to do the whole task in their dominant language (L1) or their second language (L2), or to do the storage task in L1 and the processing task in L2, and vice-versa. We also varied the types of items and pace among the three experiments. When early bilinguals had to recall digits (Experiment 1), their recall was better with only one language within a trial, but the storage language had no effect on performance. Whereas when they had to recall words (Experiment 2), their recall was better in their L1, but there was no effect of the number of languages. Late bilinguals (Experiment 1) obtained a better digit recall in L1 and in one language within a trial. Concerning response times to complete the processing task, there was no significant difference between languages (Experiment 3). Thus, the nature of the items to recall, i.e. digits or words, influenced the performance.

Keywords: bilingualism, early bilinguals, late bilinguals, working memory, language switching, executive functions

Introduction

Bilingual individuals are used to switch languages in their everyday lives. For example, when they work in a bilingual environment, one minute they might speak in one language with a colleague and the next minute speak in their second language with another person.

In this study, we investigated the cost of switching languages within a task. Several questions guided our three experiments. Is switching languages during a working memory task detrimental for bilinguals? Does being early or late bilingual influence the recall performance? We also investigated if a working memory performance entirely in a second language (L2) or third language (L3) was similar to the performance in the dominant language (L1) in early or late bilinguals.

Two languages always activated

Empirical evidence shows that both languages in a bilingual person are constantly activated (e.g. Costa, 2005; Kroll, Bobb, & Wodniecka, 2006; Hoshino & Kroll, 2008; Kroll & Bialystok, 2013). Hence, Hoshino and Kroll (2008) showed there is an activation of the dominant language (L1) when the task only required the use of the second language (L2) among Spanish-English (L1/L2) and Japanese-English (L1/L2) bilinguals. The task consisted of naming in English 72 black and white drawings, as fast and accurate as possible. Among the drawings, half of them represented words that shared cognates between the languages of a participant. Thus, the word "guitar" shares a cognate in English, Spanish (one says *guitarra*) and Japanese (one says *gi.ta.a,* ギター). The second half of drawings shared no cognate, for example "glasses" share no cognate with Spanish (*gafas*) or Japanese (me.ga.ne, 眼鏡). In terms of speed, Spanish-English bilinguals were faster with drawings sharing cognates in Spanish and English, and drawings sharing cognates in Spanish, English and Japanese, compared to drawings that shared no cognate with their L1. In terms of accuracy, the same pattern of results was found. Concerning Japanese-English bilinguals, these participants were faster with drawings sharing cognates in Japanese and English and with drawings sharing cognates in Japanese, English and Spanish, compared to drawings that shared no cognate with their L1. The same pattern of results was found in terms of accuracy. The authors concluded then that the two languages were always activated, as words that shared cognates with the L1 of participants were named faster and more accurately, even though the task and the instructions were entirely in L2.

Language switching

Since both languages are activated in a bilingual person, studies have investigated the cost of the language switch. To examine language control and the switching costs produced, researchers used language switching tasks (e.g., Christoffels, Firk, & Schiller, 2007; Costa & Santesteban, 2004; Declerck, Philipp, & Koch, 2013; Finkbeiner, Almeida, Janssen, & Caramazza, 2006; Hernández, Martin, Barceló, & Costa, 2013; Meuter & Allport, 1999; Price, Green, & Von Studnitz, 1999). Some visual stimuli are presented during such a task and participants have to name them in the required language. The stimuli are generally pictures to name, sometimes they are also digits (e.g., Meuter & Allport, 1999). A cue indicating to use the L1 or the L2 is presented either before or during the presentation of the stimulus. Blocks can comprise of one language or two languages to use. In two-language blocks, a trial requiring using the same language as the previous one is called a repetition trial. Conversely, a trial requiring naming the stimulus in a different language that the previous one is called a switch trial. Empirical results show that response times for switch trials are larger than response times for repetition trials (e.g., Costa & Santesteban, 2004; Philipp, Gade, & Koch, 2007). This difference is called "switching cost". Also, the response times are larger with two-language trials compared to one-language trials (e.g., Christoffels et al., 2007; Price et al., 1999). This difference is called "mixing cost". As reviewed by Declerck et al. (2013), both switching costs and mixing costs are showing an asymmetric difference between L1 and L2 performances in unbalanced bilinguals: both costs are larger for a trial in L1 when the previous trial was in L2, compared to a trial in L2 when the previous one was in L1. According to the inhibitory control model (Green, 1998; see Chapter 1 for further description), bilinguals inhibit the language they do not wish to use. As L1 is more dominant than L2, it requires more inhibition. Some authors proposed that there was an involuntary "persisting inhibition" when returning to L1, explaining a larger cost (Declerck et al., 2013; Linck, Schwieter, & Sunderman, 2012; Meuter & Allport, 1999; Philipp & Koch, 2009). This explanation is in line with the proactive interference model (Allport, Styles, & Hsieh, 1994) in task switching, explained in the next section.

Task switching

Language switching tasks have been derived from switching tasks, created to investigate cognitive control. In those tasks, participants receive generally two or more instructions (Vandierendonck, Liefooghe, & Verbruggen, 2010). According to a cue, participants have to perform one instruction at a time. As for language switching tasks, the switch cost is the difference of performance between two trials to carry out with different instructions and two trials to carry out with the same instructions. Switching tasks typically consist of "word reading, color and object naming, categorizing digits regarding magnitude or parity, categorizing words as living/nonliving, or responding according to the location of a stimulus" (Kiesel et al., 2010). Two similar pattern of results are shared between switching tasks and language switching tasks (Hernández et al., 2013a). As a first similarity, there is a cost caused by the change of task. There are two models of cognitive control proposing to explain those switch costs, the reconfiguration model (Rogers & Monsell, 1995) and the proactive interference model (Allport et al., 1994). The reconfiguration model proposes that the switching cost is due to the time needed to reconfigure the cognitive system, clearing out the instructions from the previous task and retrieving the instructions from the task to perform (Rogers & Monsell, 1995). According to this hypothesis, if a preparation time is available before the presentation of the stimulus, the switching cost should disappear. However, it is not the case. Rogers and Monsell (1995) still found a switch cost when a substantial preparation time was added. These authors proposed that two stages constituted the reconfiguration process. A first stage of reconfiguration takes place when one receives the information that there is a switch trial coming. Then, a second and final stage of reconfiguration occurs during the presentation of the stimulus. The proactive interference model explains switch costs by the persistence of the activation of the previous task, provoking an interference with the task to perform (Allport et al., 1994). This activation needs to be inhibited in order to complete the task required. The interference created is called a task-set inertia. Thus, it creates a cost in switch trials. However, it facilitates the performance in repetition trials, creating a positive priming effect in this later case. This model explains the second similarity found in results for task switching and language switching tasks, switch-cost asymmetries: switching costs are larger when one switches for an easier task from a difficult task. As a reminder, in language switch costs are larger for trials to perform in L1 when the previous was in L2. When performing an easy task (e.g. read one digit) compared to a more difficult second task (e.g., add two digits), the instructions from the most difficult task need to be inhibited. When performing the most difficult task, the easiest needs less inhibition. Switching cost would be larger when performing the most difficult task, because there is a residual inhibition as it was strongly inhibited, though the instructions need to be reactived in order to perform this task (Allport et al., 1994; Koch, Gade, Schuch, & Philipp, 2010). As the pattern of results between task switching and language switching tasks are very similar, the mechanisms involved in both tasks could be identical (Hernández, Martin, Barceló, & Costa, 2013). Thus, it would be interesting to create a task requiring both linguistic and non-linguistic switching.

Switching and working memory

Task switching and working memory have in common that they both use executive functions. Executive functions are general-purpose mechanisms guiding attention on a specific task at a specific moment. (Miyake et al., 2000; also see section 1.3.1 from the Introduction). Working memory is a system with a limited capacity temporarily storing and treating information (e.g., Baddeley, 1986; Baddeley & Hitch, 1974; also see section 1.4.1 from the Introduction). Working memory is an central construct in cognitive psychology, as it predicts higher cognitive skills, including reasoning and learning (e.g., Conway et al., 2005; Kane, Hambrick, & Conway, 2005). Different executive functions are in use in task switching and working memory tasks. There is also some switching in working memory, but it seems to call different executive processes. A study by Logan (2004) compared task switching and working memory. The paradigm he used involved in a single experiment (e.g., Experiment 1), task switching and working memory. There were series of tasks presented randomly that consisted either of evaluating if a stimuli was presented in the upper part or the lower part of the screen (Hi-Low), evaluating the nature of a digit (Odd-Even), or evaluating if a digit was present in digit or word form (Digit-Word). Changing tasks was the task switching component of the experiment. Participants were also required to recall the order of presentation of the task, which constituted the working memory component of the experiment. Task switching performance and working memory performance were independent of each other. Logan (2004) concluded that task switching was involving different processes than processes involved in working memory. Task switching and working memory are popular domains in which executive functioning is studied (Logan, 2004). Thus, it would be interesting to test bilinguals on working memory, a central system in contemporary psychology.

Complex span tasks to measure working memory

Complex span tasks have been widely used by Barrouillet and Camos (2010) to establish their working memory model, the Time-based Ressource-sharing Model (TBRS). With this model, they propose a new definition of cognitive load in working memory, which is of interest for our experiments. The TBRS model is based on four assumptions. First, the two functions of working memory, processing and storage, share the same limited resource, which is attention. Second, processing and storage are not performed at the same time, but one after another. Because attention can only be dedicated to one task, an individual has to switch his attention between processing and storage. Third, content placed in the focus of attention benefits from activation, though when it leaves the focus of attention it suffers from a time-decay. Four, attention is shared by a fast switching between processing and storage. This leads to a new conception of cognitive load within working memory. The more processing requires time in proportion of total available time, the higher the cognitive load. A typical complex span task might consist of memorizing series of letters. Between the presentation of each letter, the processing task might be judging the parity of series of digits (Figure 15). At the end of a trial, the participant has to write down each letter in the order of presentation.

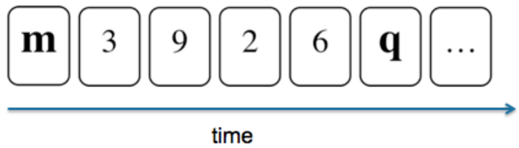

Figure 15: Example of a complex span task. Bold letters had to be recalled and the parity of the digits had to be judged by pressing a key on a keyboard.

Complex span tasks in different languages in bilinguals

Sanchez et al. (2010, Experiment 1) investigated whether bilinguals obtained a similar score if they performed the same complex span task in their L1 or in their L2. These authors conducted an experiment with English monolinguals and Spanish-English (L1/L2) bilingual young adults. Bilinguals spoke English for a minimum of 10 years. These young college students were presented two working memory tasks in English, which was their L2 for bilinguals. They completed an operation span task (Turner & Engle, 1989), in which they verified math operations, remembering series of unrelated words displayed just beside the math string. Participants were presented sets of operations in ascending order, from two to five to complete, with respectively the same number of words to remember in the correct order. Then, they completed a reading span task (Daneman & Carpenter, 1980). They had to read a sentence and to judge the likeliness of it. Next to the sentence were unrelated letters that they had to remember (Kane et al., 2004a). Participants also completed a Raven's Advanced Progressive Matrices (RAPM) (Raven, Raven, & Court, 1998). This task measured fluid intelligence, which is strongly correlated with working memory capacity (Kane et al., 2005). The task consisted of completing matrices composed of geometric patterns following a rationale. Participants had to choose the missing geometric pattern from a list of eight possible items. Bilinguals and monolinguals had similar RAPM score. Sanchez and colleagues analyzed the predicting validity of RAPM, using hierarchical regressions with operation span task and reading span task scores. For monolinguals, analysis showed that operation span task and reading span task captured the same part of variance in the RAPM. For bilinguals, operation span task captured a part of variance in the RAPM, but it was not the case for reading span task. Authors concluded that for bilinguals, reading span task was not tapping the same construct as operation span task and consequently that it was not a good measure of working memory capacity for this population. In this case, executing the reading span task in a non-native language negatively influenced the span. A task chosen adequately for a population should not be influenced by such a linguistic factor.

The present study

The aim of this study was to test how language switching increased cognitive load on a working memory task in early and late bilinguals. We compared trials performed entirely in one language - either L1, L2 or L3 - with trials including two languages, requiring a frequent language switch. Furthermore, we were interested to find out if the difference of language dominance influenced the performance in those two-language trials. Indeed, by definition a L1 is more dominant than a L2 or L3. For one-language trials, we also investigated if the language used had an effect on the performance. This last question was inspired by the study by Sanchez et al. (2010), showing that the language in which a bilingual has to complete a reading span task has its importance, although it had no importance for an operation span task. According to these results, we were interested to find out if there was a difference when a bilingual had to recall items in a cognitive task - other than a reading span task - in L2 compared to L1. This is what we investigated in these three experiments.

With this aim in mind, we used complex span tasks and made participants switch languages within trials. In our three experiments, we manipulated the nature of the items and the languages in which the task had to be done. Thus, a bilingual participant had to complete different blocks in which he had to do the trials either completely in L1 or L2, the recall in L1 and the processing in L2 and vice-versa. When the L2 was learned early (i.e, before the age of 10), we expected no difference of recall performance and processing performance compared to L1, as their L2 was learned during the first stages of development. In the study of Sanchez et al. (2010), participants were late bilinguals and obtained a smaller reading span when they performed in L2 compared to L1. There is some evidence showing that late bilinguals are executing shallower syntactic processes in real-time in their non-dominant language (Clahsen & Felser, 2006), which might explain Sanchez et al. (2010) results, as the level of syntactic processes is positively correlated to the recall performance (e.g., Friedman & Miyake, 2004). Thus, with late L2 learners, on the contrary, we expected a better working memory performance in L1 than in L2. Also, we supposed that switching language within a trial added an extra cognitive cost. Research using language switching tasks showed that language switch trials required longer response times than repetition trials to name pictures (e.g., Costa & Santesteban, 2004). According to the TBRS model (Barrouillet & Camos, 2010), a longer time needed for a process different than storage should leave less available time for storage. Thus, we expected a better recall performance in one-language trials compared to trials requiring a constant language switching between the storage task and the processing task.

Experiment 1

In the first experiment, monolinguals, early and late bilinguals completed a complex span task. The storage part of the task consisted of remembering six digits. Between each digit, two shapes were sequentially presented. Participants had to name aloud the shapes. Monolinguals only completed one block in their mother tongue. Bilinguals completed four blocks presented in random order. One block in L1, a second in L2, a third block when they read the items to be recalled in L1 and named the shapes in L2 and vice-versa for the fourth block. We also measured language proficiency, socioeconomic status (SES) and fluid intelligence using the Raven's progressive matrices (Raven et al., 1998). The reason we made participants complete these additional measures was to compare groups and to find out if there was - as we expected - homogeneity between groups in proficiency, SES and fluid intelligence. Differences on these variables could influence the working memory score (see Chapter 1).
For early bilinguals, as they were very proficient in L2, we expected no difference of recall performance and processing performance between trials when storage language was in L1 compared to trials when it was in L2. Because these participants learned their L2 in early stages of development, as it was the case for their L1, we supposed their performances would be equivalent in L1 and L2. Even though both languages are always activated in a bilingual (Hoshino & Kroll, 2008; Kroll, Bobb, & Hoshino, 2014), we hypothesized that an entire trial in a language requires less inhibition than in two-language trials, because there are repetition trials, by opposition of switch trials (Costa & Santesteban, 2004; Philipp, Gade, & Koch, 2007). Thus, we proposed that early bilinguals would show a similar performance between L1 and L2 one-language trials, because they would benefit from the repetition and need less inhibition than in two-language trials. We expected a better recall performance and processing performance in trials in one language, compared to trials in two languages. In trials in two languages, we hypothesized there was a language switching cost impairing the performance, similar to the cost found in language switching tasks (e.g., Christoffels et al., 2007; Costa & Santesteban, 2004; Declerck et al., 2013; Finkbeiner et al., 2006; Hernández et al., 2013; Meuter & Allport, 1999; Price et al., 1999). We did not expect any difference in recall and

processing between conditions in L1L2 (i.e., main task in L1, concurrent task in L2) and conditions in L2L1, as early bilinguals were very proficient in L2. Even if L1 is by definition more dominant than L2, we hypothesized the very good proficiency in both languages would result in similar performance for both processing and recall.

For late bilinguals, as they were less proficient in L2, we expected a better recall performance and processing performance when storage language was in L1 compared to when it was in L2, as Sanchez et al. (2010) found for late bilinguals in a reading span task. As with early bilinguals, we expected a better recall performance and processing performance in trials in one language, compared to trials in two languages. Again, we hypothesized there was a language switching cost impairing the performance, in regard of results in language switching tasks (e.g., Meuter & Allport, 1999). We expected a better performance on recall in L1L2 conditions, as late bilinguals were less proficient in L2. We supposed that recalling items in a significantly more proficient L1 than L2 would result in a better performance. We expected a diminished performance on processing in L2L1 compared to L1L2 conditions, according to the asymmetric language costs found in naming tasks in unbalanced bilinguals (Declerck et al., 2013; Meuter & Allport, 1999).

Method

Participants

One hundred-five psychology students (36 males; mean age= 22.5; *SD*= 2.0) were recruited at the Université de Fribourg and received experimental credits. Monolinguals (N= 26; mean age= 22.5; *SD*= 3.0) spoke only French and early bilinguals (N= 26; mean age= 22.8; *SD*= 1.7) spoke French and German, their dominant language was mainly French (N=18), although both languages have been learned before the age of 10. Dominant language from late bilinguals (N= 53; mean age= 22.3; *SD*=1.5) was French (N= 21), German (N= 11) and Italian (N= 21). Their second language was English.

Material and procedure

Participants were tested individually. First, they filled a questionnaire including a socioeconomic status test and a language proficiency test. Then, they performed a working memory span task.

Socioeconomic status test (IPSE)

We used the same socioeconomic status test as in Chapter 1, the “Indice de Position Socio-Economique“ (IPSE; Genoud, 2005) (Appendix A). See the material and procedure of this chapter for a description.

Language proficiency test

We used C-tests (Grotjahn, 1995, 2002) (Appendix B), as in Chapter 1. See this chapter for a description. For French and German C-tests, they were identical to the C-tests used in Chapter 1. Italian and English C-tests were taken from Grotjahn, Tönshoff and Hohenbleicher (1994) and Daller and Phelan (2006), respectively.

Working memory span task

The working memory span task was programmed in E-Prime 2.0 (Schneider et al., 2007). Participants had to read aloud and memorize series of six digits in their order of presentation (from 1 to 9, displayed in Arabic form, presented in random order). Between the presentation of two digits, they had to name aloud two shapes that were presented consecutively. Shapes were either circles, squares, rectangles, triangles or diamonds (Figure 16). Their color (blue, yellow, brown, black, orange, red, green, or purple) and size (about 2cm, 5 cm, or 8 cm of height and width) varied and thus there were a total of 120 different shapes in total, presented in random order.

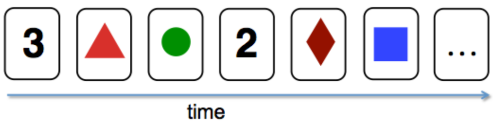

Figure 16: Example of a trial from Experiment 1. Digits had to be recalled and shapes had to be named orally.

An instruction screen explained the task and specified that naming shapes accurately was as important as memorizing digits. After a fixation point (an asterisk) presented during one second on the center of the screen, the first digit was presented, followed by two shapes, then the second digit appeared and so on. Digits and shapes were presented during one second each. Each item was presented on the center of the screen, on a white background. Digits were presented in black. Throughout the trial, the experimenter filled a form to assess the accuracy of shape naming. The experiment counted the answer as wrong when the participant gave a wrong name, did not reply or gave the name of a shape in the wrong language. After a trial, participants had to write down the numbers they remembered in the order of presentation. Then they typed it on the computer, number by number.

Monolinguals completed six trials in French. Bilinguals completed 24 trials. They were divided into four blocks: six trials in which participants had to complete the main task and the concurrent task in their dominant language (L1), six trials with both tasks in their second language (L2), six trials in which the main task was in L1 and the concurrent task in L2, and six trials with the reverse, i.e. the main task in L2 and the concurrent task in L1. The blocks were counterbalanced among participants.

Participants started with three training trials. Monolinguals completed three trials in L1L1. Early and late bilinguals completed the training as followed: a trial with the conditions L1L1 (storage task/ processing task), then a trial with the conditions L1L2 and to finish a trial with the conditions L2L1.

Raven's progressive matrices

The abbreviate version from Raven's progressive matrices (Raven, 1998) is an indicator of fluid intelligence. The test consists of a series of geometric patterns following a rationale. One has to find the missing pattern among eight possibilities. The test counts four training trials, followed by 23 trials of ascending difficulty. The participant has 20 minutes to complete the test and has to try to fill as many items as possible.

Results

We verified that groups did not differ on different characteristics. We performed on analysis of variance (ANOVA) on age with group language (monolinguals *vs* early bilinguals *vs* late bilinguals) as between-subjects factor. The monolinguals (22.5; SD=3.0) had a similar age as the early bilinguals (22.8; SD=1.7) and the late bilinguals (22.3; SD=1.5), $F<1$. An ANOVA with the same plan was performed on socioeconomic status. The monolinguals (24.5; SD=12.8) had a similar socioeconomic status (high class, from 11 to 26) than the early bilinguals (21.0; SD=7.7) and the late bilinguals (19.1; SD=8.7), the ANOVA just failed to reach significance, $F(2,102)=2.68$, $p=.07$. We compared language proficiency in L1 with an ANOVA on percentage of correct responses in a C-test. All groups scored high on the C-test for the L1. The monolinguals (96%; SD=4) had a higher percentage than the early bilinguals (93%; SD=7) and the late bilinguals (92%; SD=8), but it was only a trend, $F(2,102)=2.83$, *p*=.06. For L2, and as expected, the early bilinguals (81%; *SD*=10) were more proficient than the late bilinguals (68%; *SD*=13), *t*(77)=4.22, *p*<.001. Finally, there was no difference on Raven scores between the monolinguals (12.0; *SD*=3.7), the early bilinguals (11.8; *SD*=2.8) and the late bilinguals (11.9; *SD*=3.3), *F*<1.

Working memory task

Monolinguals vs early and late bilinguals

Concerning the working memory task, we first compared the monolinguals with the early and the late bilinguals. The monolinguals did the task only in French, which corresponded to trials in L1L1 for the early and the late bilinguals. Concerning the processing task, an ANOVA was performed on accuracy in L1L1 condition with group (monolinguals *vs* early bilinguals *vs* late bilinguals) as between-subjects factor. The monolinguals (98%; SD=2) obtained a higher percentage of correct naming than the early bilinguals (94%; *SD*=6) and the late bilinguals (86%; *SD*=8), *F*(2,104)=39.21, *p*<.001, η_p^2=.44. Further analysis showed that there was no significant difference between the monolinguals and the early bilinguals, *t*(50)=1.00, *p*=0.32. However, the monolinguals were more accurate than the late bilinguals, *t*(77)=8.30, *p*<.001 and the early bilinguals were more accurate than the late bilinguals, *t*(77)=7.30, *p*<.001. Concerning recall performance, a similar ANOVA was performed on the percentage of correct recalled digits. The monolinguals (39%; *SD*=15) recalled more digits than the early bilinguals (32%; *SD*=10), but less than the late bilinguals (51%; *SD*=16), *F*(2,102)=16.96, *p*<.001, η_p^2=.25. Further analysis showed a similar performance between the monolinguals and the early bilinguals, *t*<1. However, the monolinguals recalled less digits than the late bilinguals, *t*(77)=3.11, *p*=.003. Finally, the early bilinguals recalled less digits than the late bilinguals, *t*(77)=3.71, *p*<.001.

Early bilinguals performance

We analyzed early bilinguals performance specifically. We compared scores of this particular group between the four conditions they completed, i.e. L1L1, L2L2, L1L2 and L2L1. The following analyses answered our hypotheses about the cognitive cost induced by the switch of language within a trial. It also revealed whether performance when storage language was in L1 differed from performance when it was in L2. An ANOVA was performed on the accuracy of shape naming, with storage language (L1 *vs* L2) and number of languages in span task (one *vs* two) as within-subjects factors. There was no effect of storage language, *F*(1,25)=2.13,

p=.16 (**Figure 17**). However, participants were more accurate in the one-language condition (96%; *SD*=5) than in the two-language condition (91%; *SD*=9), $F(1,25)=24.31$, $p<.001$, $\eta_p^2=.49$. There was a significant interaction between storage language and number of languages, $F(1,25)=6.77$, $p=.02$, $\eta_p^2=.21$. We then decomposed this interaction to analyze switching costs. We analyzed whether accuracy was reduced when switching from storage in L1 to processing in L2 (i.e., L1L2 condition), switching from storage in L2 to processing in L1 (i.e., L2L1 condition), or in both cases. A planned comparison was performed with switching language and language used before switching as within-subjects factors. We analyzed the switching costs by comparing L1L1 with L1L2 conditions, and L2L2 with L2L1 conditions. Changing language when storage was in L1 reduced accuracy, $F(1,25)=15.34$, $p<.001$. Nevertheless, it was not the case when storage was in L2, $F<1$. An ANOVA was performed on recall, with storage language (L1 *vs* L2) and number of languages in span task (one *vs* two) as within-subjects factors. No effect of storage language was found, $F<1$ (**Figure 18**). Recall decreased in two-language conditions (28%; *SD*=12) compared to one-language conditions (35%; *SD*=13), $F(1,25)=24.82$, $p<.001$, $\eta_p^2=.50$. There was no interaction, $F(1,25)=2.71$, $p=.11$.

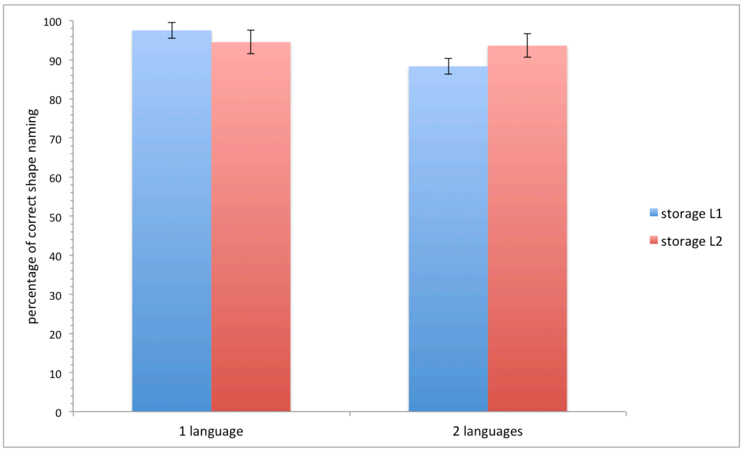

Figure 17: Percentage of accuracy in the naming task for early bilinguals, according to the number of languages and language storage.

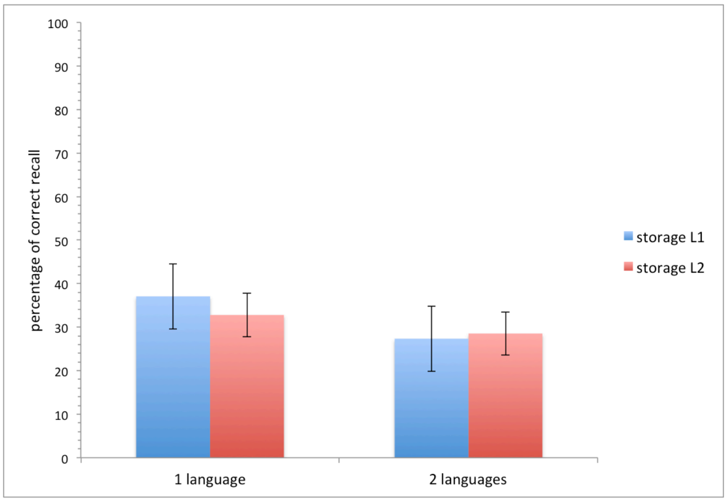

Figure 18: Percentage of recall for early bilinguals, according to the number of languages and language storage.

Late bilinguals performance

In this section, we analyzed late bilinguals performance. The goal and steps were identical to the previous early bilingual analysis. An ANOVA was performed on the accuracy of shape naming with the same design used for early bilinguals. Participants were more accurate when they had to store in L1 (80%, *SD*=10) than when they had to store in L2 (78%; *SD*=11), $F(1,52)=4.98$, $p=.03$, $\eta_p^2=.09$ (**Figure 19**). They were also more accurate in the one-language condition (83%; *SD*=8) than in the two-language condition (75%; *SD*=12), $F(1,52)=74.55$, $p<.001$, $\eta_p^2=.59$. There was an interaction between storage language and number of languages, $F(1,52)=6.99$, $p=.01$, $\eta_p^2=.12$. A planned comparison was performed with switching language and language used before switching as within-subjects factors, to analyze switching costs. Changing language when storage was in L1 reduced accuracy, $F(1,52)=58.98$, $p<.001$. It also reduced accuracy when storage was in L2, $F(1,52)=10.96$, $p=.002$. An ANOVA was performed on recall, with storage language (L1 *vs* L2) and number of languages in span task (one *vs* two) as within-subjects factors. Participants obtained a better recall performance when they had to store in their L1 (44%; *SD*=16) than in their L2 (39%; *SD*=16), $F(1,52)=12.59$, $p=.001$, $\eta_p^2=.20$ (**Figure 20**). Recall decreased in two-language conditions (37%; *SD*=16) compared to one-language conditions (46%; *SD*=16), $F(1,52)=25.64$, $p<.001$, $\eta_p^2=.33$. There was a significant interaction between storage language and number of languages in span task, $F(1,52)=15.87$, $p<.001$, $\eta_p^2=.23$. A planned comparison was performed with switching language and language used before switching as within-subjects factors. Changing language when storage was in L1 reduced accuracy,

$F(1,52)=37.51$, $p<.001$. Nevertheless, changing language when storage was in L2 did not significantly reduce accuracy, $F(1,52)=3.54$, $p=.07$. Finally, the L1 from late bilinguals were either French, German or Italian. We compared accuracy of shape naming and recall between these 3 groups. There was not any significant difference between groups in accuracy of shapes naming, $F(1,49)= 1.29$, $p= .28$, $\eta_p^2=.05$, or in recall, $F< 1$.

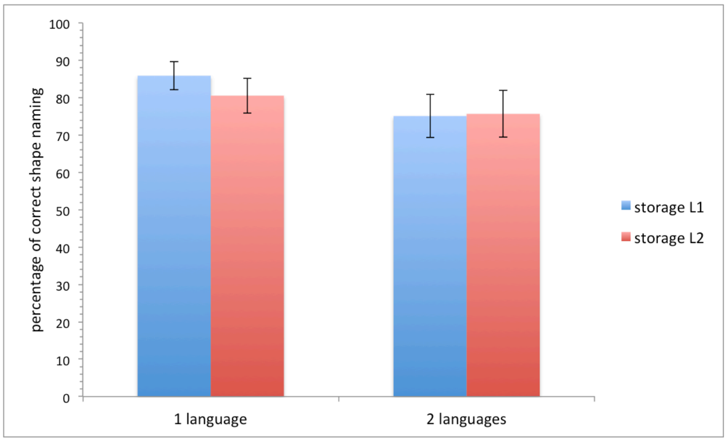

Figure 19: Percentage of accuracy in the naming task for late bilinguals, according to the number of languages and language storage.

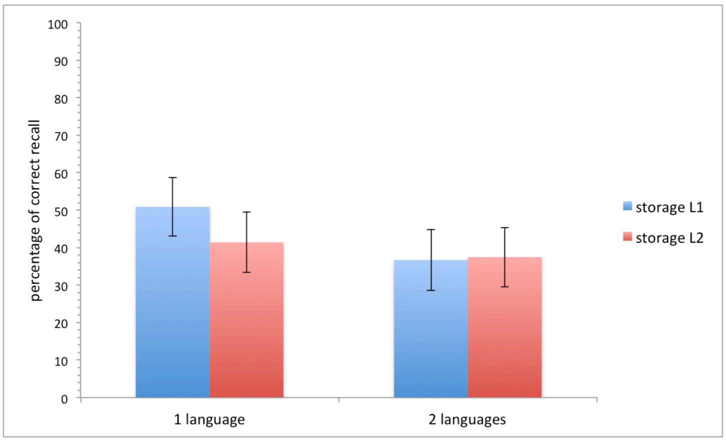

Figure 20: Percentage of recall for late bilinguals, according to the number of languages and language storage.

Early vs late bilinguals performance

Finally, we compared early and late bilinguals performance. We performed an ANOVA on shapes naming accuracy with storage (L1 *vs* L2) and number of languages in span task (one *vs* two) as within-subjects factor and language group (early *vs* late bilinguals) as between-subjects factor. No effect of storage language was present, $F<1$. Participants were more accurate in the one-language condition (71%; SD=10) than in the two-language condition

(64%; *SD*=13), *F*(1,77)=75.52, $p<.001$, $\eta^2=.50$. Early bilinguals (94%; *SD*=7) were more accurate than late bilinguals (42%; *SD*=16), *F*(1,77)=64.48, $p<.001$, $\eta^2=.46$. We found an interaction between storage language and number of language in span task, F(1,77)=13.29, $p<.001$, $\eta^2=.15$. There was an interaction between storage language and language group, *F*(1,77)=4.73, $p=.03$, $\eta^2=.06$. There was also an interaction between number of languages in span task and language group, *F*(1,77)=75.52, $p<.001$, $\eta^2=.50$. But we found no interaction between storage language, number of languages in span task and language group, $F<1$. Next, we performed an ANOVA on maintaining digits with the same plan. Participants were more accurate when they had to store in L1 (38%; *SD*=15) than in L2 (35%; *SD*=13), *F*(1,77)=7.53, $p=.008$, $\eta^2=.09$. Participants were more accurate in one-language condition (41%; *SD*=14) than two-language condition (33%; *SD*=14), *F*(1,77)=34.25, $p<.001$, $\eta^2=.31$. Late bilinguals (42%; *SD*=16) were more accurate than early bilinguals (31%; *SD*=12), *F*(1,77)=12.15, $p=.001$, $\eta^2=.14$. There was an interaction between language storage and number of languages, *F*(1,77)=13.04, $p=.001$, $\eta^2=.15$. Though there was no interaction between language storage, number of languages and group, *F*(1,77)=1.23, $p=.27$. There was no interaction between language storage and group, *F*(1,77)=1.70, $p=.20$. Also no interaction was found between number of languages in span task and group, $F<1$.

Discussion

In this first experiment, participants completed a complex span task with digits to recall and shapes to judge in this first experiment. Monolinguals were presented trials in their mother tongue. Early and late bilinguals completed four conditions: everything in L1 or L2, recalling digits in L1 and judging shapes in L2 and vice-versa. In terms of recall, monolinguals performance was similar to early and late bilinguals in L1L1 condition. Early bilinguals, among the four conditions, had an equivalent recall in L1 and L2. However, in the two-language conditions L1L2 and L2L1, recall performance was reduced. The direction of change of language (L1L2 *vs* L2L1) did not affect recall. Nevertheless, it affected negatively the accuracy of the naming task when switching from the storage task in L1 to L2 for the processing task, i.e. L1L2 condition. Late bilinguals had a better recall with trials entirely in L1 compared to trials entirely in L2. In two-language conditions, late bilinguals had their recall performance negatively affected when switching from the storage task in L1 to the processing task in L2, i.e. L1L2 condition. Yet, it was not the case when the storage task was in L2 and the processing task was in L1. The processing task was negatively affected in L1L2 and L2L1 trials, compared to one-language conditions.

These results clearly show that having to switch language within a trial in a working memory task had a significant cognitive cost, even when an individual is very proficient in L2. Early bilingual participants spoke in L2 since their early childhood and used this language frequently. Even for this population, the effect of changing language was significantly detrimental.

The processing task, i.e. naming shapes, is very easy to accomplish, even in a non-native language. Though, naming shapes for late bilinguals had a detrimental effect on their recall performance in L1L2. The easy nature of the task did not help late bilinguals to obtain similar results as in trials entirely performed in L2. Naming shapes, our processing task, can be compared to with the language-switching tasks literature. Our result is in line with research on language costs in bilinguals, showing there is a cognitive cost in a naming task when switching languages within the task (e.g., Declerck et al., 2013; Meuter & Allport, 1999).

Finally, we investigated the lower processing accuracy when early bilinguals switched from the storage task in L1 to L2, i.e. the L1L2 condition, to accomplish the processing task. As mentioned earlier, early bilinguals did not have a lower accuracy on L2L1 condition compared to one-language conditions, meaning they obtained a lower processing accuracy in two-language conditions only when they had to process in L2 compared to one-language conditions. We found two possible reasons. First, it might be due to the use of digits as items for the storage task. When participants memorized digits, even if they read it in L2, they could have memorized it in L1. So they would not be any switch of language between actual recall and processing, as participants had already switched language after reading the digit. On the contrary, in L1L2 condition, there is anyway a language switch between actual recall and processing. Thus, it would explain the difference of accuracy in the processing task between L1L2 and L2L1 conditions. Second, another possibility would be that switching from L2 to L1 is easier than switching from L1 to L2. Wang, Xue, Chen, Xue and Dong (2007) scanned Chinese-English bilinguals using fMRI during a picture naming task. Participants had to name pictures in L1 or in L2 according to a cue. The fMRI showed that switching in L1 was more straightforward than switching in L2. In the later, additional zones, i.e. the bilateral frontal cortices and the left anterior cingulate cortex, were activated, resulting in a longer process to accomplish the language switch. To disentangle these two assumptions, we designed in Experiment 2 a similar complex span task, but participants had to recall two-syllable words of similar occurrence in German and French. This way, the language used to recall the items is very likely the one used to read the items. If participants from Experiment 1 recalled in L1 the digits read in L2, in Experiment 2 processing accuracy should be impaired for both L1L2 and L2L1 conditions. If early bilinguals from Experiment 1 obtained a lower processing accuracy in the L1L2 condition, compared to the L2L1 condition because it is more difficult to switch in L2, processing accuracy should be impaired in L1L2 conditions only.

Experiment 2

The aim of this second experiment was to use words as to be remembered items in L1 or L2. In Experiment 1, participants had to read aloud numbers they had to recall. They read digits in the language required by the trial. However it is possible they recalled digits in their other language, i.e. they recalled in L1 digits read in L2. In Experiment 2, items to be recalled were two-syllable words with similar frequency of occurrence. The processing task was naming aloud digits in the language required by the trial. Moreover, we varied the pace, which was either slow or fast for the processing task. The aim of using two paces was to further investigate cognitive load. Barrouillet and Camos (2010) showed that a same processing task executed under stronger temporal constrains impeded performance. By using two paces and two languages, a dominant compared to a second language, we investigated the relationship between these two variables.

We expected no difference of recall and processing when storage language was in L1 compared to when it was in L2. Thus, we aimed to replicate the results from Experiment 1, with words to recall instead of digits. As participants were early bilinguals, Experiment 1 showed this particular group had similar performance in those two conditions. We expected a better recall and processing in trials in one language, compared to trials in two languages, as highlighted in the language switching task literature (Costa & Santesteban, 2004; Philipp, Gade, & Koch, 2007). Experiment 1 showed that switching languages during a trial impaired performance, so we should replicate these results. We expected a lower performance in digit naming in these mixed-language conditions in both cases (i.e. switching from L1 to L2 and from L2 to L1), because we privileged the assumption that participants from Experiment 1 recalled the L2-read digits in L1. However, we did not expect any difference in recall between L1L2 conditions (i.e. storage task in L1, processing task in L2) and L2L1 conditions, as early bilinguals were very proficient in L2. We expected a better recall performance and processing performance in slow pace compared to fast pace, according to the complex span task literature (e.g., Barrouillet and Camos 2010).

Method

Participants

Forty-one students (10 males; mean age= 21.6; *SD*= 1.4) were recruited at the Université de Fribourg and received experimental credits. Monolinguals (N= 22; mean age= 21.6; *SD*= 1.4) spoke only French (N= 17) or German (N= 5). Early bilinguals (N= 19; mean age= 21.7; *SD*= 1.9) spoke French and German, their dominant language was either French (N= 11) or German (N= 8). Both languages have been learned before the age of 10.

Material and procedure

As in Experiment 1, the procedure was the same, except for the following changes in the working memory span task. Participants had to read aloud and recall series of four words (**Figure 21**). These were two-syllable words of similar frequency of occurrence. Words in French were selected from the Brulex lexical database (Mousty & Radeau, 1990) and words in English were taken from the Celex lexical database (Baayen, Piepenbrock, & van H. Rijn, 1993). As recall performance in Experiment 1 was low, this time participants had to recall four items instead of six. Between each word, they had to name aloud four digits (from 1 to 9, displayed in Arabic form) that were presented consecutively. There were two possible paces: slow (1200 ms) or fast (800 ms), presented randomly.

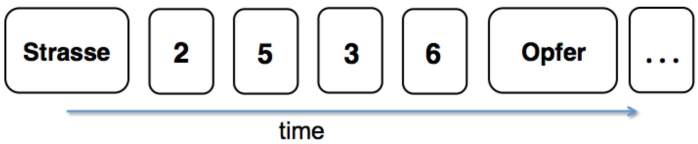

Figure 21: Example of a trial in Experiment 2. Words had to be recalled and digits had to be named orally.

Results

We first verified that participants did not differ on different characteristics. The monolinguals (21.6; *SD*= 1.4) had similar age as the bilinguals (21.7; *SD*= 1.9), $t < 1$. In terms of socioeconomic status, monolinguals (18.0; *SD*= 8.7) scored in the similar high-class status (from 11 to 26) as bilinguals (20.5; *SD*= 8.2), $t < 1$. We then analyzed proficiency in L1 by comparing percentages of correct responses in the C-test. Monolinguals (89.0%; *SD*= 8.6) obtained a similar score as bilinguals (89.0%; *SD*= 8.4), $t < 1$. We then compared Raven scores. There was no difference between monolinguals (11.7; *SD*= 3.3) and bilinguals (12.7; *SD*= 3.4), $t < 1$.

Working memory task

Monolinguals vs bilinguals performance

We first compared monolinguals with bilinguals. The monolinguals only completed the task in the L1L1 condition, i.e. in French (N=17) or in German (N=5), according to the L1 of the participant. Thus, we compared their performance with the one from the bilinguals in the same condition, i.e. in French (N=11) or in German (N=8) according to the dominant language of the bilingual participant. To analyze the processing task, naming digits, an ANOVA was performed on accuracy of shape naming with pace (slow *vs* fast) as within-subject factor and group language (monolinguals *vs* bilinguals) as between-subject factor. There was a pace effect, the faster the pace, the lower the naming accuracy (99.4%; *SD*= 0.8, for the slow pace and 98.9%; *SD*= 1.4, for the fast pace), $F(1,39) = 6.39$, $p = .02$, $\eta_p^2 = .14$. There was no difference between the monolinguals (99.3%; *SD*= 1.0) and the bilinguals (99.1%; *SD*= 1.1), $F < 1$ and no interaction, $F < 1$. A similar ANOVA was performed on the percentage of correct recalled words. The faster the pace, the lower the recall (62.9%; *SD*= 17.8, for the slow pace and 57.9%; *SD*= 15.7, for the fast pace), $F(1,39) = 6.62$, $p = .01$, $\eta_p^2 = 15$. There was no difference between monolinguals (62.0%; *SD*= 17.6) and bilinguals (59.0%; *SD*= 15.9), $F < 1$. There was no interaction, $F(1,39) = 2.27$, $p = .14$.

Bilinguals performance

As there was no difference between monolinguals and bilinguals, we analyzed bilingual performance on working memory among the four conditions they completed, i.e. L1L1, L2L2, L1L2 and L2L1. These analyses answered our hypotheses about performance when storage language was in L1 or in L2, and trials in one or two languages. Very importantly, analyses tested two assumptions suggested to account for a lower processing accuracy in L1L2 conditions in Experiment 1. We hypothesized it could be due either to the use of digits for the storage tasks, or because it was easier to switch in L1 compared to L2. An ANOVA was performed on the accuracy of digits naming with pace (slow *vs* fast), storage language (L1 *vs* L2) and number of languages in span task (one *vs* two) as within-subjects factors. There was no pace effect (98.6%; *SD*= 2.5, for the slow pace and 98.0%; *SD*= 2.4, for the fast pace), $F(1,18) = 1.91$, $p = .18$. There was no effect of storage language (98.7%; *SD*= 1.8, for storage in L1 and 97.9%; *SD*= 3.2, for storage in L2), $F(1,18) = 1.95$, $p = .18$. There was no effect of the number of languages used in span task (99.1%; *SD*= 1.3, for one language and 97.5%; *SD*= 3.7, for two languages), $F< 1$. There was an interaction between storage language and number of languages, $F(1,18)= 10.05$, $p= .005$, $\eta_p^2= .36$. We analyzed whether accuracy was reduced in L1L2 condition, L2L1 condition, or in both conditions. A planned comparison was performed with switching language and language used before switching as within-subjects factors. As in Experiment 1, to analyze the switching costs, we compared L1L1 with L1L2 conditions, and L2L2 with L2L1 conditions. This time, accuracy was reduced for both conditions, (for L1L2 condition, F(1,18)= 8.92, $p= .005$, and for L2L1 condition, $F(1,18)= 7.32$, $p= .01$). There was no other significant interaction, $Fs< 1$.

A similar ANOVA was performed on the percentage of correct recalled words. There was a pace effect, the faster the pace, the lower the recall, (63.8%; *SD*= 19.9, for the slow pace and 56.1%; *SD*= 17.9, for the fast pace), $F(1,18)= 12.48$, $p= 12.48$, $p= .002$, $\eta_p^2= .41$ (Figure 9). Participants performed better when they had to recall in L1 (62.2%; *SD*= 17.8) compared to L2 (57.8%; *SD*= 20.0), $F(1,18)= 4.68$, $p= .04$, $\eta_p^2= .21$. There was no difference whether the task was in a one language (60.3%; *SD*= 18.2) or two languages (59.7%; *SD*= 19.7), $F< 1$. There was no interaction between storage language and number of languages, $Fs< 1$, storage language and pace, $Fs< 1$, number of languages and pace, $Fs< 1$, or storage language, number of languages and pace, $F(1,18)= 1.10$, $p= .31$.

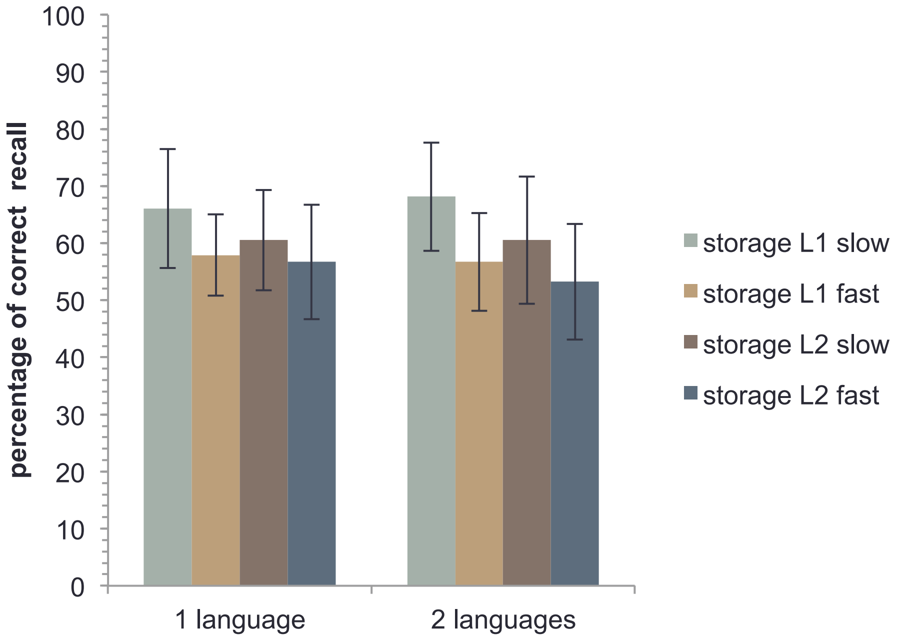

Figure 22: Percentage of recall in bilinguals, according to the number of languages, language storage and pace.

Discussion

In Experiment 2, early bilinguals completed a complex span task including words to recall and digits to read. Contrary to Experiment 1 in which participants could possibly remember digits in L1 even if they were instructed to read them in L2, words compelled participants to remember them in the language they read them. In this experiment, two different paces in which the processing task was presented were also added. Concerning the processing task, there was no pace effect, no effect of storage language and no effect of number of languages used in span task. However, there was an interaction between the storage language and the number of languages. Concerning the recall, there was a pace effect, with a lower recall in the faster pace condition. Words were better recalled in L1 than in L2. Yet, performance in one language or two languages within a trial were similar.

The main goal of this experiment was to disentangle the reasons why early bilinguals in Experiment 1 obtained a lower accuracy in the processing task when they switched from the storage task in L1 to the processing task in L2 than in the L2L1 condition. In Experiment 2, accuracy was impaired for both L1L2 and L2L1 conditions. These results seem to confirm that early bilinguals from Experiment 1 remembered in L1 digits they were reading in L2. Concerning the processing task, there was no pace effect. Participants had to name digits. This task could have been so easy that temporal constraints did not influence accuracy.

Concerning the effect of number of languages in the span task, in Experiment 1 accuracy was lower for two-language conditions. Accuracy was similar in both conditions in Experiment 2, but it is interesting to point out that percentage of accuracy was very high for both conditions. Again, this task might have been easier than naming digits and a change of language might have not influenced accuracy for this reason. As percentage of accuracy was similar and very high, it would be useful to measure response times among conditions to find out if there are differences at this level. This is what we tested in Experiment 3.

Concerning the recall, performance was better for trials requiring storage in L1 compared to trials requiring storage in L2. As L1 was the dominant language, even if bilinguals were very proficient in both languages, it was easier for them to memorize words in their L1. In Experiment 1, there was no difference between storage in L1 and L2, but items to be recalled were digits. Also, in the present experiment, there was no significant difference between one-language trials compared to two-language trials. In Experiment 1, participants obtained a better performance for one-language trials. It is again crucial to highlight that participants had to recall words, whereas in Experiment 1 they had to recall digits. As recalling words has a stronger linguistic component than recalling digits, participants were obviously not impaired by the processing task in L2 when they had to store in L1, and vice-versa. It is not surprising that the difference of the nature of the items, i.e. digits vs words, make a different pattern of results as well.

In Experiment 1, we tested monolinguals, early and late bilinguals. It would be interesting to test the performance of early bilinguals in three languages. Two very proficient languages learned before the age of 10 and a third language learned after the age of 10. Would the performance in a third language learned after the age of 10 with some good proficiency be different than a L2? Would a performance in L1L3 two-language condition be different than a L1L2 performance? Those two questions were the aim of Experiment 3. We also measured response times on the processing task to complete our understanding of this part of the task. In the two previous experiments, the processing task accuracy was very high and similar between language conditions. But are response times also similar between language conditions? We these aims in mind, we designed a three-language experiment in which participants will be tested in their L1 (German), L2 (French) and L3 (English).

Experiment 3

In Experiment 1, early and late bilinguals formed two distinct groups. In this last experiment, we recruited participants who were proficient in two languages learned before the age of 10 and practiced a third language learned after the age of 10, i.e. English. In Switzerland, English is now frequent in the life of a college student. Such an individual uses English on the Internet, when watching movies in English versions, during communication with foreign students, and so on. Though, this is a language learned lately in Switzerland, after the age of 10. One of the goals of this last experiment was to investigate the effects of these three languages on cognitive cost in a working memory task. The design of Experiment 3 allowed testing these effects within subjects. Also, the processing task was very accurate among language conditions in the two previous experiments. Information that was not available about the processing task was how fast participants answered when the stimulus was presented. We had no way to analyze whether response times were different among the conditions. Accuracy in the processing task was similar between language conditions, but they may be significantly different in response times, according to the language tested. In this experiment, we measured response times with a voice key. In this working memory task, words had to be recalled and color had to be named as the processing task. As in Experiment 2, there were the two same paces, slow *vs* fast.

The hypotheses concerning L1-L2 relations were the following. We expected no difference of processing between trials with storage language in L1 compared to storage language in L2. In Experiments 1 and 2, early bilinguals obtained similar processing scores with storage in L1 and L2. The processing task, consisting of naming colors, was easy and thus we expected no difference of accuracy. For the same reason, we expected no difference of processing between one-language trials compared to two-language trials, as in Experiment 2. In terms of response times in the processing task, we expected a faster answer in L1 compared to L2 and in one-language compared to two-language trials. First, L1 is the dominant language, that is why we expected a faster answer. Second, in two-language trials, participants had to constantly switch between the storage task and the processing task. The language switching should demand more time. Literature on language switching tasks showed that language switch trials required longer response times than repetition trials to name pictures (e.g., Costa & Santesteban, 2004). Concerning the recall, we expected a better recall in trials with storage in L1 compared to trials with storage in L2, as observed in Experiment 2, because items to be recalled were words as in Experiment 2. We expected no difference of recall between one-language trials compared to two-language trials, as in Experiment 2. The hypotheses concerning L1-L3 relations were the following. We expected a better processing score in trials when storage language was in L1 compared to when it was in L3. The later is a language learned after the age of 10. As this language has been learned from or later than 10 years old, we hypothesized it would be more difficult for participants to switch between L1 and L3, compared to switching between L1 and L2, which they were used to do on a very regular basis since childhood. Indeed, in Experiment 1, late bilinguals obtained a better processing score in the language learned before the age of 10 (L1) than in the language learned after the age of 10 (L2). For the same reasons, we expected a better processing score in one-language trials compared to two-language trials, as late bilinguals in Experiment 1. In terms of response times in the processing task, for the same reason as with L1L2 conditions, we expected a faster answer in L1 compared to L3 and in one-language compared to two-language trials. In terms of recall, we expected a better recall performance in trials with storage language in L1 compared to L3, as for late bilinguals in Experiment 1. Clahsen and Felser (2006) showed that late bilinguals were processing their non-dominant less deeply than their L1, which could explain a better recall in L1 than L3, as the level of syntactic processing is positively related to recall span (e.g., Friedman & Miyake, 2004). We also expected a better recall performance in one-language trials compared to two-language trials, as for late bilinguals in Experiment 1.

Method

Participants

Fifteen students (6 males; mean age= 22.8; *SD*= 2.7) were recruited at the Université de Fribourg. Participants were early bilinguals speaking German as L1, French as L2 and English as L3. German and French were learned before the age of 10 and English after the age of 10. Participants scored in the high-class socioeconomic status, (25.1, *SD*= 12.2).

Material and procedure

Procedure was similar as in Experiment 2, except that the processing task was naming aloud four colors from a list of six possible colors (blue, brown, yellow, black, red and green) that were presented consecutively. Response times were measured with a voice key.

Participants completed 28 trials, which were divided in seven blocks: four trials where they had to complete the main task and concurrent task in their dominant language (L1), four trials in their second language (L2) and four trials in their third language (L3) (see Table). Then four trials with the main task to be completed in L1 and the concurrent task in L2, four trials with the main task to be completed in L2 and the concurrent task in L1. Eventually four trials with the main task to be completed in L1 and the concurrent task in L3, four trials with the main task to be completed in L3 and the concurrent task in L1. The blocks order was randomized across participants. Participants started with three training trials. They completed the training as followed: a trial with the conditions L1L1 (main task/ concurrent task), then a trial with the conditions L1L2 and to finish a trial with the conditions L2L1.

		name/ recall digit		
		L1	L2	L3
name color	L1	L1L1	L2L1	L1L3
	L2	L1L2	L2L2	
	L3			L3L3

Figure 23: the language conditions in Experiment 3.

Results

An ANOVA was performed on the percentage of correct responses in the C-tests with language (L1 *vs* L2 *vs* L3) as within-subject factor. There were significant differences between languages, (88.9%; *SD*= 9.6, for L1, 77.8%; *SD*=7.9, for L2 and 72.8%; *SD*= 14.6, for L3), $F(2,28)= 6.17$, $p= .006$, $\eta_p^2= .31$. Further analyses showed there were significant differences between L1 and L2, $t(14)= 2.70$, $p= .02$, and L1 and L3, $t(14)= 3.34$, $p= .005$. However, there was no significant difference between L2 and L3, $t(14)= 1.35$, $p= .20$. Raven score (11.9; *SD*= 3.7) was similar to the score from monolingual and bilingual participants in Experiment 1 (11.9; *SD*= 3.3) and Experiment 2 (12.2; *SD*= 3.4), $F< 1$.

Working memory task

Participants were tested in one-language conditions L1, L2 or L3 and two-language conditions L1L2 or L1L3. In the following analysis, we first analyzed and compared one-language L1 and L2 conditions and the two-language L1L2 condition. Secondly, we compared one-language L1 and L3 conditions and the two-language L1L3 condition.

L1, L2 and L1L2 conditions

The following analyses will answer our hypotheses about the relations between the two languages participants learned before the age of 10. An ANOVA was performed on the accuracy of colors naming with pace (slow *vs* fast), storage (L1 *vs* L2) and number of languages in span task (one *vs* two) as within-subject factors. There was a pace effect, the faster the pace, the lower the accuracy, (97.4%; *SD*= 5.2, for the slow and 94.7%; *SD*= 7.5, for the fast pace), $F(1,21)= 11.40$, $p= .003$, $\eta_p^2= .35$. There was no effect of storage language, (96.3%; *SD*= 6.3, for storage in L1 and 95.8%; *SD*= 6.4, for storage in L2), $F< 1$. There was no effect of number of languages, (96.4%; *SD*= 5.9, for one language and 95.7%; *SD*= 6.8, for two languages), $F< 1$. There was no significant interaction, ps$\geq .28$. We then analyzed response times on the processing task. We took response times for the first color to name after a presentation of a word to recall, because they are precisely the only times there is a switch from the storage task to the processing task. A similar ANOVA was performed on the response times. There was a pace effect, the faster the pace, the faster the answer, (666 ms; *SD*= 183, for the slow and 457 ms; *SD*= 138, for the fast pace), $F(1,14)= 38.67$, $p< .001$, $\eta_p^2= .73$. There was no effect of language storage, (564 ms; *SD*= 167, for storage in L1 and 558 ms; *SD*= 154, for storage in L2), $F< 1$. There was no effect of number of languages, (568 ms; *SD*= 157, for one language and 555 ms; *SD*= 164, for two languages), $F< 1$. There was no significant interaction, ps$\geq .35$. A similar ANOVA was performed on the percentage of correct recalled words. There was no pace effect (56.5%; *SD*= 25.9, for the slow and 53.6%; *SD*= 25.6, for the fast pace), $F< 1$. There was no effect of storage language, (56.1%; *SD*= 23.9, for storage in L1 and 54.0%; *SD*= 27.6, for storage in L2), $F< 1$. There was no effect of the number of languages, (57.9%; *SD*= 25.6, for one language and 52.1%; *SD*= 26.0, for two languages), $F(1,14)= 2.02$, $p= .18$. There was no significant interaction, Fs< 1.

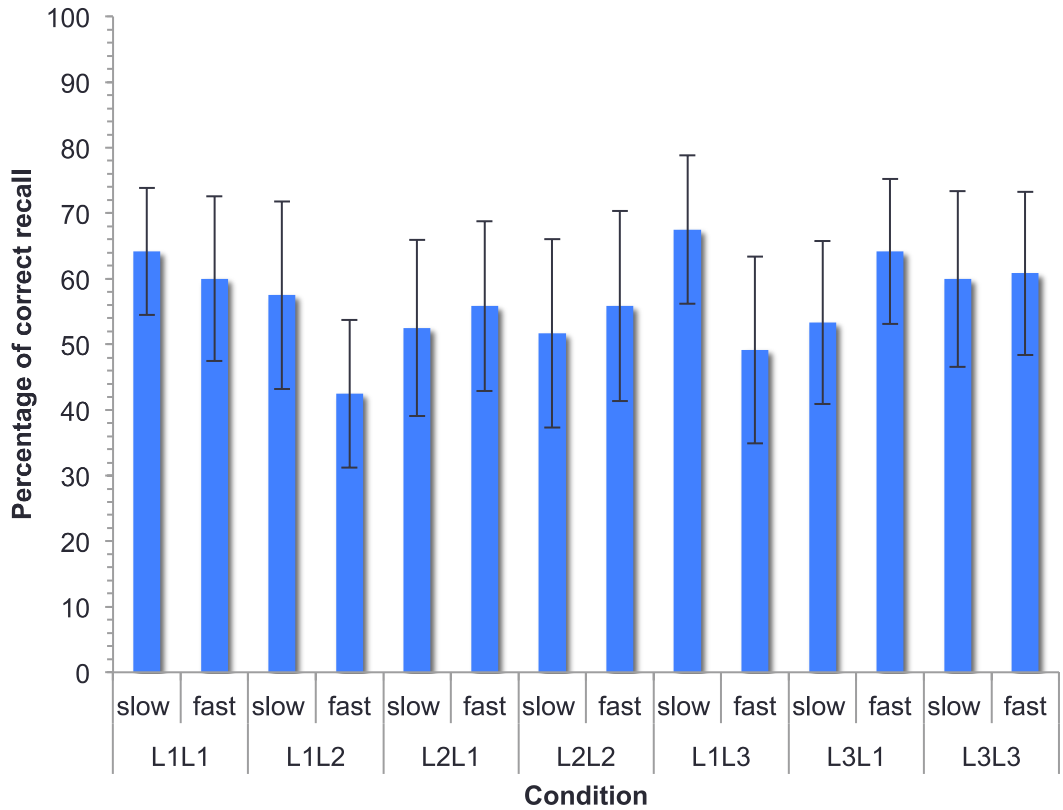

Figure 24: Percentage of recall, by language condition and pace.

L1, L3 and L1L3 condition

The following analyses will answer our hypotheses about the relations between the L1 and a language learned after the age of 10, the L3. An ANOVA was performed on the accuracy of colors naming with pace (slow *vs* fast), storage (L1 *vs* L3) and number of languages in span task (one *vs* two) as within-subjects factors. As expected, the faster the pace, the lower the percentage of correct naming, (98.3%; *SD*= 2.37, for the slow and 93.9%; *SD*= 8.4, for the fast pace), $F(1,14)= 9.82$, $p= .007$, $\eta_p^2= .21$. There was no significant different if storage was in L1 or L3, (95.8%; *SD*= 6.5, for storage in L1 and 96.4%; *SD*= 4.3, for storage in L3), $F< 1$ (Figure 10). There was an effect of number of languages, but it was only a trend, (96.9%, *SD*= 3.8, for one language and 95.3%, *SD*= 7.0), $F(1,14)= 3.8$, $p= .07$, $\eta_p^2= .21$. There was no interaction, $ps \geq .18$. An ANOVA with the same design was performed on response times. There was a pace effect, the faster the pace, the faster the answer, (685 ms; *SD*= 177, for the slow and 465 ms; *SD*= 142, for the fast pace), $F(1,14)= 42.57$, $p< 001$, $\eta_p^2= .75$ (Figure 11). There was no effect of language storage, (573 ms; *SD*= 151, for storage in L1 and 577 ms;

SD= 169, for storage in L3), $F< 1$. There was no effect of number of languages, (599 ms; *SD*= 151, for one language and 551 ms; *SD*= 168, for two languages), $F< 1$. There was no interaction, $ps \geq .30$. Finally, a similar ANOVA was performed on the percentage of correct recalled words. There was no pace effect, (61.3%; *SD*= 23.4, for the slow and 58.6%; *SD*= 25.1, for the fast pace), $F(1,14)= 1.54$, $p= .23$. (Figure 12). There was no effect of language storage, (60.2%; *SD*= 23.9, for storage in L1 and 59.6%; *SD*= 24.6, for storage in L2), $F< 1$. There was no effect of number of languages, (61.3%; *SD*=24.0, for one language and 58.6%; *SD*= 24.6, for two languages), $F< 1$. There was no interaction, $ps \geq .15$.

Discussion

We wanted to measure response times on the processing task of this last experiment, because the accuracy of the processing task was very high in the previous experiments, resulting in similar performance on this task most of the time. Response times could be a sharper measure allowing to observe differences between conditions that were not observed on the accuracy. In this case, it would show a language effect, response times being different if processing was in L1 or in a medium or highly proficient L2. Participants completed a complex span task in which they had to recall words as storage task and name colors as processing task. They were two paces and three languages. Concerning processing for L1-L2 relations, there was a pace effect, the faster the pace, the lower the accuracy, but it was only a trend. There was no effect of the language storage and no effect of the number of languages within a trial. In terms of response times, there was a pace effect, the faster the pace, the faster the response times. There was no effect of the storage language and no effect of the number of languages. Concerning the recall, there was no pace effect, neither any effect of the storage language and the number of languages. About processing for L1-L3 relations, there was a pace effect, the faster the pace, the lower the accuracy. There was no effect of the storage language. Processing accuracy was better for one language, but it was only a trend. Concerning response times, there was a pace effect, the faster the pace, the faster the response times. There was no effect of the storage language and no effect of the number of languages. In terms of recall, there was no pace effect, no effect of language storage and no effect of the number of languages. We will first discuss response times, then processing accuracy and eventually recall performance.

In terms of response times, as much for L1-L2 relations as for L1-L3 relations, there was no effect of the storage language and the number of languages within a trial. We propose two possible explanations. First, according to language proficiency C-tests, participants were as proficient in L3 as in L2. English (L3) shares the same roots as German (L1); they are both West Germanic languages. It could be the reason participants were so proficient in L3. Consequently, proficiency in the three languages used in the experiment could explain the similarity in response times. Second, the processing task, color naming, may have been too easy to encounter significant differences. Both explanations can be true at the same time and contribute to the response times results. In a future experiment, it would be ideal to choose three linguistically distant languages.

Concerning processing in L1-L3 relations, unexpectedly, there was no effect of the pace. This lack of effect is due to the fact that the cognitive load of the processing task is similar in the slow and the fast pace for the participants. We calculate the cognitive load by dividing the mean response time with the total time available. Thus, the cognitive load of the slow pace was 685 ms/ 1200 ms= 57.08. The cognitive load of the fast pace was 465 ms/ 800 ms= 58.13. As the cognitive load was similar between these two pace conditions, it was unsurprising that there was no pace effect. To test the effect of the cognitive load by varying the pace of the processing task, we should have pretested the cognitive load produced by varying the pace.

Finally, concerning the recall in L1L2 and L1L3 relations, there was no effect of the storage language and the number of languages. This is surprising, as in Experiment 1, early bilinguals obtained a better recall in one-language trials compared to two language trials and late bilinguals obtained a better recall in L1 than in L2 trials and in one-language than in two-language trials. One major difference is that in Experiment 1, participants had to recall digits, whereas in Experiment 3 they had to recall words. This difference could reflect a difference of level of processing (e.g. Craik & Tulving, 1975; Rose & Craik, 2012): recalling words requires a deeper level of processing than digit processing. We will develop this idea in the General Discussion.

General discussion

In this study, we investigated the cost of switching languages during computer-paced complex span tasks in early and late bilinguals. In Experiment 1, in which participants recalled digits, there was a cost of switching languages within a trial, impairing recall performance. But in Experiment 2 and 3, in which words had to be recalled, there was no cost of language switching. The presence of this cost was related to the type of items to recall. Remembering words, a task associated more deeply with language processes (e.g., Craik & Tulving, 1975) than remembering digits, was not influenced by the change of the language in the processing task. This is one of the key findings of this series of experiments. We will discuss further below some parallels we can draw from the literature. Another question was whether there would be a difference in recall performance between trials with L1 or L2 as the storage language, for a task that is not a reading span, this specific complex span task being intrinsically linked to language. Sanchez et al. (2010) found that assessing a reading span task in a non-native language was not a good measure of working memory capacity. Among the versions of the task we used, none is as linked to language as a reading span. But our results are in line with results from Sanchez et al. (2010): when items to recall were digits (Experiment 1), there was no difference of recall performance between storage in L1 or in L2 in early bilinguals. But when items to recall were words (Experiment 2 and 3), recall performance was better when storage was in L1 than L2 for the same population (Experiment 2). However, it was not the case in Experiment 3 in which participants were presented trials in 3 languages. The L1 recall performance was similar the L2 or L3 recall performance. We will discuss this later finding below.

Concerning late bilinguals, in Experiment 1, these participants obtained better performances in L1 and in one-language trials for both processing and recall, as predicted. As they were less proficient in L2 than early bilinguals, they were more impaired by trials in L2 and trials in two languages. In Experiment 3, participants were tested in three languages. L1, a L2 learned before the age of 10 and a L3 learned after the age of 10. There were presented trials in two different paces: slow or fast. There was a pace effect in the processing task, the slower the pace the more accurate the processing task, but there was no effect of language storage or number of languages in the trial. In terms of recall, there was no pace effect, no effect of language storage and no effect of the number a languages in the trial.

We will develop three points. First, we will discuss the effect of the number of languages in the task, i.e. language switching costs. The effect of the number of languages within the task was not ubiquitous in early bilinguals results. Rather, it depended of the nature of items to recall. Second, we will discuss the difference of performance between early and late bilinguals. Third, we will discuss the encoding strategies used to remember the items, being digits or words, and their effect on the results.

Effect of the number of languages

The effect we found in the recall performances of digits with two-language trials compared to one-language trials is congruent with the results on language switching tasks, whereas the later consist of naming items. Declerck et al. (2013) tested German/English bilinguals from different proficiencies, i.e. from low to high proficiency self-rated by participants in a 7 points scale. Bilinguals had to name a weekday sequence in the correct serial order, but in a language-switching sequence they had to learn beforehand. A language-switching sequence was for example " L1-L1-L2-L2-L1-L1 ". Language-switch trial responses were slower than language-repetition trials for all participants, i.e. a trial that had to be named in the same language as the previous one, independently of the their proficiency. Christoffels et al. (2007) tested late unbalanced German/Dutch bilinguals on a picture naming task. Bilinguals' proficiency spread from low to medium. Trials consisted of either naming pictures only in L1 or L2, or in L1L2 alternating from one language to the other. Late bilinguals were significantly naming pictures faster in L1 than in L2, as we also found for late bilinguals in Experiment 1. An important difference in our study is that participants had to recall the items, whereas in language switching tasks the participants had to name items. Thus, our study adds some findings from a different perspective on language switching in bilinguals. Our study, assessing working memory capacity in bilinguals, used a different kind of task, namely a specific complex span task with items to recall (i.e. the storage component of the task) with items to name in-between the presentation of each item to be recalled (i.e. the processing component of the task). This is in our knowledge the first time a bilingual study is carried with this specific complex span task. Furthermore, studying language switching in a working memory task is a different way of investigating that completes the findings stemming from language-switching naming tasks.

Difference in recall performance between early and late bilinguals

Early and late bilingual recall performance was not similar on all conditions. For example, in Experiment 1, recall performance was equivalent between one-language conditions L1 and L2 for early bilinguals, but recall performance was better in L1 than in L2 for late bilinguals. If one considers an important difference between early and late bilinguals in our Experiment 1, which is proficiency, our results are in line with research on language switching tasks. Early bilinguals obtained 81% (*SD*= 10) of correct responses on the language test, whereas late bilinguals were significantly lower (68%; *SD*= 13). Thus, Poulisse and Bongaerts (1994) showed in a language switching study that a lower proficiency in L2 (English) had a negative impact on the number of lexical intrusions from the L1 (Danish) which were more frequent than with a higher proficiency in L2. Thus, low proficient L2 learners of English were more impeded than higher proficient L2 learners. The difference we found about early and late bilingual could be interpreted using the inhibition model (Green, 1998; for a detailed presentation of the inhibition model see the Introduction or Chapter 1). The inhibition model proposes that a language in which a bilingual do not wish to use has to be inhibited. This model is congruent with Hoshino and Kroll (2008) findings, showing that both languages of bilingual are always activated. Using the inhibition model with our results, we propose two explanations that could be mutually true: the inhibitory system of very proficient bilinguals is either more trained and/or different than low proficient bilinguals. Further research should be carried to test these two hypotheses.

The encoding strategies used to remember the items

In Experiment 3, there was no effect of the storage language or the number of languages in a trial, whereas in Experiment 1, both early and late bilinguals obtained a better recall in one-language than in two-language trials and late bilinguals obtained a better recall in L1 than in L2. In Experiment 1, items to be recalled were digits, whereas in Experiment 3 participants had to recall words. This difference of results can be explained by research on the use of maintenance strategies, according to the nature of the task and the nature of the items to be recalled. Complex span tasks demand mainly the use of the secondary memory (i.e. long term memory) (e.g., Bailey, Dunlosky, & Kane, 2011). In such a task, as the series of items to be recalled is larger than the primary memory (i.e. the focus of attention; Cowan, 1999), the items have to be recalled from the secondary memory. To recall items from a complex task, an individual has to use an efficient encoding strategy. Research showed that the two most efficient strategy used by participants is imagery and sentence generation and the less efficient strategy was repetition (e.g., Bailey, Dunlosky, & Hertzog, 2009; Bailey, Dunlosky, & Kane, 2008; Dunlosky & Kane, 2007). Imagery consists of thinking of an image of the item to be recalled and sentence generation consists of creating a sentence or sentences that contain the items to be recalled.

In our study, as a reminder, Experiment 1 consisted of recalling digits, whereas Experiment 3 consisted of recalling words, in the order of presentation for both experiments. In the later case, it was possible to use imagery or sentence generation. It was unlikely - if not impossible

- to use these two strategies with digits on the 24 trials a participant had to complete (Experiment 1). It could maybe happen if by chance, the digit order to recall corresponded to a familiar pattern of the participant, (e.g., his birthday date), which was very unlikely. Even if it happened, it would happen a couple of times and not be impacted on the overall performance. Whereas in Experiment 3, in which words had to be recalled, imagery and sentence generation were possible, whatever the language in which the items had to be recalled. This is why we think the recall performance in Experiment 3 was similar among all conditions. In Experiment 1, as these two most effective strategies were not possible to use, the recall performance was likely more sensitive to the number of languages within the trial with a less effective strategy, two languages compared to one language within a trial adding a significant extra cognitive charge.

Conclusion

The three experiments we carried showed that the nature of items to recall have a major influence on the working memory task performance. The level of processing of the item to remember is preponderant to the performance, a deeper level of processing resulting in a better performance. On the contrary, when only a shallow level of processing is possible, switching language is detrimental to the recall performance. The patterns of results from this study are encouraging for bilinguals who are living in an environment in which language switching is very frequent. For activities requiring a deeper cognitive process in one language, a secondary process in a second language or switching language during this task might less influence them and disrupt their performance. It means that the cost of switching language might differ according to the circumstances and be less detrimental if the activity a bilingual has to complete requires a deep level of processing. Of course, further investigation with different cognitive tasks would be necessary to draw a bigger conclusion, but these results offer an encouraging perspective in this way. It would be interesting to test these findings with a reading span task. Indeed, such a task would be closer to the way bilinguals switch languages in their everyday lives. This is what we did in the next chapter, A multilingual reading span task to simulate language switching in everyday life, in which we carried a study assessing working memory capacity using a multilingual reading span task.

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Appendix

A. „Indice de Position Socio-Economique (IPSE) (Index of Socioeconomic Position) (Genoud, 2005)

What is your level of education ?

- ❑ University
- ❑ Superior professional education
- ❑ High School
- ❑ Professional High School, professional school
- ❑ Apprenticeship
- ❑ Obligatory school
- ❑ Less than obligatory school
- ❑ Other :

What is your current professional status ?

- ❑ Professional in activity [Please indicate your profession on the list below]
- ❑ Housewife/husband [Please indicate your partner's profession on the list below]
- ❑ Student [Please indicate your father/mother's profession on the list below (the highest on the list between both)]
- ❑ Annuitant [Please indicate your profession on the list below]
- ❑ Unemployed [Please indicate your profession on the list below]
- ❑ Other:

List of professional categories:

- ❑ Higher executives of large concerns, major professionals and the like
- ❑ Intellectual and scientific professions (engineers, medical doctors, professors, lawyers, etc.)
- ❑ Intermediate professions (technicians, nurse, accountants, police inspectors, etc.)

- ❑ Administrative professions (secretaries, receptionists, teller, etc.)
- ❑ Sales or service professions (cooks, waiters, hairdressers, firefighters, guides, sales assistants, etc.)
- ❑ Farmers, fishers, etc.
- ❑ Craftsman and workers (masons, carpenters, roofers, plasterers, potters, goldsmiths, silversmiths, butchers, bakers, cabinetmakers, seamstresses, etc.)
- ❑ Machine or robot operators, crane drivers, taxi drivers, train drivers, etc.)
- ❑ Unskilled workers or employees (unpackers, garbage collectors, delivery men/women, cleaners, street sellers, etc.)

B. C-tests

German C-test

Frankreich steht dieser Tage im Fokus ganz Europas. Die Anhe__ __ __ __ [1)] des Renteneint__ __ __ __ __ __ __ __ __ __ __ __ [2)] von 60 a__ __ [3)] 62 Jahre so__ __ __ [4)] in d__ __ [5)] französischen Bevöl__ __ __ __ __ __ [6)] für Un__ __ __ [7)]. Allein a__ [8)] Dienstag gin__ __ __ [9)] nach Gewerkscha__ __ __ __ __ __ __ __ __ __ [10)] wieder 3,5 Mill__ __ __ __ __ [11)] Menschen a__ __ [12)] die Str__ __ __ __ [13)] gegen d__ __ [14)] umstrittene Renten__ __ __ __ __ __ [15)]. Und im__ __ __ [16)] mehr Jugen__ __ __ __ __ __ [17)] machen b__ __ [18)] den Prot__ __ __ __ __ [19)] mit. A__ __ [20)] diesem Gru__ __ [21)] ordnete Präs__ __ __ __ __ [22)] Sarkozy a__ [23)], die Renten__ __ __ __ __ __ [24)] möglichst sch__ __ __ __ [25)] in d__ __ [26)] kommenden zw__ __ [27)] Tagen i__ [28)] Parlament z__ [29)] verabschieden.

De__ __ __ __ __ [30)] wurden Au__ __ __ [31)] in Br__ __ __ [32)] gesteckt, Bushalt__ __ __ __ __ __ __ __ [33)] und Telefon__ __ __ __ __ __ __ [34)] demoliert. In den vergangenen Tagen kam es häufig zu Zusammenstößen zwischen jungen Leuten und der Polizei.

French C-test

La France a vécu hier une nouvelle journée de mobilisation massive contre la réforme des retraites. La cra__ __ __ __ [1)] d'une para__ __ __ __ __ [2)] de l'éco__ __ __ __ __ [3)] s'est renf__ __ __ __ __ [4)], avec u__ [5)] durcissement d__ [6)] mouvement d__ [7)] contestation da__ __ [8)] les sect__ __ __ __ [9)] stratégiques d__ [10)] l'énergie e__ [11)] des trans__ __ __ __ __ [12)]. D'autre pa__ __ [13)], en ma__ __ __ [14)] des manifes__ __ __ __ __ __ __ [15)] de jeu__ __ __ [16)], la jou__ __ __ __ [17)] a é__ __ [18)] marquée p__ __ [19)] des viol__ __ __ __ __ [20)], souvent orche__ __ __ __ __ __ [21)] par d__ __ [22)] groupes d__ [23)] casseurs. D__ [24)] son cô__ __ [25)], le gouver__ __ __ __ __ __ [26)] reste dr__ __ __ [27)] dans s__ __ [28)] bottes, minim__ __ __ __ __ [29)] tant l__ [30)] nombre d__ [31)] manifestants q__ __ [32)] l'état d__ [33)] la pén__ __ __ __ [34)] d'essence. Reste que le mouvement social est approuvé par 71% des Français.

Italian C-test

1.

C'era a Perugia un giovane il cui nome era Andreuccio di Pietro; vedeva e comperava cavalli e, avendo una volta sentito che Napoli era un luogo molto buono per vendere e comperare, prese cinquecento fiorini e vi andò con altri mercanti. Pr_ _ _ di all_ _ _ egli n_ _ era m_ _ stato fu_ _ _ del s_ _ paese. Arr_ _ _ a Napoli una dome_ _ _ _ sera e i_ padrone dell'alb_ _ _ _ dove e_ _ andato a_ abitare g_ _ spiegò p_ _ bene que_ _ _ che avr_ _ _ _ dovuto fa_ _ per tro_ _ _ _ quanto desid_ _ _ _ _, e così l_ mattina do_ _ Andreuccio poté and_ _ _ al mer_ _ _ _. Vide mo_ _ _ cavalli, alc_ _ _ dei quali bellissimi, e provò allora a domandare il prezzo.

2.

Un ladro sta entrando, dopo aver forzato la finestra, nell'appartamento al terzo piano di una casa signorile, con la classica lampada oscurata. Dà u_ _ sguardo int_ _ _ _. Dal bu_ _ vediamo affi_ _ _ _ _ mobili, tend_, quadri ant_ _ _ _ e preziosi. I_ ladro acc_ _ _ _ le imp_ _ _ _, quindi acc_ _ _ _ la lu_ _. Proprio men_ _ _ sta p_ _ aprire u_ cassetto, su_ _ _ il tele_ _ _ _. Vorrebbe igno_ _ _ _ gli squ_ _ _ _ del tele_ _ _ _ , ma n_ _ ci rie_ _ _. Quatto qua_ _ _, il la_ _ _ si avvi_ _ _ _ al telefono e con un bal_ _ gli è addosso.

English C-test

1. Geography

The UK is located on a group of islands known as the British Isles, which lie between the Atlantic Ocean and the North Sea, northwest of France. At its widest t_ _ UK i_ 300 mi_ _ _ across a_ _ 600 mi_ _ _ from No_ _ _ to So_ _ . It sha _ _ _ a sin_ _ _ land bor_ _ _ with the Irish Repu_ _ _ _ . Despite i_ _ relatively sm_ _ _ size t_ _ UK boa_ _ _ incredibly var_ _ _ and of_ _ _ very beau_ _ _ _ _ scenery, fr_ _ the mountains and valleys of the North and West to the rolling landscape of the South, and from downland and heath to fens and marshland.

2. UK Passport Service

A new passport office that has opened in London will help the UK Passport Service provide a much better service to customers who need a passport urgently. The n_ _ office ru_ _ on a_ appointment-only ba_ _ _, removing t _ _ need f_ _ a len_ _ _ _ wait bef_ _ _ being se_ _. The n _ _ building, Globe House repl_ _ _ _ the Petty France off_ _ _ , which af _ _ _ 50 ye_ _ _ of conti_ _ _ _ _ service, h_ _ now clo_ _ _ its do_ _ _. The London Passport Office h _ _ the capa_ _ _ _ to issue 5000 passports weekly.

Chapter three: A multilingual reading span task to simulate language switching in everyday life

A multilingual reading span task to simulate language switching in everyday life

Language switching is very frequent for an individual living in a bilingual or multilingual environment. The aim of the present study was to assess the cost of this switching with a multilingual reading span task. Early bilingual adults who learned German (L1) and French (L2) before the age of 10 and English (L3) after the age of 10 performed a reading span task in which they had to read sentences and to memorize the last word of each sentence. Each trial was composed of several sentences either in the same language (L1, L2 or L3) or in mixed languages. In this latter condition, two languages alternated across sentences (either L1L2 or L1L3). If switching between languages induces a general cognitive cost, recall performance in the mixed condition should be lower than in the one-language trials. Language proficiency tests revealed our participants were more proficient in L1 than L2 and L3, though no significant difference emerged between L2 and L3. As expected, reading span results showed that performance was higher in L1 than in L1L2 and L1L3, whereas performance in mixed language conditions were similar as in L2 and L3 conditions. We propose that in L2 and L3 conditions, the L1 is still active and needs to be inhibited, as in L1L2 and L1L3 conditions.

Keywords: language switching, reading span, working memory

Introduction

In a bilingual or a multilingual environment, an individual has to frequently switch between languages. For example, a bilingual person often has to highlight a language and suppress the second one. Even if an area is not bilingual, nowadays many businesses or institutions frequently use several languages to operate. Thus, bilingualism is not a rare phenomenon. According to Grosjean (2010), more than half of the world's population is bilingual. In this study, we investigated language switching in a complex span task and the cost of this language switching. Our goal was to use an experimental task that was close to the type of language switching a bilingual or a multilingual individual performs in everyday life. Therefore, we created a multilingual reading span task that we presented to early German (L1)/ French (L2) bilinguals, who spoke English (L3) that has been learned after the age of 10.

The reading span task

Proposed by Daneman and Carpenter (1980), the original reading span task was created to provide a reliable measure of working memory capacity that correlates with reading comprehension. In the original version, sentences were presented in English, as it was the mother tongue of the participants. Participants had to read sentences and were instructed to recall the final word of each sentence in the order of presentation. The difficulty progressively increased during the task, participants starting with two-sentence trials and were then presented trials with three sentences, four and so on until six-sentence trials. The span corresponds to the maximum trial length the participant was able to complete correctly at least twice. There have been several variants of the task throughout the years (e.g., Daneman & Hannon, 2001; Desmette, Hupet, Schelstraete, & Van der Linden, 1995; Kane et al., 2004; La Pointe & Engle, 1990; van den Noort, Bosch, Haverkort, & Hugdahl, 2008). Thus, Desmette et al. (1995), proposed a reading span task adapted in French. The goal was to build an equivalent of the English reading span task, but in addressing some issues encountered in the original task from Daneman and Carpenter (1980). Indeed, Desmette et al. (1995) addressed three concerns from the original reading span task. First, there was some semantic links between sentences from a same series. These links could help organize words to recall in a common concept, helping the participant to recall the words. Second, some words of the original sentences were not frequently used in common language, likely perturbing the reading participant. Third, sentences used were from various complexity and length. Such differences are likely to interfere in the cognitive processes involved in reading, biasing storage and thus recall. Consequently, Desmette et al. (1995) modified the original sentences and words to recall according to the concerns listed, measuring length of sentences, word frequency and making sure there was an absence of common concepts in a same series. Recently, van den Noort et al. (2008) proposed a standardized reading span in several languages and therefore making the comparison of score between languages became possible. As Desmette et al. (1995), van den Noort et al. (2008) proposed a better control of the number of words and syllables in the sentences. Thus, length of sentences and length of words to recall were controlled, as well as word frequency in language. They also controlled the abstractness *vs* concreteness of the words to recall. Concrete words are more easily recalled than abstract words and use less working memory during reading (Kondo & Osaka, 2000). Abstractness and concreteness of their material has been pretested by native speakers of each language they developed their test. Thus, their reading span is available in four languages: English, German, Dutch, and Norwegian. This was of interest to design our multilingual reading span, as we needed material of similar difficulty between languages to compare performances in the different language conditions. Each language version comprises of 100 sentences. As in Daneman and Carpenter's (1980) reading span, sentences are presented to participants in ascending order, from 2-sentence trials to 6-sentence trials. There were two reasons van den Noort et al. (2008) kept different number of sentences in series. First, with only 2 or 3-sentence trials, there is a ceiling effect probability: participants would be able to get a perfect recall of the 2 or 3 words to remember. Second, with only 5 or 6-sentence trials, there is a floor effect probability: the number of words to recall might be too important for some or most of the participants. As van den Noort et al. (2008) pointed out, presenting only 5 or 6-sentence trials might give the impression to the participants that this number is the norm they should be able to remember. It could consequently stress them, impairing their reading span performance. This new reading span test was tested on adults speaking English, German, Dutch or Norwegian as native language. All participants were retested again two weeks later with the same task, to assess test-retest reliability. Van den Noort et al. (2008) found a significant internal reliability and test-retest reliability. Participants showed no difference in the number of recalled words between series of the reading span. Also, there was no mean difference of recalled words between the different linguistic versions of the reading span completed by participants. The different linguistic groups showed a similar digit span backward and letter-number ordering task (Wechsler, 2008), used as additional measures of working memory. These findings show that the different language versions of their task are comparable and thus valid at measuring reading span score.

The reading span in a non-native language

Performance in different kind of complex span tasks can be influenced by the language in which participants are tested. Sanchez et al. (2010) investigated the measure of working memory capacity in a non-native language. Native-Spanish speakers (Experiment 1) were tested in English, a language in which they were fluent since at least ten years. They were compared to Native-English monolinguals. Participants completed an operation span task (Turner & Engle, 1989), a reading span task (Kane et al., 2004b), and Raven's Advanced Progressive Matrices (RAPM) (Raven et al., 1998). RAPM is a measure of fluid intelligence and is well correlated with working memory capacity (Unsworth & Engle, 2005). Sanchez et al. (2010) analyzed how RAPM scores predicted the operation span task and the reading span task for both groups. The operation span task consisted of verifying a mathematical operation. Next to the operation was an unrelated word to recall. Participants completed sets in ascending order, from two to five operations to complete and as many words to recall in the order of presentation. In the reading span task, participants had to read sentences and judge the likeliness of them. Beside each sentence was a series of unrelated letters to recall. Procedure was similar to the operation span task. RAPM consisted of completing series of geometric patterns following a rationale. One pattern was missing and participants had to choose the correct pattern from a list of eight possibilities. For monolinguals, RAPM score was a good predictor of both operation span and reading span tasks. For bilinguals who completed the task in their second language, RAPM score predicted only the operation span task. The reason there is a difference between monolinguals and bilinguals in terms of predictions between RAPM and reading span, but not between RAPM and operation span resides in the language used to complete the tasks. Concerning the operation span, even though participants had to read the operation in their L2, they had to solve the operation silently and then could choose the language to solve it, which was likely their L1. In the reading span, sentences participants had to read were in their L2, so contrary to the operation span task that could be solved in their L1, the reading task was compulsorily completed in their L2. The authors concluded that assessing a reading span task in a non-native language was not an adequate way to measure working memory capacity. That is why in our study we also investigated performance in the reading span task for trials entirely in one language in the L1, L2 and L3 from participants. We wanted to find out how different would be the reading span performance according to the language in the same individual.

A multilingual reading span task

We constructed a multilingual reading span task, using sentences in German and English, taken out from van den Noort et al. (2008), and French sentences taken out from Desmette et al. (1995). Sets were presented in ascending order, from two to five sentences. Participants completed one-language trials in L1 (German), L2 (French) or L3 (English). They also completed two-language trials in L1L2 and L1L3. In those trials, when one sentence was in L1, the next one was in the other language. We measured reading times, though participants were not aware of it. We wanted to evaluate if reading times were different between the dominant language and the L2 and L3. First, we predicted a better reading span in one-language trials compared to two-language trials. We hypothesized that switching language induced an additional cognitive cost that impeded the performance: switch of language induces an additional cognitive cost in a task, as highlighted in the task switching literature (e.g., Christoffels et al., 2007; Costa & Santesteban, 2004; Declerck et al., 2013; Finkbeiner et al., 2006; Hernández et al., 2013; Meuter & Allport, 1999; Price et al., 1999, see chapter 2). Thus, for one-language trials in L2 and L3, we hypothesized that completing trials even in a non-dominant language would less impede participants that completing trials in two languages. Second, we predicted a better reading span entirely in L1 compared to reading spans entirely in L2 and L3, as L1 was the dominant language. As Sanchez et al. (2010) found that assessing a reading span task in L2 was not a good measure of working memory capacity, we hypothesized that performance in L2 and L3 would be lower than in L1, as our task was also a reading span. Third, concerning reading times, we predicted participants would read faster in L1 than in L2 and L3. As it is their dominant language, we predicted there would be an effect on the reading pace. There is consequent research evidence than reading in L1 is faster than reading in L2 (e.g., Clahsen & Felser, 2006; Dussias & Sagarra, 2007; Fraser, 2007; Haynes & Carr, 1990; Hernandez & Li, 2007; Papadopoulou & Clahsen, 2003). Fourth, in L1L2 and L1L3 conditions, we predicted shorter reading times in L1 than in the other language. Again, we hypothesized a faster reading pace, because L1 was the dominant language.

Method

Participants

Nineteen students from the Université de Fribourg (5 males; mean age= 21.4; *SD*= 3.4) were recruited. Participants were early bilinguals and spoke German as L1, French as L2 and English as L3. They learned German and French before the age of 10 and spoke it on a daily basis. They learned English after the age of 10 and spoke it at least on a monthly basis.

Material and procedure

Participants were tested individually in a cubicle. They first filled a socioeconomic status test, a questionnaire on the use of languages and three language proficiency tests (L1, L2, L3). Then we administered orally a digit span task and a letter-number sequencing task. Next, participants completed a computerized reading span task.

Socioeconomic status test

We used the same socioeconomic status test as in Chapter 1, the “Indice de Position Socio-Economique“ (IPSE; Genoud, 2005) (Appendix A). See the material and procedure of this chapter for a description.

Language proficiency tests

We used C-tests (Grotjahn, 1995, 2002) (Appendix B), as in Chapter 1. See this chapter for a description. For French and German C-tests, they were identical to the C-tests used in Chapter 1. The English C-test was taken from Daller and Phelan (2006).

Digit span

The digit span task was taken out from the Wechsler Adult Intelligence Scale IV (WAIS-IV, Wechsler, 2008). The task was divided in two parts. In the first part, the experimenter read digits participants had to recall in the order of presentation. The task comprised of eight series composed of two trials. Each series contained an additional digit in its series compared to the previous one. The first item contained series of two digits, the second item contained series of three digits, and so on until the eighth and final series, containing nine digits. The task stopped when the participant failed two trials in a raw from a series. Then the second part was administered. This part was similar, the only exception was that the participant had to recall digits in the reverse order of presentation. The score was the number of correct trials the participant was able to complete.

Letter-number sequencing

The letter-number sequencing was also taken out from the WAIS-IV (Wechsler, 2008). The experimenter read a trial of digits and letters, (e.g. “M – 4 – E – 7 – Q – 2”). Participants had first to recall digits in ascending order, then letters in alphabetical order. There was a total of seven series. Each series was composed of three trials. The first series comprised of a letter and a digit. Then item two comprised of an additional letter in the series, item three an additional digit, and so on. The task stopped when the participant failed all three trials from one specific series. The score was the number of correct trials completed.

Reading span task

A multilingual reading span task was programmed in Psyscope (Cohen, MacWhinney, Flatt, & Provost, 1993). Participants were tested in three different languages: German (L1), French (L2) and English (L3). We created five conditions involving different languages: three conditions with a single language and two with mixed language conditions L1L2 and L1L3. In mixed language conditions, when a sentence was in L1, the next one was in the other language. The sentences presented were taken from van den Noort et al. (2008) for German and English, and from Desmette et al. (1995) for French sentences. All sentences have been tailored by these authors to meet rigorous criteria in a number of dimensions. Each sentence comprised of 12 to 17 words, 20 to 26 syllables. Frequency of the last words of the sentences, i.e. the words to recall, have been controlled with CELEX for German and English (van den Noort et al., 2008) and BRULEX for French (Desmette et al., 1995). Each reading span task was presented with an ascending order of sentences from two to five (see Appendix C). Then it was presented a second time with the same ascending order. Thus, each participant completed two reading span tasks per language condition. For mixed language conditions, the first ascending order was in L1 for the first sentence of each series. The second ascending order was in L2 or L3 (depending on the condition) for the first sentence. We designed the experiment with two span tasks per condition, because we wanted to counterbalance the language order in mixed trials conditions. Thus, participant also had two reading span tasks in ascending order for one-language conditions. This way, the number of trials was equal between one-language and two-language conditions, which made scores between language conditions comparable in terms of length.

An instruction screen was presented, asking participants to read sentences in a normal pace and to press the space bar at the end of the last word. Participants were explicitly instructed not to wait to press the space bar, but to press it as soon as the last word of a sentence was read. Furthermore, they were instructed to memorize the last word of each sentence. Four training trials were presented: 2 trials in L1 (2 and 4 sentences trials) and 2 trials in L1L2 (2 and 4 sentences trials). Then, they were presented in random order one of the five conditions: all sentences in L1, L2 or L3 or mixed language conditions L1L2 or L1L3. In total, they completed the five conditions and consequently had to memorize a total of 140 words. Reading times were recorded by the software, but the participants were not aware of it. The software started a timer when a sentence was presented and stopped it when the participant pressed the space bar. After a trial, participants had to write the words they recalled, in a free order, as in studies by Van den Noort et al. (2008) and Desmette et al. (1995). The score was calculated the following way: each condition comprised of two trials of 2-3-4-5-sentence series. When a series was correct, 0.5 point was given. This calculation took into account that each kind of series, for example 2-sentence series, was presented twice in a condition. So if both 2-sentence series were correct, a participant would get one point. An additional point (a basis point) was then added to the score to get the reading span, as there was of course no use evaluating 1-sentence series.

Results

We first analyzed socioeconomic status, digit span task, letter-number sequencing task and C-tests. Participants obtained a socioeconomic score of 26.00 (*SD*= 14.95) which corresponds to a superior middle class in the IPSE (Genoud, 2005). In the WAIS digit span, participants obtained an average of 7.79 (*SD*= 1.47) and an average of 12.84 (*SD*= 2.81) on the WAIS letter-number sequencing task. The small standard deviations showed that participants had similar scores, suggesting they were similar on working memory capacity. We analyzed C-tests scores between languages. We performed an analysis of variance (ANOVA) on percentage correct of correct answers with language (German= L1 *vs* French= L2 *vs* English= L3) as within-subject factor. There was a significant difference between languages, $F(2,36)= 6.02$, $p= .006$, $\eta^2= .25$. We then performed t-tests between languages. Participant obtained a higher percentage on L1 (81.57%; *SD*= 8.98) than on L2 (75.23%; *SD*= 10.01), $t(18)= 2.47$, $p= .02$. They also obtained a better percentage on L1 (81.57%; *SD*= 8.98) than on L3 (72.35%; *SD*= 10.94), $t(18)= 3.37$, $p= .003$. There was no significant difference between L2 (75.23%; *SD*= 10.01) and L3 (72.35%; *SD*= 10.94), $t(18)= 1.01$, $p= .33$.

Reading span task

Reading times

We first investigated reading times. We hypothesized participants would read faster in L1 than L2 or L3, because it was their dominant language. We also hypothesized that in L1L2 and L1L3 conditions, reading times in L1 would be faster than reading times in L2 and L3. We trimmed the data by disregarding reading times that were more or less than 2.5 *SD*s from the average reading times, which were 2.03 % (*SD*= 1.05) of trials. This avoided keeping possible mistakes by the participant, such as pressing the space bar by error or forgetting to press it. We performed an ANOVA on reading times with type of trial (L1 *vs* L2 *vs* L3 *vs* L1L2 *vs* L1L3) as within-subject factor. Mauchly's test showed that the assumption of sphericity had been violated, $\chi^2(9)= 39.48$, $p< .001$. Hence, we applied the Greenhouse-Geisser correction. There was a trend, $F(1.79,72)= 3.05$, $p= .07$, $\eta^2= .15$. We performed t-tests between conditions with a Bonferroni adjustment. There was no significant difference between L1 (6357 ms; *SD*= 1066) and L2 (6853 ms; *SD*= 1362), $t(18)= 1.27$, $p> 1$ (

Tableau 7). Reading times were also similar between L1 (6357 ms; *SD*= 1066) and L3 conditions (6838 ms; *SD*= 1082), $t(18)= 2.24$, $p= .38$. Reading times in L2 (6853 ms; *SD*= 1362) were similar to reading times in L3 (6838 ms; *SD*= 1082), $t< 1$.

Tableau 7: Reading times (ms) (and SD) of the sentences of the multilingual Reading span task, by language condition (L1= German, L2= French, L3= English).

L1	L2	L3	L1L2	L1L3
6357 (1066)	6853 (1362)	6838 (1082)	6201 (823)	6571 (998)

We then further analyzed reading times on mixed trials L1L2 and L1L3. We compared reading times for each language in these trials in which half of the time sentences were in L1 and the other half in L2 or L3. Reading times could be different when language changed for each sentence to read. We performed an ANOVA on reading times by language on mixed trials with language in condition (L1 from L1L2 *vs* L2 from L1L2 *vs* L1 from L1L3 *vs* L3 from L1L3) as within-subject factor. Mauchly's test showed that the assumption of sphericity had been violated, $\chi^2(5)= 19.94$, $p=.001$. Hence, we applied the Greenhouse-Geisser correction. There was a significant difference, $F(2.09,54)= 18.71$, $p< .001$, $\eta^2= .51$. We then performed t-tests between conditions with a Bonferroni adjustment. For L1L2 trials, reading times in L1 (5875 ms; *SD*= 1094) were faster than in L2 (7014 ms; *SD*= 1434), $t(21)= 5.21$, $p< .001$ (**Tableau 8**). For L1L3 trials, reading times in L1 (6269 ms; *SD*= 1314) were faster than in L3 (7300 ms; *SD*= 1276), $t(21)= 7.50$, $p< .001$. We then compared L1 reading times between L1L2 and L1L3 trials. Reading times in L1 were similar on L1L2 trials (5875 ms; *SD*= 1094) as in L1L3 trials (6269 ms; *SD*= 1314), $t(21)= 2.65$, $p= 0.23$. Next, we compared L2 reading times in L1L2 trials compared to L3 reading times in L1L3 trials. Reading times in L2 in L1L2 trials (7014 ms; *SD*= 1434) were not significantly different than reading times in L3 in L1L3 trials (7300 ms; *SD*= 1276), $t(21)= 1.34$, $p= .95$.

Tableau 8: Reading times (ms) (and SD) of the sentences of the multilingual reading span task in mixed conditions L1L2 and L1L3, by language (L1= German, L2= French, L3= English).

L1L2		L1L3	
L1	L2	L1	L3
5875 (1094)	7014 (1434)	6269 (1314)	7300 (1276)

Reading span

We analyzed reading span score. The results answered our hypothesis about a better performance in one-language conditions compared to two-language conditions. They also revealed if performance in one-language was similar between L1, L2 and L3 conditions. We performed an ANOVA on reading span with type of trial (L1 *vs* L2 *vs* L3 *vs* L1L2 *vs* L1L3) as within-subject factor. There was a significant difference, $F(4,72)= 5.88$, $p< 001$, $\eta^2= .25$. We then performed t-tests between conditions with a Bonferroni adjustment. Reading span was better on trials in L1 (3.39; *SD*= 0.72) than trials in L2 (2.53; *SD*= 0.72), $t(18)= 4.86$, $p< .001$ and L3 (2.84; *SD*= 0.73), $t(18)= 3.52$, $p= .03$ (Tableau 9). There was no significant difference between trials in L2 (2.53; *SD*= 0.72) and L3 (2.84; *SD*= 0.73), $t(18)= 1.43$, $p> 1$. Reading span was better on trials with L1 (3.39; *SD*= 0.72) than trials with mixed conditions in L1L2 (2.82; *SD*= 0.63), $t(18)= 3.64$, $p= .02$. and L1L3 (2.92; *SD*= 0.67), $t(18)= 3.26$, $p= .04$. There was no significant difference between trials in L2 (2.53; *SD*= 0.72) and trials with mixed conditions in L1L2 (2.82; *SD*= 0.63), $t(18)= 1.38$, $p> 1$. Also, there was no significant difference between trials in L3 (2.84; *SD*= 0.73) and trials with mixed conditions in L1L3 (2.92; *SD*= 0.67), $t< 1$. Finally, there was no significant difference between L1L2 (2.82; *SD*= 0.63) and L1L3 (2.92; *SD*= 0.67), $t< 1$.

Tableau 9: Reading span (and SDs) according to the language condition (L1= German, L2= French, L3= English).

L1	L2	L3	L1L2	L1L3
3.39 (0.72)	2.53 (0.72)	2.84 (0.73)	2.82 (0.63)	2.92 (0.67)

We then analyzed recall on mixed trials L1L2 and L1L3, comparing performance in L1 with L2 or L3. As we decomposed performance within trials, thus decomposing span as well, we analyzed recall percentage. These analyses allowed finding out if there was a significant difference in recall between languages in two-languages conditions. We performed an ANOVA on recall percentage by language on mixed trials with language in condition (L1 from L1L2 *vs* L2 from L1L2 *vs* L1 from L1L3 *vs* L3 from L1L3) as within-subject factor. There was a trend, $F(3,54)= 2.81$, $p= .05$, $\eta^2= .14$. We then performed t-tests between conditions with a Bonferroni adjustment. For L1L2 trials, recall performance in L1 (69.93%; *SD*= 12.04) was not significantly different than recall performance in L2 (77.82%; *SD*= 10.62), $t(18)= 2.69$, $p= .09$ (Tableau 10). For L1L3 trials, recall performance in L1 (75.56%; *SD*= 12.44) was not significantly different than recall performance in L3 (77.82%; *SD*= 14.26), $t< 1$. We then compared L1 recall performance between L1L2 and L1L3 trials. Recall performance was not significantly better in L1 on L1L2 trials (69.93%; *SD*= 10.04) than on L1L3 trials (75.56%; *SD*= 12.44), $t(18)= 1.81$, $p= .52$. Next, we compared L2 recall performance in L1L2 trials compared to L3 recall performance in L1L3 trials. Recall performance in L2 in L1L2 trials (77.82%; *SD*= 10.62) was not different than recall performance in L3 in L1L3 trials (77.82%; *SD*= 14.26), $t< 1$.

Tableau 10: Recall percentage in mixed trials conditions L1L2 and L1L3, by language (L1= German, L2= French, L3= English).

L1L2		L1L3	
L1	L2	L1	L3
69.92 (12.04)	77.82 (10.62)	75.56 (12.44)	77.82 (14.26)

Finally, we analyzed if participants recalled the words in the order of presentation, even though they could recall them in a free order. We recalculated the reading span taking the order into account. We then performed an ANOVA with the order (free recall *vs* recall in order of presentation) as within-subject variables. There was a significant difference, meaning that participants did not reply in the order of presentation, $F(1,18)= 450.43$, $p< .001$, $\eta^2= .96$.

Discussion

In this study, we assessed the cost of language switching in a multilingual Reading span task and we compared reading span when trials were entirely in L1, L2 or L3. Concerning comparisons between one-language and two-language trials, reading span in trials in L1 compared to two-languages conditions L1L2 and L1L3 was higher. However, there was no difference between reading span in L2 or L3 compared to reading span in L1L2 and L1L3. Concerning trials entirely in one language, reading span in L1 was superior to reading span in L2 or L3. Nevertheless, there was no significant difference between trials in L2 and L3. In terms of differences in reading times among all conditions, there was only a trend. Further analysis showed there was no significant difference between L1, L2 and L3 conditions. We only found significant reading times differences in two-language trials, i.e. L1L2 and L1L3. We compared within these trials reading times in L1 with reading times in L2 or L3. In those two-language conditions, sentences in L1 were read faster.

First, we will discuss the reading span scores, comparing our results with the study from Sanchez et al. (2010) and the task switching literature. Second, we will discuss the reading times. Finally, we will discuss implications for bilinguals and multilinguals in their everyday life.

Firstly, concerning reading span performance on one-language conditions, Sanchez et al. (2010, Experiment 1) found that the reading span of bilinguals was better in L1 than in L2. Bilinguals were young adults that spoke Spanish as L1. They were fluent in English, i.e. their L2, for at least ten years (14.25 years; SD= 2.82). They began to learn English at 5 years old in average (5.33 years old; SD= 2.45). Thus, participants from this experiment were early bilinguals. In our experiment, participants were also early bilinguals. Their L1 was German, their L2 was French. Thus, our results are in line with the ones from Sanchez et al. (2010) concerning reading span being superior in L1 than in L2. Our experiment also used English as L3, as participants learned English after the age of ten and were proficient in this language. Unsurprisingly, their reading span was also better in L1 than in L3. Concerning the similar reading span between L2 and L3 one-language conditions, it is important to point out that proficiency in L2 and L3 were similar. Participants spoke German (L1), French (L2) and English (L3). We suppose they were also proficient in L3, because German and English are both West Germanic languages. As they share the same roots, it would be easier for participants to learn English compared to a more distant language. Proficiency in L2 being similar as proficiency in L3 easily explains why there was no significant difference between conditions involving L2 and L3.

About reading span in two-language conditions, we found that switching language within the reading span induced an additional cognitive cost, but only when the one-language condition was in L1, i.e. when L1 reading span was compared to L1L2 and L1L3 reading spans. In the two-language conditions in our experiment, participants had to read a sentence and maintain a word in a language and then reading the next one plus maintain a word in a second language. This result is in line with the task switching literature, showing there is a cost when one has to change language during trials consisting for example in naming, word reading, categorizing words (e.g., Christoffels et al., 2007; Costa & Santesteban, 2004; Declerck et al., 2013; Finkbeiner et al., 2006; Hernández et al., 2013; Meuter & Allport, 1999; Price et al., 1999, see chapter 2 in which task switching research has been reviewed). Very importantly, however, in our experiment, there was no difference between L2 and L3 one-language conditions compared to L1L2 and L1L3 conditions. In other words, the reading span was similar between switching-language trials and one-language trials in a non-native language. In terms of reading times, there was no difference between L1, L2 and L3 one-language conditions. Thus, the reading span difference that was found only between the L1 one-language condition and the two-language conditions could not be due to a difference of reading speed. Rather, this could mean that L1 is always active and that completing a trial in L2 or L3 involves a similar cognitive cost to inhibit the L1 as switching languages in two-language trials. Hoshino and Kroll (2008) showed in a study that when a task only requires the use of a second language, L1 is still activated. Spanish-English (L1/L2) and Japanese-English (L1/L2) bilinguals completed a task in their L2. They had to name drawings in English as fast and accurate as possible. Half of the drawings shared a cognate with the L1 from bilinguals. The second half shared no cognate with their dominant language. If L1 was not activated when bilinguals completed the task, accuracy and pace would be similar between drawings sharing cognates and the ones not sharing cognates. However, participants were faster and more accurate when they named drawings that shared cognates with their dominant language. As the experiment did not require the use of the L1 from participants at any moment, Hoshino and Kroll concluded that the L1 was always active when participants completed the task in L2. This finding might explain our pattern of results. It is important to note that the maintenance component of the task is more cognitively demanding that the reading component of the task, the later being the concurrent task. It could explain that the fact that the L1 is always activated has more influence on the most demanding cognitive task. To go into these findings in depth, a follow-up study might add a judgment of plausibility of sentence after a sentence is presented, as in Daneman and Carpenter (1980), in order to increase the cognitive load of the concurrent component of the task. Another follow-up study might investigate if participants process the meaning of the sentences and words to recall when they perform the reading span task. To test it, instead of using L2 and L3, a pseudo-language could be used instead. Thus, participants would perform the task in their L1 and in a pseudo-language with similar language conditions, i.e. everything in L1 and in the pseudo-language and mixed conditions composed of L1 and the pseudo-language. If the pattern of results is similar than the results of this study, we could then suppose than participants from our study did not process the meaning of the sentences and the words to recall.

Reading times pointed out an interesting find. In conditions entirely in one language, reading times were similar between L1, L2 and L3. This is an unexpected result, as reading times are generally faster for L1 than for L2 or L3 (e.g., Fraser, 2007; Haynes & Carr, 1990). Though, very interestingly, in mixed conditions in which participants had to frequently switch between their dominant language and a second language, there was a clear difference in reading times. Sentences in the dominant language were read faster, i.e. sentences in L1 were read faster than sentences in L2 or L3. In mixed conditions, there is a difference of 1139 ms between L1 and L2 reading times and a difference of 1031 ms between L1 and L3 reading times. L1 reading times in mixed conditions are faster than in L1 one-language conditions. L2 and L3 in mixed conditions are slower than in L2 and L3 one-language conditions. Thus, as reading was self-paced and there was no special instruction about the speed in which the sentences had to be read, we suppose that participants adapted their reading times in an average speed for one-language conditions. It was only when participants were confronted to two-language trials that the difference of reading times between L1 and L2 or L1 and L3 generally found in the literature (e.g., Clahsen & Felser, 2006; Dussias & Sagarra, 2007; Fraser, 2007; Haynes & Carr, 1990; Hernandez & Li, 2007; Papadopoulou & Clahsen, 2003) was found. Thus, participants did not average their reading speed between languages as they did for one-language conditions. We suppose they had a reading speed that was that was closer to their actual reading speed in non-experimental conditions. To sum up the results in mixed-language conditions, frequent switching put participants in a constraint that resulted in a facilitation to read in their dominant language.

Concerning bilinguals or multilinguals in their everyday life, the results are drawing the following conclusion. Frequently switching languages induces an additional cognitive cost to a task; however this cost is not more important than the one induced when an individual is executing a cognitively demanding task in a non-dominant language. Thus, according to the results of our multilingual reading span task, developing in a bilingual or a three-language environment in which there is a very frequent switching of language would not be more cognitively demanding that developing in an environment when one entirely speaks in L2 or L3. Of course, further investigation with other tasks involving strong language components would provide additional support to this conclusion.

Thank you to Nolwenn Berclaz for helping me testing the participants.

Appendix

A. „Indice de Position Socio-Economique (IPSE) (Index of Socioeconomic Position) (Genoud, 2005)

What is your level of education ?

- ❑ University
- ❑ Superior professional education
- ❑ High School
- ❑ Professional High School, professional school
- ❑ Apprenticeship
- ❑ Obligatory school
- ❑ Less than obligatory school
- ❑ Other :

What is your current professional status ?

- ❑ Professional in activity [Please indicate your profession on the list below]
- ❑ Housewife/husband [Please indicate your partner's profession on the list below]
- ❑ Student [Please indicate your father/mother's profession on the list below (the highest on the list between both)]
- ❑ Annuitant [Please indicate your profession on the list below]
- ❑ Unemployed [Please indicate your profession on the list below]
- ❑ Other:

List of professional categories:

- ❑ Higher executives of large concerns, major professionals and the like

- ❑ Intellectual and scientific professions (engineers, medical doctors, professors, lawyers, etc.)
- ❑ Intermediate professions (technicians, nurse, accountants, police inspectors, etc.)
- ❑ Administrative professions (secretaries, receptionists, teller, etc.)
- ❑ Sales or service professions (cooks, waiters, hairdressers, firefighters, guides, sales assistants, etc.)
- ❑ Farmers, fishers, etc.
- ❑ Craftsman and workers (masons, carpenters, roofers, plasterers, potters, goldsmiths, silversmiths, butchers, bakers, cabinetmakers, seamstresses, etc.)
- ❑ Machine or robot operators, crane drivers, taxi drivers, train drivers, etc.)
- ❑ Unskilled workers or employees (unpackers, garbage collectors, delivery men/women, cleaners, street sellers, etc.)

B. C-tests

German C-test

Frankreich steht dieser Tage im Fokus ganz Europas. Die Anhe__ __ __ __ [1)] des Renteneint__ __ __ __ __ __ __ __ __ __ __ [2)] von 60 a__ __ [3)] 62 Jahre so__ __ __ [4)] in d__ __ [5)] französischen Bevöl__ __ __ __ __ __ [6)] für Un__ __ __ [7)]. Allein a__ [8)] Dienstag gin__ __ __ [9)] nach Gewerkscha__ __ __ __ __ __ __ __ __ __ [10)] wieder 3,5 Mill__ __ __ __ __ [11)] Menschen a__ __ [12)] die Str__ __ __ __ [13)] gegen d__ __ [14)] umstrittene Renten__ __ __ __ __ __ [15)]. Und im__ __ __ [16)] mehr Jugen__ __ __ __ __ __ [17)] machen b__ __ [18)] den Prot__ __ __ __ __ [19)] mit. A__ __ [20)] diesem Gru__ __ [21)] ordnete Präs__ __ __ __ __ [22)] Sarkozy a__ [23)], die Renten__ __ __ __ __ __ [24)] möglichst sch__ __ __ __ [25)] in d__ __ [26)] kommenden zw__ __ [27)] Tagen i__ [28)] Parlament z__ [29)] verabschieden.

De__ __ __ __ __ [30)] wurden Au__ __ __ [31)] in Br__ __ __ [32)] gesteckt, Bushalt__ __ __ __ __ __ __ __ [33)] und Telefon__ __ __ __ __ __ __ [34)] demoliert. In den vergangenen Tagen kam es häufig zu Zusammenstößen zwischen jungen Leuten und der Polizei.

French C-test

La France a vécu hier une nouvelle journée de mobilisation massive contre la réforme des retraites. La cra__ __ __ __ [1)] d'une para__ __ __ __ __ [2)] de l'éco__ __ __ __ __ [3)] s'est renf__ __ __ __ __ [4)], avec u__ [5)] durcissement d__ [6)] mouvement d__ [7)] contestation da__ __ [8)] les sect__ __ __ __ [9)] stratégiques d__ [10)] l'énergie e__ [11)] des trans__ __ __ __ __ [12)]. D'autre pa__ __ [13)], en ma__ __ __ [14)] des manifes__ __ __ __ __ __ __ [15)] de jeu__ __ __ [16)], la jou__ __ __ __ [17)] a é__ __ [18)] marquée p__ __ [19)] des viol__ __ __ __ __ [20)], souvent orche__ __ __ __ __ __ [21)] par d__ __ [22)] groupes d__ [23)] casseurs. D__ [24)] son cô__ __ [25)], le gouver__ __ __ __ __ __ [26)] reste dr__ __ __ [27)] dans s__ __ [28)] bottes, minim__ __ __ __ __ [29)] tant l__ [30)] nombre d__ [31)] manifestants q__ __ [32)] l'état d__ [33)] la pén__ __ __ __ [34)] d'essence. Reste que le mouvement social est approuvé par 71% des Français.

English C-test

1. Geography

The UK is located on a group of islands known as the British Isles, which lie between the Atlantic Ocean and the North Sea, northwest of France. At its widest t_ _ UK i_ 300 mi_ _ _ across a_ _ 600 mi_ _ _ from No_ _ _ to So_ _ . It sha _ _ _ a sin_ _ _ land bor_ _ _ with the Irish Repu_ _ _ _ . Despite i_ _ relatively sm_ _ _ size t_ _ UK boa_ _ _ incredibly var_ _ _ and of_ _ _ very beau_ _ _ _ _ scenery, fr_ _ the mountains and valleys of the North and West to the rolling landscape of the South, and from downland and heath to fens and marshland.

2. UK Passport Service

A new passport office that has opened in London will help the UK Passport Service provide a much better service to customers who need a passport urgently. The n_ _ office ru_ _ on a_ appointment-only ba_ _ _, removing t _ _ need f_ _ a len_ _ _ _ wait bef_ _ _ being se_ _. The n _ _ building, Globe House repl_ _ _ _ the Petty France off_ _ _ , which af _ _ _ 50 ye_

_ _ of conti_ _ _ _ _ service, h_ _ now clo_ _ _ its do_ _ _. The London Passport Office h _ _ the capa_ _ _ _ to issue 5000 passports weekly.

Chapter four: A descriptive study of German/French and French/German bilinguals from the Université de Fribourg

A descriptive study of German/French and French/German bilinguals from the Université de Fribourg

The aim of this study was to investigate the acquisition and use of languages in a population of early bilinguals from the Université de Fribourg. One hundred forty young adults completed the Language Experience and Proficiency Questionnaire (LEAP-Q; Marian, Blumenfeld and Kaushanskaya, 2007), a validated questionnaire. Performing a discriminant analysis on the answers of the questionnaire, two bilingual profiles emerged. The first profile was composed of individuals that spoke both languages at home. The second profile consisted of individuals that spoke one language at home and the second outside their home. Furthermore, answers showed that participants learned in average their second language between 2 and 3 years old, showing they learned both languages simultaneously.

Keywords: bilingualism, Switzerland, German, French, descriptive study

Introduction

Bilinguals who participated in our experimental studies presented in the previous chapters are predominantly students from the Université de Fribourg. This chapter intends to carry out an in-depth description of this population. Information about the order of dominance and acquisition, the factors contributing to the learning, current exposition and so forth will enable to characterize the nature of bilingualism of these students. Does the order of language acquisition corresponded to the current order of dominance? Is the most dominant language the first acquired language? To take part in this study, individuals had to learn French and German until the age of ten. Thus, we were interested in early bilinguals. Moreover, they had to practice both languages at least weekly. In this chapter we also proposed to classify bilinguals in several profiles, according to how they learn their languages and how they use it. Thus, this in-depth description intends to open perspectives and an understanding of some of the results and data we presented in the previous chapters, that will later be developed in the general discussion of this thesis.

With these aims in mind, we chose a validated questionnaire, the Language Experience and Proficiency Questionnaire (LEAP-Q), developed by Marian, Blumenfeld and Kaushanskaya (2007). This questionnaire is adapted to a population of adults and teenagers of all provenances, as long as they are neurologically healthy. It has been created for the description of participants in experimental researches. This questionnaire is currently translated in several languages. Thus, our participants could fill it either in German or in French. The goal of the questionnaire was to appreciate the richness of the bilingual or multilingual experience in acquisition and use of the languages. The authors mentioned that the reason they built such a questionnaire was precisely the lack of a tool that took into account at the same time the language acquisition and the use. Domains covered by this questionnaire are "acquisition history, contexts of acquisition, present language use, language preference and proficiency ratings (across the four domains of language use: speaking, understanding, reading, and writing), and accent ratings" (p.945), (Marian et al., 2007). The LEAP-Q was validated after two studies. The first study aimed at building an internal validity of the questionnaire. The type of questions analyzed in this study was created from previous experiments from the authors' lab or was inspired by already existing bilingual questionnaires (Flege, Mackay, & Piske, 2002; Flege, Yeni-Komshian, & Liu, 1999; Jia, Aaronson, & Wu, 2002; Marian & Spivey, 2003; Vaid & Menon, 2000). This version of the questionnaire was filled by a group of multilinguals. There were 34 different languages spoken across participants. Data was then analyzed through a series of factor analyses and multiple regressions. Questions that did not fit in the regression models were excluded in the next version. Thus, results allowed producing a new version of the questionnaire to be tested in a second study. This following study tested the criterion-based validity and replicated the internal validity of this new version, which was tested on a different group of participants, Spanish/English and English/Spanish bilinguals. To test criterion-based validity, participants also filled a series of standardized behavioral measures evaluating language skills. The results from these measures were then compared to self-proficiency questions from the LEAP-Q using Pearson correlations. The battery of standardized measures included for example the Peabody Picture Vocabulary Test in English (Dunn, Dunn, & Dunn, 1997) and Spanish (Dunn, Padilla, Lugo, & Dunn, 1986), and subtests from the Woodcock-Johnson Tests of Achievement in English (Woodcock, McGrew, & Mather, 2001) and Spanish (Woodcock, 1993). Self-proficiency evaluations from the LEAP-Q strongly correlated with the battery of standardized measures. Also, this version of the LEAP-Q obtained a good statistical internal validity.

Thus, the LEAP-Q is a valid and efficient tool to describe bilinguals or multilinguals. This is a simple and convenient tool that a participant can fill without the help of an experimenter. It can capture both global and specific characteristics of the language experience and performance. It can investigate bilingualism/multilingualism of participants from different cultures, areas and languages. Used in researches in cognitive psychology, it can be a tool to compare participants from different studies, as proficiency and use of language can influence results from experimental tasks. This questionnaire is very frequently used in the bilingual and multilingual literature (e.g., Bialystok, Craik, Green, & Gollan, 2009; Kirk, Fiala, Scott-Brown, & Kempe, 2014; Martin et al., 2013; Morales, Gómez-Ariza, & Bajo, 2013; Paap & Liu, 2014; Prior & Gollan, 2011; Ratiu & Azuma, 2015). In our case, it allowed us to highlight characteristics of early bilingual college students, proficient in German and French, the population in which we recruited most of our participants in the experimental studies from the previous chapters.

Method

Participants

One hundred forty college students (37 males; mean age=23.0; *SD*= 4.8) were recruited at the Université de Fribourg. To participate, individuals had to be proficient in German and French and have learned both languages until the age of 10, at the latest.

Material and procedure

The LEAP-Q is composed of two distinct parts. The first part consists of ranking languages on several aspects and the second part is targeting one language at a time with specific questions. The second part can be duplicated according to the number of languages investigated. In our case, this second part was duplicated in order to collect information for two languages, as we investigated German and French (see Appendix).

Concerning the first part, it started with questions about the order of dominance and acquisition of languages. It could contain a maximum of five languages. Then information about the current exposition was collected for every mentioned language. This part also comprised of questions concerning the language one chose to read or speak when each language was equally available and the cultures with which a participant would identify.

The second part was addressing specific languages. It started with an indication to complete, giving information if it was a first, second, third (etc.) language. The next questions were about age. The age when the individual started to acquire the language, became fluent, started to read and became fluent at reading this language. Then, questions were about the time spent in the following language environments: a country, a family, a school and/or a working environment. Self-proficiency in speaking, understanding and reading were the next evaluations. Afterwards, the contribution to the learning of the language by the following factors had to be completed on a scale from zero to ten: interacting with friends, interacting with family, reading, language tapes/self instruction, watching TV and listening to the radio.

The current exposition to these six factors was also to be completed. Finally, there were two questions about the accent. How it was self-perceived and how frequently other individuals noticed one was not a native speaker. Participants completed the questionnaire on the internet.

Results

The results section will be divided into six parts. The first part of the results presents scores concerning all languages known by participants. The order of dominance and the order of acquisition of these languages are addressed, as well as current exposition to their L1 (the most dominant language) and their L2 (their second language). The second part is focusing on the L1: the age of acquisition, fluency, reading beginning, reading fluency. It also addresses the years spent in this language environment. Furthermore, results of participants' self-rating about their level of proficiency in speaking, understanding and reading L1 are displayed. Then, factors that contributed to the language learning and current exposition to these factors are analyzed. The third part is about L2. The same topics as in the L1 section are treated. It is important to note that in the second and third section, we only took into account participants whose L1 was German or French (N=129; 92% of participants), and L2 was French or German (N=121; 86% of participants). The reason is the following: we chose that parts two and three from the LEAP-Q asked detailed questions for German and French respectively. Those were the languages we wanted to investigate as L1 and L2, because most of the time it corresponded to L1 and L2 languages in the following chapters. The fourth part will compare data from the two previous sections, i.e. the acquisition and use of L1 compared to L2.
The fifth part will compare bilinguals that rated German *vs* French as their L1.
The sixth and last part will use a model to class participants in different bilingual profiles.

Dominance, acquisition and use

Participants rated French (56%) as the most dominant language, followed by German (36%) (Tableau 11). As second language, German (54%) was the most represented, followed by French (32%). In total, 79% of the participants listed French and German as their two most dominant languages (L1 and L2). Thus, either French was their L1 and German their L2 or vice-versa. The questionnaire comprised of five boxes in which participants could rank dominance in languages they knew. Data showed that nearly the totality of participants knew more than two languages: 98% of participants knew a third language, 61% a fourth language and 20% a fifth language.

In terms of the order of acquisition, German (47%) was the most often mentioned as the first acquired language, followed by French (41%) (Tableau 12). As second acquired language, German (48%) was also ahead of French (42%), The third acquired language was mostly and clearly English (75%). It is unsurprising, as English is taught in obligatory school, whatever the study options chosen by students.

We analyzed whether the order of dominance was significantly corresponding to the order of acquisition. We performed a Kendall's Tau, showing there was a good correlation between the most dominant language and the first acquired language, as one could expect, $T_c = .31$, $p < .001$. However, there were weak correlations between the second language in terms of dominance and the second acquired language, $T_c = .19$, $p = .001$, and between the third language and the language acquired in third position, $T_c = .13$, $p = .02$. It suggests that the use of second and third languages is more influential than the order of acquisition. There was no significant correlation between the fifth language and the language acquired in fifth position, $T_c = .22$, $p = .23$.

Tableau 11: Languages known by participants in order of dominance (and percentage)

Rank	1	2	3	4	5
	French (56.4)	German (54.3)	English (74.5)	Italian (33.7)	Italian (25.0)
	German (35.7)	French (32.1)	French (9.5)	Spanish (23.3)	Spanish (21.4)
	Luxembourgish (5.0)	English (7.9)	Spanish (8.0)	English (19.8)	English (14.3)
	English (1.4)	Italian (2.9)	German (5.1)	German (9.3)	Chinese (7.1)
	Italian (1.4)	Albanian (0.7)	Italian (1.5)	Polish (2.3)	Portuguese (7.1)
		Polish (0.7)	Arabic (0.7)	Portuguese (2.3)	Arabic (3.6)
		Serbian (0.7)	Czech (0.7)	Swedish (2.3)	Armenian (3.6)
		Spanish (0.7)		Brazilian (1.2)	Czech (3.6)
				Dutch (1.2)	French (3.6)
				French (1.2)	Polish (3.6)
				Hungarian (1.2)	Romans (3.6)
				Luxembourgish (1.2)	Russian (3.6)
				Turkish (1.2)	

We analyzed current exposition to languages. We examined current exposition to L1 and L2. Again, 79% of participants had French and German as these two languages. Participants were currently exposed 50% (*SD*= 16) of the time to their L1 and 33% (*SD*= 16) of the time to their L2. It showed they were exposed to a balanced bilingual or multilingual environment and that the use of several languages in their everyday lives was the rule. A balanced bilingual or multilingual environment is an environment in which two or more language are used at a more or less similar level (Madrid & Hughes, 2011).

The two following questions addressed the language used when the individual can freely choose it. First, when a text was displayed in any language, participants had to indicate in which percentage they would choose to read it in one of their language. We analyzed in which percentage they would read it in their L1, L2 and in English, as this last language was the most known third language (75%). Participants chose to read a text in L1 57% (*SD*= 25) of the time. This result showed they were balanced bilinguals or multilinguals, otherwise they would have rated L1 as 100% or near this percentage. The L2 was chosen 27% (*SD*=23) of the time. The important standard deviation showed there was a dichotomy among participants: they tended to either choose it a lot or a very few, i.e. a 23% standard deviation for a 27% mean. Finally, English was chosen 17% (*SD*= 15) of the time. The next question was similar, but addressing speech. It asked the percentage of time they would choose a language to speak, when an individual is fluent in any language. The L1 was chosen 50% (*SD*= 23) of the time and the L2 30% (*SD*= 18) of the time. Again, it showed they were balanced bilinguals or multilinguals. English was chosen 15% (*SD*= 15) of the time.

We analyzed correlations between percentage of current exposition and the percentage of time participants chose a language to read or to speak for L1 and L2. Regarding current exposition scores displayed above, there would likely be good correlations, because current exposition should have an important influence on their choices: a person exposed to a bilingual or a multilingual environment in his everyday life should be more willing to speak several languages. We performed Pearson correlations. Current exposition to L1 was positively related to the choice to read in L1, $r= .43$, $p=< .001$, and to the choice to speak in L1, $r= .55$, $p< .001$. Current exposition to L2 was positively related to the choice to read in L2, $r= .46$, $p< .001$, and to the choice to speak in L2, $r= .52$, $p< .001$.

The acquisition and the use of the L1

We first focused on the age of acquisition of the L1 (German or French), when individuals started to learn, became fluent, started to read and became fluent at reading in this language.

Participants started to learn the L1 at 1.6 (*SD*= 2.1) years old. They became fluent at 3.9 (*SD*= 2.2) years old. They began to read in L1 at 6.1 (*SD*= 1.6) years old, and became fluent at reading it at 7.8 (*SD*= 2.5) years old. Participants spent 19.6 (*SD*= 7.8) years in a country in which their L1 is spoken. They spent 19.3 (*SD*= 8.9) years in a family in which this language is spoken. Finally, they spent 16.1 (*SD*= 7.3) years in a school or a working environment in which their L1 is used.

Participants then self-rated their proficiency in speaking, understanding and reading L1, on a scale from 0 to 10. They rated their speaking fluency at 9.3 (*SD*= 1.9), their understanding fluency at 9.3 (*SD*= 2.0) and their reading fluency at 9.1 (*SD*= 2.1).

The next series of questions was about factors that contributed to the acquisition of L1. Participants had to select the contribution of each factor on a scale from 0 to 10. In the order of importance, from the most to the less relevant, participants first rated interacting with friends (8.4; *SD*= 2.8) and reading (8.4; *SD*=2.5), then interacting with family (8.3; *SD*= 2.9), watching TV (6.7; *SD*= 3.5) and listening to the radio (5.4; *SD*= 4.0). As one could expect, language tapes/self-instruction (3.4; *SD*= 3.8) was considered as the less important in the learning of L1.

Participants were then asked to rate their current exposition to these same factors, also on a scale from 0 to 10. In the order of importance, they rated interacting with friends (8.0; *SD*= 2.3), reading (7.6; *SD*= 2.5), interacting with family (6.8; *SD*= 3.4), watching TV (5.4; *SD*= 4.1) and listening to the radio (4.5; *SD*= 3.7). As for factors contributing to the language acquisition, using tapes or doing self-instruction (1.9; *SD*= 3.4) was the less frequent.

We then investigated these six factors to find out if there were correlations between the contribution to the learning and the current exposition for each factor. Thus, we wanted to find out if there was a correspondence for a factor between how important participants rated it for learning the language and its rating concerning the exposition to it nowadays. We performed Pearson correlations. Each factor showed a positive link between these two ratings: for interacting with friends, $r= .39$, $p= .005$, for interacting with family, $r= .46$, $p< .001$, for reading, $r= .48$, $p< .001$, for language tape/self-instruction, $r= .51$, $p< .001$, for watching TV, $r= .34$, $p< .001$ and for listening to radio, $r= .63$, $p< .001$. Thus, a factor that contributed a lot to the learning of the language was still important in its current exposure.

The last variables that participants evaluated for L1 were two questions about their accent in this language. They were first asked to self-rate themselves and then to evaluate how frequently people noticed they were non-native speakers if that was the case. About self-evaluation, 92% of participants considered they did not have any foreign accent, 8%

considered they had a slight foreign accent and no individual considered not sounding as a native speaker. About how others perceive their accent, 92% reported that they were never considered having a foreign accent, 6% considered it sometimes was the case and 2% considered they were always perceived a non-native speakers.

The acquisition and the use of the L2

In this part, we addressed the same questions as the ones presented in the previous section, but this time for the acquisition and use of the L2 (German or French). Participants started to acquire their L2 at 2.7 (*SD*= 3.1) years old. They were fluent at 5.6 (*SD*= 4.1) years old. They started to read at 8.1 (SD= 3.0) years old. They considered being fluent at reading at 10.6 (*SD*= 4.0) years old.

Participants have been living in a country in which their L2 is spoken during an average of 14.2 (*SD*=10.1) years. They spent 14.4 (*SD*= 11.3) years in a family in which their L2 is spoken. Finally, they spent 8.1 (*SD*= 7.5) years in a school or a working environment in which this language is spoken. The important standard deviations in these ratings shows the heterogeneity of L2 language profiles. There are on one side individuals speaking L1 at home and L2 outside the family. On the other side, there are individuals speaking both languages in their family, but speaking only L1 outside of it.

Self-proficiency was then addressed. Individuals had to score it on a scale from 0 to 10. Oral proficiency was rated 8.4 (*SD*= 1.8). Participants evaluated their oral comprehension at 9.1 (*SD*= 1.6) and their fluency at reading at 8.3 (*SD*= 1.9). Thus, individuals rated themselves as not as proficient in L2 as in L1, but still they considered being very proficient in this language. We will compare further these ratings in the next section.

Concerning factors that contributed to the learning of the L2, participants had to rate the following factors on a scale from 0 to 10. Interacting with family was considered an important factor (7.4; *SD*= 3.4), as well as interacting with friends (7.0; *SD*= 3.3), reading (6.9; *SD*= 2.8) and watching TV (6.0; *SD*= 3.3). Listening to the radio (4.1; *SD*= 3.4) and the use of language tapes or self-instruction (3.0; *SD*= 3.7) were factors rated with the lower scores. Thus, L2 was not a self-learned language, but a language learned primarily from the environment.

Next, individuals rated their current exposition to these six factors. Following the order of importance, they rated interacting with friends (6.2; *SD*= 3.3), reading (6.2; *SD*= 2.8), and interacting with family (6.0; *SD*= 3.7). It was followed by watching TV (5.0; *SD*= 3.3), listening to the radio (3.7; *SD*= 3.5) and using learning tapes/self-instruction (1.7; *SD*= 2.9).

Next, we analyzed whether there were correlations between the contribution to the learning and the current exposition for each factor. We performed Pearson correlations. There were significant correlations for each factor: for interacting with friends, $r= .41$, $p< .001$, for interacting with family, $r= .76$, $p< .001$, for reading, $r= .52$, $p< .001$, for language tape/self-instruction, $r= .68$, $p< .001$, for watching TV, $r= .50$, $p< .001$ and for listening to the radio, $r= .62$, $p< .001$. We can conclude there is a correspondence of the degree in which participants are currently exposed to the factors that contributed to the learning of the L1.
Finally, the two last questions were about the accent in L2. There were 65% of individuals who considered they had no foreign accent, 29% evaluated they had a slight foreign accent and 7% indicated they did not sound as native speakers in L2. Concerning how others perceived their accent when they speak, 61% considered nobody ever noticed their accent as non-native, 29% reported that a slight foreign accent was distinguished and 10% indicated they were always recognized as non-native speakers.

Comparison of ratings between L1 and L2

In this section, we compared the evaluation participants gave for L1 and L2. We analyzed if ages of acquisition were significantly different, as well as the numbers of years spent in an environment in which the language is spoken. We were also interested to compare L1 and L2 proficiency ratings.
Concerning ages of acquisition, all analysis showed significant differences. The L1 was always acquired earlier than the L2. Participants learned their L2 in average 1.1 ($SD= 4.0$) year later than their L1, $t(110)= 2.94$, $p= .004$. They spoke in L2 1.82 ($SD= 4.9$) year later than in L1, $t(110)= 3.90$, $p< .001$. They began to read in L2 1.95 ($SD= 3.3$) year later than in L1, $t(110)= 6.31$, $p< .001$. Finally, they were fluent in reading in L2 2.71 ($SD= 4.1$) years later than in L1, $t(110)= 6.91$, $p< .001$.
About the number of years spent in the language environment, L1 counted significantly more years than L2 on all three ratings. Participants spent an average of 5.4 ($SD= 11.2$) more years in a country where L1 is spoken, $t(110)= 5.09$, $p< .001$. They spent 4.5 ($SD= 12.2$) more years in a family in which L1 is spoken, $t(110)= 3.89$, $p< .001$. They spent 7.9 ($SD= 11.3$) more years in a school or a working environment where L1 is spoken, $t(110)= 7.40$, $p< .001$.
We then compared proficiency. Participants rated themselves as more proficient in L1 for the three factors to be evaluated. Thus, they indicated they were more proficient in L1 orally (with a difference of 0.9 ($SD= 1.6$) point), $t(110)= 6.03$, $p< .001$, in comprehension (with a

difference of 0.4 (*SD*= 1.6) point), *t*(100)= 2.52, *p*= .01, and in reading (with a difference of 0.8 (*SD*= 2.2) point), *t*(110)= 3.97, *p*< .001.

Comparison of ratings between participants with French or German as dominant language

We then compared the ratings of the LEAP-Q items between participants that had French *vs* German as their dominant language, i.e. L1. Except for the ratings hereinafter, all the ratings were similar, *t*s > .10. Concerning the age in which participants began to read and were fluent reading in L2, German dominant bilinguals (9.4; *SD*= 3.6) started later than French dominant bilinguals (7.5 years old; *SD*= 2.3), *t*(109)= 3.21, *p*= .002, and German dominant bilinguals (11.9 years old; *SD*= 4.9) were fluent later than French dominant bilinguals (10.1 years old; *SD*= 3.3), *t*(108)= 2.34, *p*= .02. Furthermore, German dominant speakers (12.4 years; *SD*= 12.2) spent less years in a family in which their L2 was spoken compared to French dominant speakers (17.1 years; *SD*= 10.0), *t*(108)= 2.18, *p*= .03.

Bilingual profiles

With all the data collected, we computed it using a discriminant function analysis to find how many early bilingual profiles we were able to extract and what were the characteristics of these profiles. First, to test if such an analysis would generate a strong model and how many profiles such a strong model would include, we performed a Wilks's Lamdba analysis. The Wilks's lambda is a probability distribution to be used in a multivariate hypothesis testing. A Wilks's Lambda ranges from 0 to 1, the smallest score near 0 predicting a strong model with variables clearly defining it. We performed a Wilks's Lambda on every quantitative variable from the LEAP-Q questionnaire. The Wilk's Lamba predicted a strong model, Λ= .02, X^2(94)= 294.61, *p*< .001, differencing two different bilingual profiles. We then performed the discriminant analysis, which revealed two discriminant functions allowing us to establish our two bilingual profiles. The first explained 64.4% of the variance, canonical R^2= .88, and the second function explained 35.6% of the variance, canonical R^2= .81. The canonical R^2 is the equivalent of the effect size, which in both cases indicates a strong effect size. The correlations between the variables from the questionnaire and the discriminant functions revealed that the proficiency in L2 reading loaded evenly onto both functions (*r*= .66 for both functions); as well for the percentage of L2 spoken in the family currently (*r*= .55 for the first function and *r*= .70 for the second function). The age in which the reading in L2 was proficient (*r*= .61), the contribution of learning the L2 by listening to the radio (*r*= .62) and the current exposition to L1 by listening to the radio (*r*= 66) loaded highly on the first function. Finally, the current exposition to L2 by interacting with the family (r= .70) loaded highly on the second function. Importantly, none of the evaluations about the L3 did contribute to the model. To sum up, the discriminant function analysis split bilinguals in two profiles, differentiating them mainly on four variables. First, the age in which they proficiently read in their L2. Second, whether listening to the radio was a variable that contributed to the learning of the L2. Currently interacting with the family in L2 was the third variable. The fourth and last variable was currently listening to the radio in L1.

Conclusion

The aim of this study was to describe German/French and French/German bilinguals from the Université de Fribourg. Participants were required to have learned both languages until the age of ten to take part in the study. Importantly, results showed that participants learned their L2 on average significantly earlier than ten years old, i.e. during their second year. Thus, we can conclude that most participants were simultaneous bilinguals, in other words that most of them were learning their L2 around the same time there were acquiring their L1.

There were two profiles concerning the use of languages. The first one comprised of individuals who spoke one language at home and another one (or other ones) outside of home. The second profile characterizes participants who spoke two (or more) languages in every environment they spent time in.

Learning L2 by self-instruction or by language tapes was the lowest-rated factor. This language was learned by the interaction with the environment. Corroborating this idea, participants revealed they spent on average 14.2 years in a country in which L2 is spoken. Thus, it is not surprising that individuals considered being proficient in understanding, speaking and reading in L2. In addition to these two points, two other evidences showed that most participants were balanced bilinguals. First, when they were free to choose a language to talk or read, they chose to speak in L1 only 50% of the time. Second, their current exposition to L1 and L2 was more or less balanced, respectively 50% and 33%.

Importantly, these percentages showed that L1 and L2 were not the only languages individuals were exposed to. A total of 98% knew a third language. English was the language the most credited as third language (75%). This result showed the importance of English nowadays in a college student's life.

This leads us to an important point. In the college student population in Switzerland, we can select early bilinguals by choosing individuals who learned and regularly used precisely two languages until the age of ten. If we choose to select college students by the number of languages they are currently exposed to, regardless of the age of the languages acquisition, then we would need to call this group multilinguals. Indeed, it would be very difficult to find college students in Switzerland who learned and are currently exposed to precisely two languages. Thus, when we used the term “monolinguals” in the previous experiments, we were referring to individuals who learned and regularly use one language before the age of ten. In Switzerland, teaching of a second national language begins in fourth year of primary school, when children are around nine years old. These first courses are a brief introduction to the new language. There is not an actual immersion in this language with a proper exposition and use, that is why we still considered that these individuals were monolinguals, by opposition to early bilinguals.

Appendix

Appendix (p. 1 of 2). Language Experience and Proficiency Questionnaire.

Last Name		First Name		Today's Date	
Age		Date of Birth		Male ☐	Female ☐

(1) Please list all the languages you know in order of dominance:

1 Language A	2 Language B	3 Language C	4 Language D	5 Language E

(2) Please list all the languages you know **in order of acquisition** (your native language first):

1 Language A	2 Language B	3 Language C	4 Language D	5 Language E

(3) Please list what percentage of the time you are *currently* and *on average* exposed to each language.
(*Your percentages should add up to 100%*):

List language here:	Language A	Language B	Language C	Language D	Language E
List percentage here:					

(4) When choosing to read a text available in all your languages, in what percentage of cases would you choose to read it in each of your languages? Assume that the original was written in another language, which is unknown to you.
(*Your percentages should add up to 100%*):

List language here	Language A	Language B	Language C	Language D	Language E
List percentage here:					

(5) When choosing a language to speak with a person who is equally fluent in all your languages, what percentage of time would you choose to speak each language? Please report percent of total time.
(*Your percentages should add up to 100%*):

List language here	Language A	Language B	Language C	Language D	Language E
List percentage here:					

(6) Please name the cultures with which you identify. On a scale from zero to ten, please rate the extent to which you identify with each culture. (Examples of possible cultures include US-American, Chinese, Jewish-Orthodox, etc.):

List cultures here	Culture A (click here for scale)	Culture B (click here for scale)	Culture C (click here for scale)	Culture D (click here for scale)	Culture E (click here for scale)

Appendix (p. 2 of 2). Language Experience and Proficiency Questionnaire.

Language: Language X

This is my (please select from scroll-down menu: First, Second, Third, etc.) language.
All questions below refer to your knowledge of Language X.

(1) Age when you…:

began acquiring Language X:	*became fluent* in Language X:	*began reading* in Language X:	*became fluent reading* in Language X:

(2) Please list the number of years and months you spent in each language environment:

	Years	Months
A country where Language X is spoken		
A family where Language X is spoken		
A school and/or working environment where Language X is spoken		

(3) On a scale from zero to ten, please select your *level of proficiency* in speaking, understanding, and reading Language X from the scroll-down menus:

Speaking	(click here for scale)	Understand spoken language	(click here for scale)	Reading	(click here for scale)

(4) On a scale from zero to ten, please select how much the following factors contributed to you learning Language X:

Interacting with friends	(click here for scale)	Language tapes/self instruction	(click here for scale)
Interacting with family	(click here for scale)	Watching TV	(click here for scale)
Reading	(click here for scale)	Listening to the radio	(click here for scale)

(5) Please rate to what extent you are currently exposed to Language X in the following contexts:

Interacting with friends	(click here for scale)	Listening to radio/music	(click here for scale)
Interacting with family	(click here for scale)	Reading	(click here for scale)
Watching TV	(click here for scale)	Language-lab/self-instruction	(click here for scale)

(6) In your perception, how much of a foreign accent do you have in Language X?
(click here for scale)

(7) Please rate how frequently others identify you as a non-native speaker based on your accent in Language X:
(click here for scale)

RESUME ET DISCUSSION GENERALE

Résumé et discussion générale

Le but de cette thèse était d'investiguer l'effet du bilinguisme sur la mémoire de travail. Les recherches concernant les bilingues et la cognition sont la plupart du temps menées en analysant une fonction exécutive à la fois (e.g., Bialystok et al., 2004; Costa et al., 2009; Martin-Rhee & Bialystok, 2008; Morton & Harper, 2007). En évaluant les participants sur leur capacité de mémoire de travail, nous avons opté pour une approche plus globale. En effet, la mémoire de travail requiert l'utilisation des fonctions exécutives (Baddeley et al., 1996; Miyake & Shah, 1999). En outre, une étude de McCabe et al. (2010), montre que la capacité en mémoire de travail corrèle fortement (r=.97) avec les capacités du contrôle exécutif.

Dans un premier temps, nous avons comparé des performances de bilingues précoces et tardifs avec celles de monolingues sur des tâches de mémoire de travail.

Ensuite, nous nous sommes également intéressés aux coûts cognitifs provoqués par des changements de langue à l'intérieur même d'un essai d'une tâche de mémoire de travail. De plus, nous avons analysé et comparé les performances de mémoire de travail dans des essais de difficultés identiques exécutés soit dans une langue dominante (L1) ou une deuxième langue (L2) apprise précocement, i.e. jusqu'à l'âge de dix ans, ou tardivement, i.e. après l'âge de dix ans ou une troisième langue (L3) apprise tardivement.

Pour terminer, nous nous sommes intéressés à la nature du bilinguisme des étudiants de l'Université de Fribourg, lesquels constituaient les participants principaux de nos études, à savoir l'acquisition et l'utilisation de leurs langues.

Au début de ce travail, nous avons donc été guidés par deux questions principales : les bilingues ont-ils des avantages en mémoire de travail comparé aux monolingues ? De quelle manière le changement de langues influence-t-il la performance en mémoire de travail chez les bilingues ?

Nous allons résumer les résultats des expériences menées en partant de ces deux questions. Egalement, nous comparerons les résultats des différents chapitres et les discuterons. Finalement, nous conclurons en traitant des implications des résultats pour les bilingues, ainsi que la recherche sur le bilinguisme et la cognition. Plus précisément, en revenant sur les résultats principaux de ce travail, nous discuterons de la comparaison des performances en mémoire de travail entre monolingues et bilingues, du coût cognitif provoqué par le changement de langue, du bilinguisme précoce et tardif, ainsi que de l'acquisition et l'utilisation des langues chez les bilingues. Nous proposerons dans une dernière partie des directions futures pour de nouvelles recherches.

La comparaison entre monolingues et bilingues : l'avantage bilingue, une exception plus que la règle

Dans notre comparaison des monolingues et des bilingues à l'aide de tâches de mémoire de travail, nous avons voulu contrôler le statut socio-économique et le niveau d'éducation. Des recherches ont déjà montré que le niveau socio-économique et le niveau d'éducation influençaient les performances d'individus en mémoire de travail (Lee et al., 2003; Noble et al., 2007) ou dans le contrôle exécutif (Farah et al., 2006; Mezzacappa, 2004; Noble et al., 2005). Ces recherches montrent qu'un niveau socio-économique et/ou un niveau d'éducation élevé corrélaient positivement avec ces capacités. Les résultats de notre premier chapitre offrent une articulation nouvelle entre niveau socio-économique, niveau d'éducation, capacités en mémoire de travail et bilinguisme. Nous avons recruté dans un premier temps des monolingues et bilingues de l'Université de Fribourg, qui avaient un haut niveau socio-économique et d'éducation selon le test de mesure de l'Indice de Position Socio-Economique (IPSE; Genoud, 2005). Les bilingues étaient précoces dans l'Expérience 1, c'est à dire qu'ils avaient appris leurs deux langues avant l'âge de dix ans. Les bilingues de l'Expérience 2 étaient tardifs, ayant appris leur deuxième langue après l'âge de 10 ans. Dans un troisième temps, nous avons recruté des apprentis qui se formaient dans des métiers manuels et qui avaient un score socio-économique significativement plus bas. Nous avons trouvé un avantage des bilingues en mémoire de travail comparé à des monolingues uniquement dans une population de niveau socio-économique et d'éducation bas, c'est-à-dire parmi la population d'apprentis. Aucune différence significative n'a été trouvée entre les universitaires monolingues et bilingues. Il n'y avait pas de différence significative non plus entre les bilingues précoces et tardifs. Les universitaires ayant été sélectionnés pour leurs bonnes capacités cognitives, il est fort probable qu'un potentiel avantage bilingue ne s'observe pas. Les monolingues universitaires auraient des capacités cognitives similaires aux bilingues, puisqu'ils ont justement été sélectionnés durant leur scolarité et se sont conséquemment dirigés vers des études supérieures. En effet, le baccalauréat est sélectif en Suisse. Selon l'Office Fédéral de la Statistique (2014), seul 34% de la population adolescente a obtenu un baccalauréat en 2013. Les résultats de nos expériences des Chapitres II et III vont dans la même direction. Nous avons comparé les scores des universitaires bilingues lorsqu'ils effectuaient la tâche de mémoire de travail dans leur langue dominante avec le score des universitaires monolingues dans cette même condition, ces derniers ayant servi de groupe contrôle. Si les bilingues avaient un avantage en capacité de mémoire de travail, ils auraient dû obtenir un meilleur score que les monolingues. Or, aucune différence significative n'a été mesurée en capacité de mémoire de travail entre ces deux groupes.

Ces résultats s'additionnent aux études ne trouvant que rarement ou ne trouvant pas d'avantage sur des fonctions exécutives (Gathercole et al., 2014; Kirk et al., 2014; Paap & Greenberg, 2013; Paap & Liu, 2014) ou la mémoire de travail (Ratiu & Azuma, 2015). Comme nous l'avons abordé dans l'Introduction et le Chapitre I, un nombre important d'études a été mené sur un potentiel avantage bilingue sur une ou plusieurs fonctions exécutives (e.g., Bialystok, 2006; Bialystok et al., 2004; S.Carlson & Meltzoff, 2008; Colzato et al., 2008; Costa et al., 2009, 2008; Hilchey & Klein, 2011; Martin-Rhee & Bialystok, 2008; Morton & Harper, 2007; Tao et al., 2011). Un nombre bien moins important d'études a été réalisé en mesurant la mémoire de travail (e.g., Bonifacci et al., 2010; Ratiu & Azuma, 2015). Notre travail amène donc des éléments qui complètent la recherche actuelle sur cette question. De plus, seul un petit nombre d'études mesurent le statut socio-économique et le niveau d'éducation (pour une revue, voir Hilchey & Klein, 2011). Pourtant ce sont des facteurs importants qui ont une influence considérable sur les fonctions exécutives (Farah et al., 2006; Mezzacappa, 2004; Noble et al., 2005) et la mémoire de travail (Lee et al., 2003; Noble et al., 2007). Toutes les personnes qui ont participé à nos expériences ont été testées sur ces variables, par le biais du test d'Indice de Position Socio-Economique (IPSE, Genoud, 2005). De plus, à notre connaissance, l'étude du Chapitre I est la première étude à montrer l'articulation entre bilinguisme et niveau socio-économique/ niveau d'éducation.

Le coût cognitif engendré par le changement de langues

Les expériences des Chapitres II et III avaient pour but d'investiguer les coûts cognitifs provoqués par l'utilisation de langue différentes dans une tâche de mémoire de travail et le changement de langue à l'intérieur même d'un essai de cette tâche. Le principe des tâches présentées dans le Chapitre II était le suivant : les participants effectuaient une tâche d'empan complexe dans laquelle ils devaient lire et mémoriser des items, soit des chiffres ou des mots. Ils devaient les rappeler dans l'ordre de présentation à la fin d'une série. Entre chaque item, ils devaient effectuer une tâche dite concurrente, qui consistait à nommer soit des formes, des chiffres ou des couleurs à haute voix. Dans le Chapitre III, les participants effectuaient un reading span multilingue. Ils devaient lire à haute voix une phrase et se souvenir du dernier mot de cette dernière. A la fin de séries comprenant deux à cinq phrases, ils devaient rappeler ces mots. Les expériences du Chapitre II ont montré que lorsque les items à mémoriser étaient des chiffres, la performance des participants était meilleure lorsque l'essai se déroulait en une seule langue que lorsque l'essai se déroulait en deux langues, i.e. en devant lire les items à mémoriser en L1 et en effectuant la tâche concurrente en L2 et vice-versa. Cependant, lorsque les items à mémoriser étaient des mots, il n'y avait pas de différence entre ces deux types d'essai. La littérature sur les stratégies d'encodage dans la recherche sur la mémoire de travail peut expliquer ces résultats. Ainsi, Bailey et al. (2011) ont montré que dans des tâches d'empan complexe mesurant la capacité de mémoire de travail, l'utilisation de stratégies efficientes d'encodage selon la nature des items à mémoriser est primordiale. Leurs recherches ont mis en évidence que les stratégies les plus efficaces, lorsque leur utilisation est possible, étaient l'imagerie et la création de phrases (*sentence generation*) (Bailey et al., 2009, 2008; Dunlosky & Kane, 2007). L'imagerie consiste à penser à l'image d'un item à mémoriser et la création de phrases consiste à créer une ou plusieurs phrases qui contiennent les items à mémoriser. Dans nos études, les expériences qui consistent à mémoriser des mots permettent aisément d'utiliser ces deux stratégies, tandis que la possibilité d'utiliser l'imagerie et la création de phrases semble improbable, voire impossible, lorsqu'il s'agit de mémoriser des chiffres. Nous proposons que les performances équivalentes de mémorisation de mots, entre les conditions comportant une seule langue et deux langues de l'Expérience 3 du Chapitre II, sont dus au fait que l'utilisation des stratégies d'imagerie et de création de phrases était possible. Cela permettait de bénéficier d'une stratégie d'encodage efficiente, indépendamment des langues dans lesquelles les items étaient présentés. Tandis que pour les tâches d'empan complexe qui consistaient à mémoriser des chiffres, comme l'utilisation de ces deux stratégies d'encodage était peu probable, la performance de rappel était plus sensible au nombre de langues présentes dans l'essai. Dans le Chapitre III, qui consistait également à mémoriser des mots, le rappel dans les essais entièrement en L1 était supérieur au rappel des essais en langues mixtes L1 et L2. Une différence majeure entre les expériences du Chapitre II et l'expérience du Chapitre III réside dans la nature de la tâche concurrente. Dans le Chapitre II, les participants doivent soit lire des chiffres, soit nommer des formes ou des couleurs. En revanche, dans le Chapitre III, ils doivent lire des phrases. D'une part, la durée de la tâche concurrente est plus longue, laissant plus de délai entre la présentation de chaque item à mémoriser. Comme les participants doivent lire la phrase à voix haute à un rythme normal, les opportunités d'utiliser la boucle phonologique pour maintenir les items sont bloquées et les opportunités de rafraîchissement attentionnel sont faibles à cause du rythme de lecture, engendrant ainsi un coût cognitif important de la tâche concurrente. D'autre part, on peut supposer que les intrusions lexicales des mots lus sont importantes, alors que dans le Chapitre II, les intrusions lexicales des chiffres à lire ou des formes ou couleurs à nommer sont plus faibles. Ainsi, les importantes intrusions lexicales interféreraient de manière importante avec les mots à mémoriser. Cette hypothèse serait à vérifier lors d'une expérience *follow-up*, dont nous parlerons dans la section *Directions futures*.

Bilinguisme précoce et tardif

Concernant le Chapitre II, d'autres résultats notables que nous avons observés se situent au niveau de la comparaison des bilingues précoces et tardifs, selon la nature des items à mémoriser. Lorsqu'il s'agissait de chiffres à mémoriser, les bilingues précoces obtenaient un score similaire s'ils devaient les lire en L1 ou en L2, tandis que les bilingues tardifs obtenaient un meilleur score lorsqu'ils devaient les lire en L1 qu'en L2. Les bilingues tardifs maîtrisaient moins leur L2 que les bilingues précoces, comme l'ont indiqué les tests de maîtrise des langues des participants. Ce meilleur résultat des bilingues précoces rejoint une recherche menée par Poulisse et Bongaerts (1994). Ces derniers ont montré que les individus qui maîtrisent significativement moins leur deuxième langue que leur première langue souffraient de plus d'intrusions de leur première langue lorsqu'ils effectuaient une tâche en deuxième langue.

Dans le reading span du Chapitre III, les performances étaient meilleures lorsque les participants devaient se souvenir des mots entièrement dans leur L1, comparé à leur L2 (i.e. une deuxième langue apprise jusqu'à l'âge de 10 ans) et leur L3 (une troisième langue apprise après l'âge de 10 ans). Il n'y avait pas de différence significative de performance entre les conditions L2 et L3. Cette similarité de performance est très probablement due à la bonne maîtrise de la L3, qui était équivalente à leur maîtrise de la L2. A noter que les performances entièrement en L2 ou L3 étaient similaires aux performances des essais à deux langues L1L2 et L1L3. Nous faisons l'hypothèse que cela est dû au fait que la L1 est toujours activée lorsqu'un participant effectue une tâche dans une autre langue (e.g., Hoshino & Kroll, 2008). Ainsi, même si l'essai ne comporte pas de phrases en L1, la L1 est activée et vient faire intrusion dans l'essai en L2 ou L3. Concernant les temps de lecture des phrases du reading span, il n'y avait pas de différence de temps de lecture dans les essais ne comprenant qu'une seule langue. Néanmoins, dans les essais comprenant deux langues, i.e. une phrase en L1 et la suivante en L2 ou L3, le temps de lecture en L1 est plus court que le temps de lecture en L2 ou en L3. Comme le temps de lecture n'était pas limité, les participants devant lire à un rythme normal, nous faisons l'hypothèse que la différence de vitesse de lecture s'est manifestée uniquement lorsque la L1 était directement confrontée à la L2 ou L3.

L'acquisition et l'utilisation des langues

Le Chapitre IV était une partie qui décrivait les bilingues à l'aide d'un questionnaire validé, le LEAP-Q (Marian et al., 2007). Cet outil s'intéresse à l'acquisition et l'utilisation des langues d'un individu bilingue ou multilingue. L'idée de cette ultime partie était de soumettre ce questionnaire à un nombre beaucoup plus élevé de participants que dans les parties expérimentales, afin de pouvoir effectuer des analyses statistiques avec un effet de puissance suffisant. En effet, le questionnaire comportait plusieurs dizaines de questions, il fallait donc un nombre suffisant de participants en contrepartie afin de pouvoir effectuer des analyses valides. La majeure partie des expériences que nous avons menées se sont penchées sur les bilingues français/allemands ou allemands/français. La raison qui nous a amenés à choisir ce type de participants est simplement le statut bilingue français/allemand du canton, ainsi que le statut bilingue de l'Université de Fribourg, la seule offrant une filière bilingue en Suisse. Pour ce chapitre, nous avons donc recruté des universitaires bilingues qui ont appris le français et l'allemand jusqu'à l'âge de 10 ans, dans le souci de décrire au mieux les participants qui ont pris part à nos études. En réalité, les participants ont acquis les deux langues bien avant cet âge, en moyenne à l'âge de 2.7 ans. Les participants sont donc en majeure partie des bilingues simultanés, c'est à dire des bilingues qui ont appris leurs deux langues en même temps. En outre, la quasi-totalité des participants parlait une troisième langue, principalement l'anglais, apprise après l'âge de 10 ans. Dans nos études, nous avons la plupart du temps étudié le bilinguisme précoce. Si nous avions étudié le bilinguisme sans faire de distinction quant à l'âge d'acquisition, nous n'aurions pas ou très rarement trouvé de bilingues, c'est à dire de participants qui parlaient précisément deux langues. Nous aurions alors dû les considérer comme multilingues. A l'aide d'une analyse discriminante, deux profils de bilingues ont émergé de cette étude. Le critère principal qui a permis de classer les participants en deux groupes a été l'utilisation de leurs langues. Un premier groupe parlait une langue à son domicile et une autre à l'extérieur. Un deuxième groupe parlait ces deux langues dans tous les environnements qu'il fréquentait.

Le bilinguisme par nécessité

La pratique d'un bon nombre d'activités a une influence positive sur les fonctions exécutives, la recherche ayant montré une amélioration de ces dernières par la pratique régulière de ces activités. Ainsi, par exemple la pratique de la musique (e.g., Amer, Kalender, Hasher, Trehub, & Wong, 2013; Bialystok & DePape, 2009; Bugos, Perlstein, McCrae, Brophy, & Bedenbaugh, 2007; Moreno et al., 2011; Schellenberg, 2005), des jeux vidéo (Anguera et al., 2013; Bavelier, Green, Pouget, & Schrater, 2012; Bialystok, 2006; C. S. Green, Sugarman, Medford, Klobusicky, & Bavelier, 2012; Strobach, Frensch, & Schubert, 2012), ou encore des activités physiques demandant de la discipline comme des sports de combat, le yoga et la méditation (pour une revue de littérature, voir Diamond & Lee, 2011) ont montré des effets positifs.

Néanmoins, ces activités possèdent une différence majeure avec le bilinguisme précoce et dans certains cas le bilinguisme tardif. Concernant les activités citées ci-dessus, la décision de les pratiquer émane-t-elle d'un fonctionnement du contrôle exécutif plus développé au départ ou est-ce leur pratique qui a réellement et significativement amélioré les performances en contrôle exécutif ? Le fait de s'essayer à une activité et de percevoir que l'on possède des facilités à la pratiquer peut influencer l'exercice de cette dernière (Valian, 2015). En effet, les individus pratiquant ces activités ont potentiellement des traits de personnalité ou des spécificités dans leurs capacités cognitives qui expliquent la motivation à exercer ces activités et à persévérer. En d'autres termes, la pratique de ces activités émane d'un choix, tandis que le bilinguisme précoce n'est pas un choix. Comme les résultats de l'étude sur l'acquisition et l'utilisation des langues du Chapitre IV l'ont montré, les bilingues précoces ont appris leur L2 simultanément à leur L1. De plus, cette étude a révélé que les participants parlaient soit leurs deux langues dans leur ménage, soit parlaient une langue chez eux et une deuxième à l'extérieur. Ainsi, ils ont soit des parents bilingues, un parent parlant leur L1 et l'autre leur L2 ou les deux parents parlant les deux langues, soit ils vivent dans un pays ou une région dont la langue est différente de celle de leurs parents. Toutes ces possibilités montrent que les bilingues précoces sont bilingues par nécessité et non par choix. Ici, l'hypothèse de Valian (2015) n'est donc pas envisageable. En d'autres termes, les bilingues précoces n'ont pas appris et persévéré dans la pratique d'une deuxième langue car ils éprouvaient de la facilité dans cet exercice. Ainsi, lorsqu'un avantage bilingue sur la mémoire de travail ou des fonctions exécutives est mesuré, on peut être conforté dans l'idée que l'apprentissage et la pratique d'une deuxième langue influence positivement ces capacités. Concernant le bilinguisme tardif, il n'est dans certains cas pas un choix non plus. Ainsi, une famille ou un individu qui ont été forcé d'émigrer ne deviennent pas bilingues par choix, mais également par nécessité.

Directions futures

Les recherches qui pourraient être menées pour compléter ce travail pourraient s'intéresser à des populations d'âges différents. Ainsi, les questions suivantes pourraient être investiguées : est-ce que l'avantage bilingue sur la capacité de mémoire de travail que nous avons trouvé chez une population au niveau socio-économique et niveau scolaire plus bas se trouve-t-il déjà dans une population d'enfants en école primaire ? Est-ce que cet avantage se maintient chez des personnes âgées ? En outre, une étude longitudinale pourrait s'avérer très intéressante, bien que difficile à réaliser. Le fait de suivre des bilingues depuis l'enfance jusqu'à leur vieillesse pourrait apporter des éléments très intéressants. Les études longitudinales sur plusieurs décennies concernant des bilingues sont rares, mais existent. Ainsi, Bak, Nissan, Allerhand et Deary (2014) ont étudié l'influence du bilinguisme sur le vieillissement cognitif en testant à nouveau plus de 800 participants qui avaient complété une batterie de tests cognitifs en 1947 lorsqu'ils avaient 11 ans. Ces mêmes participants avaient une septantaine d'années lors de la période de retest.

Un suivi possible des Chapitres II et III serait de remplacer les mots à mémoriser par des non-mots, afin de tester si des différences de performances interviennent. Si c'est le cas, cela voudrait dire que les participants font un processing de l'information lexicale des mots, c'est-à-dire qu'ils utilisent cette information lexicale et cela influence leur performance de rappel. S'il n'y pas de différence, cela laisserait penser que les participants ne font pas de processing de l'information lexicale. Dans un deuxième temps, faire lire aux participants des phrases composées de non-mots, excepté le dernier mot à mémoriser, permettrait de tester si la tâche concurrente d'un reading span, en d'autres termes la lecture d'une phrase, a une influence négative sur la performance de rappel à cause des intrusions lexicales provoquées par les mots composant la phrase.

Une possibilité plus axée sur la recherche de terrain serait de tester le programme de remédiation pour des bilingues en difficulté scolaire, que nous avons proposé dans la discussion du Chapitre I. Pour rappel, nous avons proposé un programme qui avait pour but de générer de la motivation intrinsèque chez des bilingues qui éprouvaient des difficultés scolaires, en utilisant des exercices requérant l'utilisation de la mémoire de travail. Comme les bilingues d'un niveau socio-économique plus bas qui avaient participé à notre étude ont montré une meilleure capacité de mémoire de travail, leur faire exécuter des exercices basés sur la mémoire de travail devrait leur redonner un sentiment de self-efficacité et ainsi faire remonter leur motivation intrinsèque. Nous avons fondé cette proposition en fonction de la théorie d'auto-détermination de Deci et Ryan (e.g., Deci et al., 1999; Deci & Ryan, 1985, 2002), qui vise à stimuler la motivation intrinsèque.

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