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Contribution des représentations sémantiques et lexicales au rappel sériel immédiat

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La tâche de rappel sériel immédiat (RSI) est une tâche couramment utilisée par les chercheurs en sciences cognitives ou en neuropsychologie. Intéressés à l'étude des processus mnésiques, ils se sont servis de cette tâche afin de mesurer la capacité d'emmagasiner de l'information pour de brèves périodes de temps. Les données empiriques recueillies supportent l'une des conceptions de la mémoire les plus influentes : le modèle de la mémoire de travail de Baddeley (1986; Baddeley & Hitch, 1974). Ce modèle stipule que le RSI de courtes listes d'items verbaux est essentiellement déterminé par des facteurs phonologiques. De plus, l'information à rappeler est emmagasinée dans un système distinct de celui responsable du langage, témoignant d'une approche par « store ». Or, d'autres chercheurs principalement issus du domaine de la psycholinguistique ont utilisé le RSI chez des patients atteints de troubles du langage. Leurs études suggèrent que les processus impliqués dans le traitement du langage et le RSI sont indissociables. N. Martin & Saffran (1997) proposent le modèle d'activation interactive qui s'inscrit dans une perspective procéduraliste où les processus responsables du traitement assurent aussi le stockage de l'information (Allport, 1985; Craik & Lockhart, 1972; Crowder, 1989; 1993; McClelland & Rumelhart, 1985). Ce modèle stipule que le RSI est influencé non seulement par des facteurs phonologiques mais par tous les niveaux de représentations linguistiques, incluant les connaissances lexicales et sémantiques.

Le but de cette thèse est d'examiner si les différents niveaux de représentations linguistiques contribuent à la performance au RSI, tel que postulé par le modèle d'activation interactive (N. Martin & Saffran, 1997). Plus particulièrement, l'influence des représentations sémantiques et lexicales est évaluée à la fois chez le participant normal et pathologique. En complément, il est démontré qu'une conception procéduraliste de la mémoire peut rendre compte de la dissociation postulée par l'approche par store, entre la mémoire à court terme (MCT) et la mémoire à long terme (MLT).

La contribution lexicale et sémantique au RSI a d'abord été évaluée auprès de participants normaux (Articles 1 et 2). La méthode expérimentale utilisée consiste à manipuler le matériel à rappeler selon le type de représentations linguistiques qu'il active ou possède. Trois types de stimuli ont été utilisés : (1) des mots de classe ouverte (substantifs abstraits) qui activent des représentations sémantiques et lexicales (e.g. idée), (2) des mots de classe fermée (e.g., conjonctions) qui possèdent des représentations lexicales mais peu de sémantique lorsque présentés de façon isolée (e.g. ainsi) et (3) des pseudo-mots, qui n'ont pas de représentations lexico-sémantiques (e.g. aupha). L'Article 1 évalue l'effet sur le RSI de la contribution lexico-sémantique en fonction de la position sérielle. L'interaction de la similarité phonologique des items et de la suppression articulatoire avec ces facteurs linguistiques a été évaluée dans deux expériences. Les résultats indiquent que les mots de classe fermée sont mieux rappelés que les pseudo-mots, indépendamment des manipulations expérimentales. Les résultats montrent également un avantage des mots de classe ouverte sur ceux de classe fermée mais cet effet ne se trouve que

lorsque les conditions expérimentales empêchent l'utilisation des représentations phonologiques (suppression articulatoire ou items phonologiquement similaires). L'Article 2 vise à s'assurer que cet effet n'est pas lié à la présentation répétée des items qui pourrait avoir favorisé les mots. Les résultats montrent que les effets lexico-sémantiques au RSI sont observés même lorsque les items ne sont jamais répétés.

L'Article 3 présente l'étude de cas d'une patiente (H.P.) montrant une atteinte des connaissances sémantiques pour certains items à la suite d'une encéphalite herpétique. La contribution linguistique au RSI a été évaluée à l'aide des trois types de stimuli suivants : (1) des mots connus de H.P., qui activent des représentations sémantiques et lexicales; (2) des mots dont H.P. ne connaît pas le sens mais qu'elle peut reconnaître comme étant des mots de la langue française. Ces mots possèdent donc des représentations lexicales mais pas ou peu de représentations sémantiques; et (3) des pseudo-mots. Les résultats montrent un meilleur rappel pour les mots connus que pour les mots perdus et ces derniers sont mieux rappelés que les pseudo-mots. Ils suggèrent que les représentations sémantiques contribuent au RSI de façon distincte des représentations lexicales. De plus, il est proposé que ces influences linguistiques s'étendent au RSI de pseudo-mots qui sont similaires aux mots connus de H.P. via un processus d'activation interactive.

L'hypothèse procéduraliste a été évaluée dans l'Article 4, chez une patiente (I.R.) présentant une MCT touchée et une MLT normale. Selon l'approche par store, cette dissociation MCT/MLT constitue un argument majeur pour postuler l'existence de systèmes de mémoire distincts. Par ailleurs, selon l'approche procéduraliste, une atteinte au niveau du traitement phonologique aura des répercussions sur toute les

tâches de maintien de l'information, indépendamment qu'elles soient dites à court ou à long terme. La méthode expérimentale choisie a été d'utiliser des tâches classiques de rappel à court et à long-terme et d'évaluer la contribution des représentations phonologiques et lexico-sémantiques à chacune de ces tâches. Les résultats appuient l'hypothèse procéduraliste et indiquent d'une part, une atteinte de la performance lorsque la tâche exige un traitement phonologique, sans égard au type de rappel utilisé (à court ou long terme). D'autre part, l'utilisation des informations lexico-sémantiques a été montrée, tant dans les tâches de rappel à court terme qu'à long terme. Ainsi, les atteintes « sélectives de la MCT » rapportées dans la littérature, peuvent être attribuées au fait que les tâches dites de MCT reposent essentiellement sur l'utilisation des représentations phonologiques qui sont déficitaires chez ces patients.

En résumé, la contribution des représentations lexicales et sémantiques au RSI normal et pathologique observée dans nos travaux, appuie le modèle d'activation interactive (N. Martin & Saffran, 1997) et de façon plus générale l'approche procéduraliste de la mémoire mais des hypothèses alternatives sont discutées. Ces travaux permettent d'aborder la capacité de traitement de l'information de façon nouvelle et offre une alternative aux modèles par store qui prévalent depuis un certain nombre d'années. Cette conception pourrait nous amener à revoir les dissociations à la base d'autres syndromes cliniques et notamment dans le cas de l'amnésie. Des évidences en ce sens ont déjà été rapportées dans quelques études (MacKay, Burke, & Stewart, 1998; Mackay, Stewart, & Burke, 1998).

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MCT :	Mémoire à court terme
MLT :	Mémoire à long terme
RSI :	Rappel sériel immédiat

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Chapitre 1

INTRODUCTION

INTRODUCTION GÉNÉRALE

Le rappel sériel immédiat (RSI) est l'une des tâches les plus fréquemment utilisées, tant dans le domaine de la psychologie cognitive que de la neuropsychologie. D'abord, la capacité de rappeler une courte séquence d'items a été longtemps considérée comme un facteur déterminant les limites du traitement de l'information de l'individu. Il n'est donc pas étonnant que différentes informations importantes à mémoriser, par exemple un numéro de téléphone, aient été modelées sur la limite du RSI des sujets normaux (*The magic number seven* : Miller, 1956). Ensuite, plusieurs chercheurs ont utilisé le RSI pour comprendre les mécanismes qui sous-tendent la capacité de traitement de l'information pour de courts laps de temps. Il est en effet apparu clair que la tâche pouvait révéler des informations cruciales sur l'organisation de la mémoire et de la cognition.

Le modèle le plus répandu pour rendre compte des performances au RSI propose que des facteurs phonologiques sont essentiellement responsables de la capacité à rappeler l'information dans cette tâche. Toutefois, des facteurs lexicaux et sémantiques s'ajouteraient aux facteurs phonologiques pour supporter la performance au RSI. L'objectif général de cette thèse est d'évaluer la contribution des connaissances sémantiques et lexicales au RSI telle que proposée par une approche psycholinguistique du RSI. De façon générale, le design expérimental choisi consiste à manipuler le matériel à mémoriser lors d'une tâche de RSI en utilisant des items qui varient quant à leur contenu sémantique et lexical. Un deuxième objectif, qui se veut complémentaire au premier, est de montrer que l'approche procéduraliste dans

laquelle s'inscrivent les modèles linguistiques peut aussi rendre compte de la performance des patients ayant une atteinte sélective de la mémoire à court terme (MCT), telle que conçue dans une approche par store, sans avoir à postuler l'existence d'un store dédié à cette capacité.

Cette thèse est présenté sous forme de quatre articles. L'introduction vise à fournir au lecteur les éléments de la littérature nécessaires à la compréhension de la problématique soulevée dans la partie expérimentale de la thèse. L'introduction est divisée en quatre parties. La première section de l'introduction présente la conception théorique la plus répandue de la capacité à traiter l'information durant de courtes périodes de temps et selon laquelle le RSI repose essentiellement sur l'existence d'un store phonologique. La deuxième section expose de façon critique les travaux récents qui ont évalué la contribution des connaissances lexicales et sémantiques au RSI, tant chez le participant normal que cérébrolésé. La troisième section présente différents modèles qui supportent une contribution des représentations lexicales et sémantiques au RSI. Enfin, la dernière section présente la problématique à l'étude dans cette thèse et les hypothèses découlant de l'approche théorique préconisée.

1. Modèle de la Mémoire de Travail

Un des modèles les plus influents pour rendre compte de la capacité à traiter brièvement l'information présentée, est le modèle de la mémoire de travail élaboré par Baddeley et Hitch (1974; Baddeley, 1986). Ce modèle vise à rendre compte des données empiriques obtenues au RSI de courtes listes d'items. Ainsi, les nombreux

travaux réalisés à l'aide de cette tâche ont donné lieu à trois effets expérimentaux robustes : l'effet de similarité phonologique, l'effet de longueur de mots et l'effet de suppression articulatoire.

L'effet de similarité phonologique consiste en une moins bonne performance au RSI lorsque les items sont similaires au plan phonologique, particulièrement au niveau de la rime (e.g., b, p, g, v, t,), que lorsqu'ils sont dissimilaires sur ce plan (e.g., h, k ,r ,f ,m; Baddeley, 1966; Conrad & Hull,1964). Cet effet est observé tant en modalité de présentation auditive que visuelle et suggère que l'information verbale est maintenue sous un code phonologique. L'effet de longueur de mots se traduit par un plus petit nombre d'items rappelés lorsque ces derniers sont longs (e.g., mots de cinq syllabes) que lorsqu'ils sont courts (e.g., mots de 2 syllabes; Baddeley, Thompson, & Buchanan, 1975). Enfin, l'effet de suppression articulatoire consiste en une performance inférieure au RSI lorsque le participant répète de façon continue un segment verbal (e.g., bla-bla-bla) comparativement à une situation où il garde le silence (Murray, 1967). La suppression articulatoire module les effets de similarité phonologique en fonction de la modalité d'entrée des items à mémoriser; elle fait disparaître l'effet de similarité phonologique lorsque les items sont présentés par écrit mais pas lorsqu'ils sont présentés oralement. Il a été également montré que la suppression articulatoire élimine l'effet de longueur de mots, quelle que soit la modalité de présentation des items (Baddeley, Thompson, & Buchanan, 1975).

Ces résultats expérimentaux ont motivé le modèle de la mémoire de travail de Baddeley (1986; Baddeley & Hitch, 1974). Selon cette hypothèse, la mémoire de

travail serait spécifiquement dédiée au maintien temporaire de l'information. Cette mémoire serait fonctionnellement distincte des autres systèmes de mémoire, par exemple la mémoire à long-terme (MLT), et des systèmes de traitement du langage. La mémoire de travail est un système tripartite qui inclut une composante spécialisée dans le maintien de l'information visuo-spatiale, une composante spécialisée dans le maintien de l'information verbale, *la boucle phonologique*, et une composante attentionnelle responsable du contrôle de l'action et de la gestion des ressources. Puisque le travail présenté dans cette thèse concerne spécifiquement la rétention de matériel verbal, nous nous attarderons ici à décrire la boucle phonologique de la mémoire de travail.

La boucle phonologique comprend deux sous-composantes: le *registre phonologique* et la *procédure de répétition subvocale* (voir Figure 1, p. 24). Le registre phonologique est en quelque sorte un store, ou réservoir, qui permet de contenir l'information verbale. La procédure de répétition subvocale permet de « rafraîchir » la trace phonologique qui, selon cette approche, se dégraderait rapidement. L'accès au registre phonologique diffère selon la modalité d'entrée au système. En présentation auditive, l'information accède directement au registre phonologique. En présentation visuelle, l'information orthographique doit être recodée phonologiquement via la procédure de répétition subvocale avant d'accéder au registre.

Le modèle permet de rendre compte des effets expérimentaux décrits plus haut. L'effet de longueur de mots reflète l'utilisation de la procédure de répétition subvocale. Puisqu'il faut plus de temps pour répéter des mots longs que des mots

courts, moins de mots longs auront été « rafraîchis » par la procédure de répétition subvocale, pour une même période de temps. En conséquence, les mots longs sont défavorisés par rapport aux mots courts. L'effet de la suppression articulatoire a aussi été attribué à la procédure de répétition subvocale. Lorsque le participant prononce le segment demandé, celui-ci occupe la procédure de répétition subvocale ce qui empêche les items d'être rafraîchis. De plus, les items présentés en modalité visuelle ne peuvent être recodés phonologiquement et accéder au registre phonologique éliminant ainsi l'effet de similarité phonologique. Cela ne serait pas le cas en modalité auditive puisque l'information accède directement au registre phonologique.

En résumé, les données empiriques montrent que le RSI est fortement influencé par les propriétés phono-articulatoires des items à rappeler. Le modèle de Baddeley (1986) rend compte de ces effets et relie la performance au RSI verbal à des facteurs essentiellement phono-articulatoires. Puisque les composantes de la boucle phonologique sont insensibles au statut lexical ou sémantique des items à rappeler, ce modèle prédit que seuls des effets phono-articulatoires seront observés lors du RSI de courtes listes d'items verbaux.

Le modèle de la mémoire de travail de Baddeley (1986) a d'abord été mis à l'épreuve par des études qui ont rapporté des effets de la fréquence d'utilisation des mots dans le RSI, un facteur associé au traitement lexical (Forster, 1976; Jescheniak & Levelt, 1994). Watkins et Watkins (1977) ont comparé le rappel de courtes listes (8 items) de mots fréquents à celui de mots rares. Les résultats montrent un avantage pour le RSI de listes de mots fréquents comparativement à celui de listes de mots

rares et suggèrent que des facteurs autres que ceux reliés aux représentations phonologiques contribuent au RSI.

D'autres chercheurs se sont penchés sur cette même question. La prochaine section présente un ensemble non-exhaustif des travaux qui ont évalué différents facteurs lexico-sémantiques pouvant affecter la performance au RSI, tant chez le participant normal que cérébrolésé.

2. Évidences de la Contribution des Représentations Lexicales et Sémantiques au Rappel Sériel Immmédiat

Effets Lexicaux dans le Rappel Sériel Immédiat: Études chez le Sujet Normal

La contribution des représentations lexicales au RSI a d'abord été montrée en comparant le rappel de mots au rappel de pseudo-mots. Les études récentes qui ont mesuré cet effet ont généralement pris soin d'apparier la vitesse d'articulation des mots et des pseudo-mots en utilisant des stimuli de longueurs différentes (Hulme, Maughan & Brown, 1991; Hulme, Roodenrys, Brown, & Mercer, 1995). On sait en effet que les pseudo-mots sont généralement prononcés plus lentement que les mots et cette différence dans la vitesse d'articulation pourrait rendre compte de leur moindre rappel. Les résultats montrent un avantage pour le rappel des mots comparativement aux pseudo-mots et suggèrent ainsi une contribution lexicale au RSI, non reliée à des facteurs articulatoires. A l'aide d'un paradigme légèrement

différent, un effet de lexicalité indépendant de la boucle phonologique a aussi été montré par Besner et Davelaar (1982). Ces chercheurs ont utilisé des pseudo-homophones (e.g. pheuil) qu'ils ont comparés à des pseudo-mots (e.g. bruc) en modalité visuelle. Lorsqu'ils sont entendus, les pseudo-homophones ressemblent à des mots réels mais ne le sont pas visuellement. Le RSI a été réalisé dans des conditions de silence et de suppression articulatoire de manière à bloquer l'accès à la boucle phonologique tel que postulé par le modèle de Baddeley, (1986; voir Figure 1, p. 24). Les résultats montrent que le rappel des pseudo-homophones est supérieur à celui des pseudo-mots et l'effet est attribué à la lexicalité des pseudo-homophones.

Les résultats des études précédentes ont été attribués à la forme phonologique des mots (ou niveau lexical des représentations). Or, deux de ces études (Besner & Davelaar, 1982; Hulme et al, 1991) ont utilisé des stimuli pour lesquels les représentations lexicales et sémantiques étaient confondues. En effet, les mots avec lesquels le rappel des pseudo-mots était comparé contiennent ou activent ces deux niveaux de représentations. Par conséquent, il est impossible de savoir si l'avantage des mots par rapport aux pseudo-mots dans la performance au RSI est lié à la contribution du niveau lexical, du niveau sémantique ou des deux niveaux.

La contribution lexicale a aussi été évaluée en mesurant l'effet de fréquence des mots lors d'une tâche de RSI (Gregg, Freedman & Smith, 1989; Hulme, Roodenrys, Schweickert, Brown, S. Martin, Stuart, 1997; Roodenrys, Hulme, Alban, Ellis & Brown, 1994; Tehan & Humphreys, 1988;). Toutes ces études rapportent un avantage pour le rappel des mots fréquents comparativement aux mots rares. Encore

ici, ces effets de fréquence ont été obtenus en contrôlant les différents paramètres pouvant affecter la performance dont la vitesse d'articulation, la répétition subvocale et l'imageabilité des stimuli. Ils sont donc attribués au niveau de représentation lexicale.

Les études ayant rapporté des effets de lexicalité et de fréquence dans le RSI appuient l'hypothèse voulant que des niveaux linguistiques autres que le niveau phonologique contribuent au RSI. Étant donné la nature de ces variables, ces effets sont interprétés comme reflétant l'influence des représentations lexicales. Dans la prochaine section, nous examinerons les arguments empiriques appuyant une contribution des représentations sémantiques au RSI.

Effets Sémantiques dans le Rappel Sériel Immédiat: Études chez le Sujet Normal

Depuis environ 10 ans, un nombre de plus en plus important d'études ont examiné la contribution possible des représentations sémantiques dans le RSI. Poirier et Saint-Aubin (1995) ont comparé le RSI de mots provenant de catégories sémantiques homogènes (e.g., tous des animaux) à celui de mots issus de catégories sémantiques hétérogènes. Les résultats montrent que les mots de la même catégorie sont mieux rappelés que ceux de catégories différentes. De plus, l'effet de la catégorie sémantique, obtenu en modalité visuelle, a été maintenu en condition de suppression articulatoire.

Certains chercheurs (Bourassa & Besner, 1994; Tehan & Humphreys, 1988)

ont utilisé un paradigme ingénieux qui manipule le type de mots utilisé dans le but d'isoler l'influence des représentations sémantiques sur le RSI. Dans ce type d'étude, des mots provenant de deux catégories grammaticales distinctes ont été utilisés : des mots de classe ouverte (e.g., noms concrets, adjectifs) et des mots de classe fermée (e.g., conjonctions). Le choix de ces items repose sur l'hypothèse voulant que le type de représentations linguistiques qui caractérisent ces mots varient d'une catégorie à l'autre : les mots de classe ouverte activent des représentations sémantiques et lexicales alors que les mots de classe fermée activent des représentations lexicales mais peu ou moins de sémantique, lorsqu'ils ne sont pas placés dans le contexte d'une phrase (e.g., *table* vs. *de*). Les résultats montrent un meilleur rappel des mots de classe ouverte que celui des mots de classe fermée. Cet effet de la catégorie grammaticale obtenu en modalité visuelle, est observé à la fois en condition de silence et de suppression articulatoire. Ces résultats sont donc interprétés comme reflétant une contribution sémantique indépendante de la boucle phonologique. Malheureusement, cette étude ne permet pas de comparer l'ampleur des effets sémantiques à celle des effets lexicaux puisqu'elle ne compare pas le rappel des mots de classe fermée à celui des pseudo-mots.

Par ailleurs, la contribution de facteurs sémantiques au RSI ne semble pas être observée de façon aussi systématique que celle associée aux facteurs lexicaux. Notamment, Baddeley (1966) a comparé le RSI de synonymes à celui de mots ayant tous un sens différent. Les résultats montrent que le RSI est désavantagé par l'usage de synonymes comparativement à celui de mots de significations différentes. Bourassa et Besner (1994) ont aussi montré que l'effet de catégorie grammaticale

attribué à des facteurs sémantiques était éliminé lorsque les items étaient appariés au niveau de l'imageabilité. Dans une autre étude comparant le RSI de mots provenant de la même catégorie sémantique à celui de mots de catégories distinctes, Crowder (1979) montre que l'avantage des mots de catégories sémantiques homogènes dépend de la méthode de cotation utilisée. Ainsi, l'influence des facteurs sémantiques sur le RSI semble plus fragile que celle des facteurs lexicaux et dépend davantage des paramètres expérimentaux tels que les critères de cotation utilisés et le contrôle des facteurs confondants.

Apport de la Neuropsychologie

L'étude de patients cérébolésés montrant des atteintes marquées de certaines composantes cognitives offre une autre façon de mieux comprendre les mécanismes qui sous-tendent le comportement. Tel que mentionné précédemment, plusieurs études impliquant des patients avec des troubles du langage ont mis en évidence la contribution des facteurs lexicaux et sémantiques au RSI. Ainsi, N. Martin et Saffran (1997) ont montré que les effets d'imageabilité lors d'une tâche de répétition de paires de mots sont négativement corrélés à la capacité des patients aphasiques à utiliser les représentations phonologiques. Ces résultats suggèrent que des facteurs non-phonologiques tels l'imageabilité, soutiennent la performance au RSI lorsqu'il y a atteinte des représentations phonologiques. La même corrélation était attendue entre les effets de fréquence et l'atteinte phonologique mais elle ne s'est pas avérée significative. Toutefois, une autre étude a montré un effet de la fréquence d'usage des mots sur le RSI de courtes listes d'items (trois ou quatre items) chez un patient atteint

d'aphasie sensorielle transcorticale (N. Martin & Saffran, 1990). Ces résultats appuient ainsi l'idée voulant que des facteurs lexicaux contribuent au RSI.

R.C. Martin, Shelton et Yaffee (1994) ainsi que Saffran et N. Martin (1990) ont utilisé le RSI de listes d'items pour examiner l'effet de position sérielle chez des patients aphasiques présentant des troubles sémantiques en plus de leur déficit phonologique. Ils ont montré que ces déficits se reflétaient dans leur performance au RSI. L'effet de position sérielle normal avec des listes légèrement au dessus de l'empan, consiste en un meilleur rappel des premiers items (appelé effet de primauté) et des derniers items de la liste (nommé effet de récence) comparativement aux items du centre. L'effet de primauté est généralement associé à la contribution des représentations lexico-sémantiques alors que l'effet de récence dépendrait davantage des représentations phonologiques. Les résultats de ces deux études ont montré une réduction de l'effet de primauté chez les patients avec un déficit sémantique et suggèrent une contribution du niveau lexico-sémantique au RSI.

D'autres chercheurs ont examiné le RSI de patients atteints de démence sémantique. Afin d'évaluer l'influence des connaissances sémantiques, ils ont manipulé le niveau de connaissance des items à rappeler (Knott, Patterson, & Hodges, 1997; Patterson, Graham, & Hodges, 1994). Ces chercheurs ont ainsi comparé le RSI de mots connus des patients à celui de mots perdus en raison du processus dementiel. Les résultats montrent un meilleur rappel des mots connus que des items perdus et ont été attribués au fait que les mots connus possèdent plus d'information sémantique que les mots perdus.

A l'instar de ce qui est observé chez les participants normaux, les effets sémantiques dans le RSI de patients cérébrolésés n'ont pas toujours été obtenus de façon systématique. Warrington (1975) n'a pas trouvé d'avantage dans le RSI de mots connus versus perdus chez des patients atteints de démence sémantique. Funnell (1996) et McCarthy et Warrington (1987) n'ont observé aucun effet de la connaissance des items dans le RSI chez le même type de patients.

Toutefois, plusieurs difficultés méthodologiques ont été relevées dans ces études et pourraient rendre compte des résultats observés. D'abord, il est à noter que dans certaines études, la fréquence des items à rappeler n'a pas été contrôlée (McCarthy & Warrington, 1987; Patterson et al., 1994; Warrington, 1975). Or, tel que mentionné précédemment, de nombreuses études ont démontré que ce facteur influence la performance au RSI. D'autres études (Knott et al.,1997; McCarthy & Warrington, 1987; Patterson et al., 1994; Warrington, 1975) n'ont pas utilisé de groupes contrôles afin de s'assurer notamment que les différents stimuli peuvent être rappelés de manière équivalente lorsqu'il n'y a pas d'atteinte cognitive. Par ailleurs, des effets plafond ont été observés dans l'une de ces études (McCarthy & Warrington, 1987) lors du rappel de mots perdus, ce qui aurait pu empêcher des effets sémantiques potentiels de se manifester.

Certaines limites méthodologiques ont aussi été observées parmi les études qui ont montré des effets de la connaissance des items au RSI. Une limite potentiellement majeure tient au niveau de connaissance des items dits « perdus ». Dans leurs études respectives, Knott et al. (1997) et Patterson et al. (1994) n'ont pas

rapporté le statut lexical des mots perdus utilisés. Puisque les patients déments ont généralement des atteintes sémantiques plus globales que les patients cérébrolésés ou sont susceptibles d'en développer, il est possible que les représentations sémantiques et *lexicales* de ces mots aient été perdues et qu'ils correspondaient davantage à des pseudo-mots pour ces patients. Par conséquent, l'avantage des mots connus (avec signification) versus perdus rapporté dans ces études pourrait être dû à l'influence des représentations lexicales autant que celle des connaissances sémantiques. Ce dernier point met en lumière les difficultés inhérentes aux études impliquant des patients souffrant de pathologies évolutives.

En résumé, plusieurs travaux de la littérature appuient l'idée voulant que des facteurs linguistiques autres que ceux déjà postulés par le modèle de Baddeley (1986) contribuent également à la performance au RSI. Les résultats obtenus jusqu'à maintenant suggèrent que les niveaux sémantiques et lexicaux pourraient contribuer à différents degrés au RSI. Des explications théoriques ont été avancées afin de rendre compte de ces effets, tant par les tenants d'une approche par store que par ceux d'une approche procéduraliste.

3. Explications Théoriques des Effets Lexico-sémantiques au Rappel Sériel Immédiat

Le Modèle de la Mémoire de Travail Révisé

Baddeley, Gathercole et Papagno (1998) ont proposé des modifications au modèle original de Baddeley (1986) afin d'expliquer les résultats montrant une

contribution lexicale au RSI. Dans cette dernière version, il est postulé que le registre phonologique interagit avec la forme phonologique des mots emmagasinée en MLT. Cette interaction permettrait d'expliquer les effets liés aux facteurs lexicaux. Selon cette dernière version, l'accès à la forme phonologique des mots se fait uniquement via le registre phonologique. Par conséquent, cette proposition ne peut rendre compte des effets lexicaux obtenus lorsque les items sont présentés visuellement et que la suppression articulatoire bloque l'accès au registre phonologique (Poirier et St-Aubin, 1995; Bourassa & Besner, 1994). Par ailleurs, Baddeley (1996) tente de rendre compte des effets associés aux facteurs sémantiques en attribuant à l'administrateur central un rôle dans le recrutement de ces représentations. Toutefois, les mécanismes impliqués dans ce processus de recrutement ne sont pas précisés.

Le Modèle d'Activation Interactive

Les chercheurs intéressés à comprendre les processus impliqués dans le traitement du langage et ayant utilisé la tâche de RSI auprès de patients aphasiques, ont mis en évidence un lien étroit entre les différents troubles de compréhension/production de ces patients et leur performance au RSI (N. Martin & Saffran,1990; R.C. Martin & Breedin, 1992; R.C. Martin, Shelton, & Yaffee, 1994; Patterson, Graham, & Hodges, 1994; Saffran, 1990; Saffran & Martin, 1990).

N. Martin et Saffran (1997) ont proposé le modèle d'activation interactive qui postule que les processus impliqués dans le traitement du langage sous-tendent également la performance au RSI. Selon ces auteurs, puisque la

compréhension/production du langage implique que l'information traitée par chacun des niveaux linguistiques soit maintenue temporairement jusqu'à la fin du traitement, ces même processus seraient utilisés lors du RSI d'items verbaux. Selon plusieurs modèles du traitement du langage, différents niveaux de connaissances ou représentations sont utilisés lors de la compréhension/production du langage. Certains de ces modèles incluent notamment les niveaux de représentations phonologique, lexical et sémantique (e.g., Dell, 1986; Ellis & Young, 1988; Levelt, 1989). Par exemple, le niveau phonologique de représentations permet de reconnaître chacun des sons ou phonèmes qui composent un mot présenté verbalement (e.g., *b-a-t-o*), le niveau lexical permet de savoir que cette suite de phonèmes forme un mot et maintient le caractère unifié des phonèmes formant ce mot (car on pourrait entendre un pseudo-mot tel *ridrin*) et le niveau sémantique permet d'attribuer un sens à ce mot. Cependant, il est à noter que la nature exacte de ces représentations et notamment celle du niveau lexical fait l'objet d'un débat (voir e.g., Seidenberg & McClleland, 1989 pour conception alternative).

N. Martin et Saffran (1997) se sont inspirés du modèle de production du langage de Dell et O'Seaghda (1992; Dell, 1986) qui concerne la répétition de mots. Selon ces derniers, les différents niveaux de représentations linguistiques sont reliés par des connections bi-directionnelles. Par conséquent le traitement de l'information à un niveau donné entraîne une activation des niveaux adjacents qui permettent de maintenir l'activation via des cycles de proaction/rétroaction entre les niveaux (voir Figure 2, p. 25). Ce modèle postule également que les niveaux de représentations sont activés de façon sérielle. Ainsi, le niveau activé en premier dépend de l'épreuve

utilisée. Par exemple, lors d'une épreuve de dénomination, l'activation est descendante (top-down) à partir du concept jusqu'à sa production. A l'inverse, lors d'une épreuve de répétition, l'activation est ascendante (bottom-up) à partir de l'input auditif. Dans ce type de modèle, la modalité d'entrée et la nature de la tâche sont importantes puisqu'elles déterminent le déroulement temporel des différentes activations.

Ce modèle assume en effet que la force de l'activation dépend de quel niveau est accédé en premier. Les niveaux de représentations accédés en premier auront une activation plus forte et plus de temps pour bénéficier du soutien de l'activation des autres niveaux via les cycles de proaction/rétroaction que les derniers niveaux activés. C'est d'ailleurs ce dernier postulat qui permet de rendre compte de l'effet de position sérielle lors du rappel de *listes* de mots. Selon ces chercheurs, les mots en début de liste sont activés en premier et cette activation bénéficiera de la proaction/retroaction des différents niveaux linguistiques, d'où leur avantage sur les items du milieu. Les derniers items auront moins de temps pour activer les différents niveaux et leur rappel sera principalement déterminé par l'activation du niveau phonologique qui sera plus récente. Les premiers items devraient donc bénéficier davantage des activations sémantiques que les items plus récemment présentés.

Le modèle d'activation interactive (N. Martin & Saffran, 1997) s'inscrit dans une perspective procéduraliste où les processus responsables du traitement de l'information assurent le maintien ou stockage de l'information jusqu'à la fin du traitement (Craik & Lockhart, 1972; Crowder, 1989; 1993; McClelland & Rumelhart,

1985). Par conséquent le traitement du langage est perçu comme étant indissociable de la performance au RSI. Ainsi, le modèle d'activation interactive prédit que tous les niveaux de représentations contribuent (à des degrés variables) au RSI. Des effets des facteurs phonologiques, lexicaux et sémantiques devraient alors être observés aux tâches de RSI.

Le Modèle Psycholinguistique de R. C. Martin, Lesch et Bartha (1999)

Tout comme le modèle d'activation interactive de N. Martin & Saffran (1997), R.C. Martin, Lesch et Bartha (1999) ont proposé un modèle qui s'inscrit dans une perspective linguistique de la mémoire, où la capacité de maintenir des informations à court terme est liée aux processus de traitement de cette information. Ainsi, ces chercheurs postulent que les processus et représentations impliqués dans la compréhension/production du langage sont responsables de la performance au RSI. Des influences de tous les niveaux linguistiques et notamment les niveaux phonologiques, lexicaux et sémantiques sont ainsi postulées. Toutefois, à l'encontre du modèle de N. Martin et Saffran, l'information issue des différents niveaux de traitement linguistique est maintenue dans des registres (ou stores) lors du RSI. R.C. Martin et al. avancent qu'il peut y avoir chez certains patients une atteinte dans la capacité à maintenir certains types d'information malgré une compréhension/production normale du langage. Il serait donc nécessaire de postuler l'existence de registres séparés afin de rendre compte de cette dissociation. Ces chercheurs postulent ainsi l'existence d'un registre lexico-sémantique et de deux registres phonologiques; un lié à l'entrée (input phonologique) et un autre à la sortie

(output phonologique). Cette dernière distinction est proposée par R.C. Martin et al. après qu'ils aient rapporté le cas d'un patient anomique ayant une performance déficitaire lorsque la tâche de RSI exige une réponse verbale mais une performance normale au RSI sans réponse verbale.

L'Hypothèse de la Redintégration

Contrairement aux deux modèles précédents qui stipulent que les effets lexico-sémantiques au RSI se manifestent pendant l'encodage et la rétention des items, une approche alternative postule une influence lexico-sémantique lors de la récupération en MCT seulement. L'hypothèse de la redintegration (Hulme et al. 1997; Schweickert, 1993), d'abord proposée afin de rendre compte des effets lexicaux, stipule que les items à rappeler sont maintenus dans un système de mémoire phonologique. Les items peuvent être rappelés directement de cette mémoire (« direct readout ») lorsque la trace phonologique n'est pas dégradée. Toutefois, les items partiellement dégradés peuvent être reconstruits ou « redintégrés » en complétant les traits absents à l'aide des représentations linguistiques en MLT. Ainsi, les effets associés aux facteurs lexicaux sont expliqués par l'utilisation de la forme phonologique des mots en MLT pour aider la reconstruction de la trace phonologique lors du rappel. Récemment, Walker et Hulme (1999) ont suggéré un processus de redintégration similaire à celui invoqué pour les effets lexicaux, afin de rendre compte des effets sémantiques. Ainsi, des traces sémantiques temporaires seraient reconstruites à l'aide des représentations sémantiques stockées en MLT.

Le Modèle des Traits de Nairne (Feature Model)

Le modèle des Traits de Nairne (Feature Model; 1990; Neath & Nairne, 1995) vise à expliquer tant les effets lexicaux que sémantiques rapportés dans la littérature. Ce modèle propose que chaque caractéristique du stimulus est représentée en mémoire primaire par des *traits* qui sont soit dépendants ou soit indépendants du contexte de présentation des items. Le rappel des items est réalisé grâce à un processus d'appariement entre la trace primaire dégradée et la trace permanente en MLT. Ainsi les facteurs lexicaux et sémantiques associés aux stimuli sont représentés sous formes de traits et sont utilisés pour faciliter le RSI des items présentés.

Dans cette dernière section, nous avons voulu présenter les conceptions théoriques qui sont compatibles avec la présence d'effets lexicaux et sémantiques dans le RSI. Les différentes conceptions proposées ici illustrent bien l'importance accordée à la compréhension des mécanismes impliqués dans le traitement de l'information tel qu'évalué par la tâche de RSI mais surtout l'intérêt croissant pour une approche intégrant les systèmes de représentations du langage et les systèmes soutenant leur maintien dans le temps. Dans la prochaine section, nous résumerons la position du problème et présenterons les hypothèses que nous avons voulu tester en fonction de ces différentes approches théoriques.

4. Position du Problème

Parmi les nombreux travaux portant sur le RSI de courtes listes d'items, certains ont montré que des facteurs lexicaux et sémantiques contribuent à la performance des sujets. Ceci va à l'encontre du modèle de Baddeley (1986) qui suppose que la performance au RSI est essentiellement déterminée par des facteurs phonologiques. Le but de cette thèse est d'évaluer clairement la contribution des représentations linguistiques au RSI et en particulier l'influence des représentations sémantiques, telle que postulée par les modèles linguistiques. En effet, les modèles postulant l'existence de stores distincts peuvent accommoder la présence d'effets lexicaux dans le RSI. Ils ont toutefois plus de mal à expliquer pourquoi et comment les représentations sémantiques pourraient influer sur le RSI. Par ailleurs, il appert que les effets sémantiques rapportés dans la littérature sont plus fragiles que les effets lexicaux.

Le but des Articles 1 et 2 est d'examiner l'influence des représentations lexicales et sémantiques sur le RSI normal, tel que postulé par le modèle d'activation interactive (N. Martin & Saffran, 1997), en contrôlant pour plusieurs des facteurs susceptibles d'influencer la performance. La méthode expérimentale utilisée dans ces deux articles consiste principalement à manipuler le matériel à rappeler selon le type de représentations linguistiques qu'il active. Ainsi, des mots provenant de trois catégories différentes ont été utilisés : (1) des mots de classe ouverte (substantifs abstraits) qui activent ou possèdent des représentations sémantiques et lexicales (e.g. *idée*), (2) des mots de classe fermée (e.g., conjonctions) qui possèdent des

représentations lexicales mais peu ou moins de sémantique (e.g., *ainsi*) et (3) des pseudo-mots (e.g., *aupha*) qui n'ont pas de représentations lexicales ou sémantiques. Par ailleurs, d'autres paramètres ont été manipulés afin d'examiner leurs interactions avec les influences lexico-sémantiques. Dans l'Article 1, les effets de similarité phonologique des items et de suppression articulatoire sur la contribution sémantique et lexicale ainsi que de position sérielle ont été examinés dans deux expériences. Dans l'Article 2, l'effet de fréquence de présentation des stimuli sur l'influence des représentations lexicales et sémantiques a été évalué. Nous faisons l'hypothèse que des effets lexicaux et sémantiques se manifesteront dans ce paradigme, c'est-à-dire que les mots de classe ouverte seront mieux rappelés que les mots de classe fermée et que ces derniers seront mieux rappelés que les pseudo-mots. Par ailleurs, la similarité phonologique et la suppression articulatoire pourraient accroître ces effets. En effet, ces facteurs diminuent la force de la trace phonologique (voir le modèle de la redintégration).

L'article 3 évalue la contribution des représentations lexicales et sémantiques dans le RSI chez une patiente (H.P.) ayant perdu la connaissance d'items spécifiques suite à une encéphalite herpétique. La méthode expérimentale utilisée est celle de manipuler le type de stimuli à rappeler selon qu'ils possèdent ou non une signification pour la patiente. Trois types de stimuli ont été utilisés : (1) des mots connus de H.P., qui activent des représentations sémantiques et lexicales, (2) des mots dont H.P. ne connaît plus la signification mais qu'elle peut reconnaître comme étant des mots de la langue française. Ces mots possèdent donc des représentations lexicales mais pas ou peu de représentations sémantiques; et (3) des pseudo-mots. L'effet de ces différents

types d'items sur le RSI a été évalué chez la patiente ainsi que chez un groupe de personnes neurologiquement saines. Huit expériences ont été réalisées. Celles-ci ont été conçues afin d'évaluer la présence de la contribution sémantique, son caractère général ou spécifique, le rôle potentiel d'une atteinte phonologique dans l'expression de l'effet sémantique chez H.P. et l'influence de l'atteinte sémantique sur le rappel de pseudo-mots plus ou moins proches des mots perdus.

Le dernier article explore la façon dont la conception procéduraliste peut expliquer la présence d'une atteinte isolée de la MCT. L'article présente le cas d'une patiente ayant une dissociation classique entre une MCT touchée et une MLT intacte. Selon l'approche par store, un système de stockage indépendant (MCT) des autres systèmes de maintien doit être postulé pour rendre compte de cette dissociation. I.R., une patiente présentant une atteinte sélective de la MCT telle que définie par la littérature classique, a été évaluée dans diverses situations expérimentales. Globalement, la méthode utilisée consiste à examiner la contribution des différents niveaux de représentations linguistiques (phonologique ou lexico-sémantique) aux tâches dites de MCT et de MLT. Selon l'approche procéduraliste, I.R. devrait montrer une difficulté à maintenir l'information phonologique quel que soit le type de tâches utilisées (MCT et MLT).

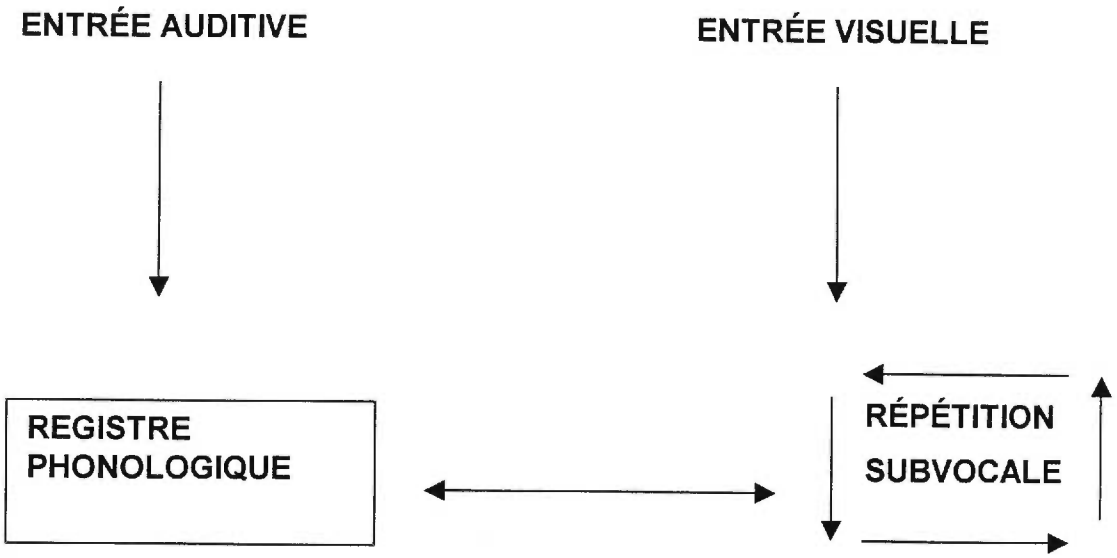

Figure 1. Modèle de la boucle phonologique selon Baddeley (1986)

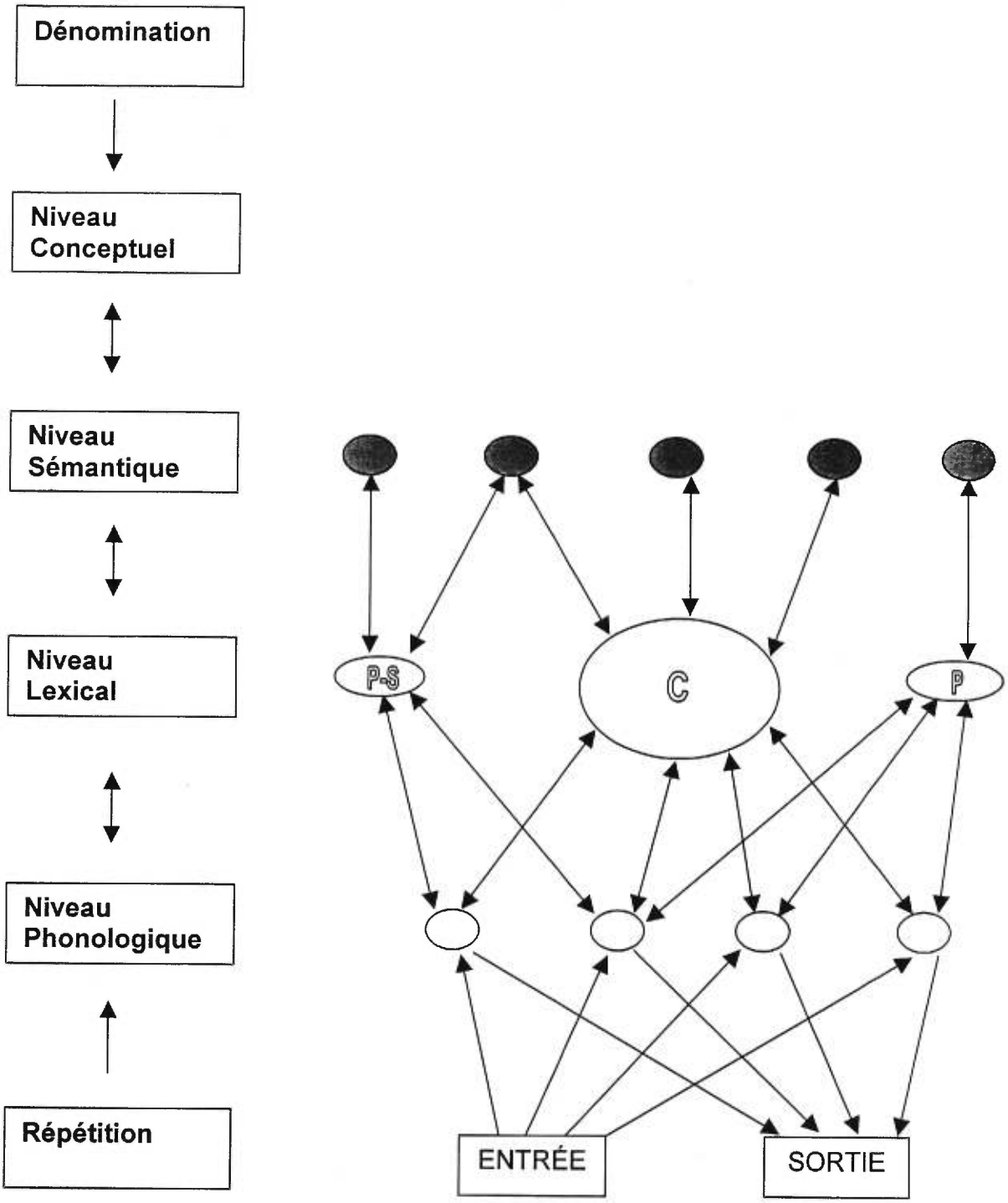

Figure 2. Modèle d'activation interactive selon N. Martin et Saffran (1997; adapté de Dell et O'Seaghdha, 1992). P-S = Mots similaires au plan phonologique et sémantique, P = Mots similaires au plan phonologique, C = Mots cibles

Chapitre 2

SECTION EXPÉRIMENTALE

Article no 1

Semantic and Lexical Effects on Immediate Serial Recall: Interaction with Rehearsal and Phonological Similarity

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ABSTRACT

Two experiments are presented which demonstrate that lexical and semantic representations make distinct contributions to immediate serial recall performance. The relation of these factors with phonological and articulatory variables are also examined. In Experiment 1, items varying according to the type of linguistic representation that they contained were recalled under two rehearsal conditions: silent and articulatory suppression. Results in both conditions revealed worse recall for words without lexico-semantic representation (non-words) as compared to words with lexical but limited semantic content (function words). Furthermore, in the suppression condition, words with both lexical and semantic representations (content words) were better recalled than function words. In Experiment 2, content words, function words, and non-words that rhymed were presented auditorily with and without articulatory suppression. Results from both conditions indicated advantages for function words over non-words and for content over function words. These findings provide evidence for a language processing view of immediate serial recall performance. The effects of phonological and articulatory factors on these linguistic contribution and interaction with serial position are discussed in light of current models of immediate serial recall.

INTRODUCTION

The intricate relation between memory and language has long been investigated by memory and psycholinguistic theorists. Recently, both research domains have provided evidence in favor of a contribution to immediate serial recall (ISR) performance from language factors typically associated with long-term memory (LTM). The purpose of the present experiments was to explore in more detail this linguistic influence, namely the specific contribution of lexical (word level) and semantic representations on immediate serial recall of short word lists. We argue that these effects are better accounted for by a language processing view of STM (Belleville, Caza & Peretz, submitted; Caza & Belleville, 1999; Crowder, 1989; N. Martin & Saffran, 1997; R. C. Martin, Lesch & Bartha, 1999; Monsell, 1984) than by the phonological loop account (Baddeley, 1986; Baddeley & Hitch, 1974).

Psycholinguistic and memory theorists provide distinct functional accounts of ISR performance. The finding of a co-occurrence of "verbal STM impairments" in patients with language deficits have led authors such as N. Martin and Saffran (1997) and R. C. Martin et al. (1999) to suggest that the codes or representations supporting ISR performance are those derived from language processing at all levels, including (according to many language theorists) the phonological, lexical and semantic levels of representation. The interactive activation hypothesis proposed by N. Martin and Saffran is one of several language-based accounts of ISR performance (e.g.,Crowder, 1993; MacKay, 1987; R. C. Martin et al., 1999). This proposal was inspired by Dell and O'Seaghda's (1992; Dell, 1986) model of language production, which assumes that linguistic representations interact via bi-directional connections between levels

of representation and are thus mutually reinforcing. Another assumption is that each level of representation is accessed serially. Hence, when a word is presented for subsequent recall, the phonological representation is primed first, followed by the lexical and then the semantic levels of representation. Because these linguistic representations are activated at different points in time, differences in strength of activation ensue; since the phonological representation is activated first, it remains more influential than the semantic representation in normal word retrieval. Hence, the type of tasks used is important in determining which level of representations gets activated first.

A prevailing view assumes that verbal STM represents an independent cognitive subsystem that is distinct from other systems, notably those designated to language processing. Such a view is embodied in the very influential phonological loop model of Baddeley and Hitch (1974; Baddeley, 1986). According to this framework, verbal STM is determined by a phonological store that maintains information in a phonological code and a rehearsal process that allows decaying phonological traces to be "refreshed". Thus, ISR performance is essentially mediated by phono-articulatory factors. The view that STM and language processing are independent is supported by neuropsychological data which indicate, in some patients, severe STM impairments despite apparently normal language processing (e.g., Basso, Spinner, Vallar, & Zanobio, 1982; Shallice & Butterworth, 1977).

Recently, studies involving normal participants have presented evidence in favor of an influence from non-phonological representations to immediate serial recall. In such studies, the frequency of items to be recalled was manipulated. Participants showed better recall for high as compared to low frequency words

(Gregg, Freedman & Smith, 1989; Hulme, Roodenrys, Schweickert, Brown, S. Martin, Stuart, 1997; Roodenrys, Hulme, Alban, Ellis & Brown, 1994; Tehan & Humphreys, 1988; Watkins 1977; Watkins & Watkins, 1977). A frequency effect is normally interpreted as reflecting lexical processing (Forster, 1976). Other studies compared words with non-words (Hulme, Maughan & Brown, 1991; Hulme, Roodenrys, Brown, & Mercer, 1995) or non-words that sound like real words (pseudohomophones) with standard non-words (e.g., *brane* vs. *slint*) in an immediate serial recall task (Besner & Davelaar, 1982). The results indicated that there was an advantage for words (or pseudohomophones) over non-words. Given that non-words are assumed to have no linguistic representation, the word (or pseudohomophone) effect is attributed to lexical representation in some items compared to others.

Both the frequency and word effects are thought to be mediated by the phonological forms of the words in LTM; specifically, the lexical level of representation. The problem with this interpretation is that, in some of these studies and most notably those involving comparison of words with non-words, the influence of lexical and semantic representations are confounded because words contain both levels of representations in comparison to non-words. Consequently, it is unclear whether the observed effect is attributable to the lexical, the semantic or to both levels of representation.

Neuropsychological studies involving patients with language and classical STM deficits provide evidence for a contribution from the semantic level of representation in addition to lexical representation. In a correlational study involving word pair repetition, N. Martin and Saffran (1997) found that aphasic patients with more phonological deficits, benefited most from the imageability of the items to be

recalled. These results were interpreted as being indicative of an increased reliance on semantic representations when phonological capacities are deficient. Further evidence of this is provided by our own study involving a patient with a typical selective STM deficit (Belleville et al., submitted). The patient was evaluated on an ISR task of material tapping different domains. The results revealed both a lexical and semantic effect. However, compared to the performance of matched controls, the semantic effect was exaggerated (13.3% vs. 3.4%) in the patient. Conversely, the patient's lexical effect was smaller than the controls' lexical effect (30.8% vs. 76,4%). These results are compatible with the notion that different linguistic representations, and particularly semantic representations, are used to support serial recall in patients with phonological deficits.

It appears in the literature that a large part of the evidence in favor of a *semantic* contribution involves patients with some degree of phonological impairment (N. Martin & Saffran,1990; R.C. Martin & Breedin, 1992; R.C. Martin, Shelton, & Yaffee, 1994; Saffran, 1990; Saffran & N. Martin, 1990). This observation has lead Saffran and N. Martin to suggest that " these semantic influences are not ordinarily detectable because the interaction of lexical and phonological representations is sufficient to support normal span performance " (p. 162). A natural implication of this is that semantic effects in *normal* participants will be difficult to obtain unless particular attention is given to the experimental paradigm used. Tehan and Humphreys (1988) designed a study that allowed detection of semantic influences. They compared recall performance across three classes of words; nouns, adjectives, and function words (e.g., prepositions and conjunctions). The different word classes are assumed to vary according to the type of linguistic

representations they contain: When function words are presented in isolation (i.e., not within the context of a sentence), they are said to contain less semantic representation than both nouns and adjectives (e.g., *of* vs. *hat*). However, all stimuli have lexical representation. Participants were tested with and without articulatory suppression and the stimuli were presented visually. The findings revealed that recall was better for both nouns and adjectives than for function words. This word class effect was interpreted as evidence for a semantic contribution to ISR performance. Interestingly, the size of the semantic effect was similar in both conditions. If semantic effects can be "masked "by the effective use of phonological and lexical representations as suggested by Saffran and N. Martin, than a larger semantic effect in the articulatory suppression condition would have been expected. In a similar study, Bourassa and Besner (1994) found a word class effect between content and function words that was also of the same magnitude in both the silent and the articulatory suppression conditions. However, this word class effect completely disappeared when controlling for the imageability value of the stimuli. In a study manipulating concreteness, a semantic factor that is highly correlated with imageability, Walker and Hulme (1999) found an advantage in the ISR of concrete words relative to abstract words.

Although these studies provide some evidence for semantic influences on normal ISR, many questions remained. Why would controlling the imageability value of the items to be recalled in the Bourassa and Besner (1994) study completely abolish the semantic effect? The ease with which a word can evoke matching predicates (ease of predication) has been proposed to account for the existence of particular difficulties in reading certain word classes, such as function words as compared to content words in deep dyslexic patients (Jones,1985). It is thus assumed

that content words can evoke more predicates than function words. Thus, when imageability was controlled in the Bourassa and Besner study, the semantic richness of content words over function words should have prevailed. Another important question relates to the relations that the different linguisitic representations entertain and how they interact with ISR. For instance it is surprising that the size of the semantic effect reported by Bourassa and Besner and Tehan and Humphreys (1988) was not modified by the use of articulatory suppression which reduces access to phonological representations. As mentionned above, the semantic effect is increased in patients with impaired phonological processing (Belleville et al. submitted). Factors known to hinder the use of phonological representations such as presence of phonological similarity among items might affect the semantic contribution to ISR. Providing clear answers to these questions might contribute to understand the way by which linguistic influences come about in ISR performance.

From a theoretical standpoint, specifying the nature of the linguistic influence is of great relevance because of the differential accounts made by both theoretical frameworks. The finding of a contribution to ISR from factors associated with LTM challenges the phonological loop proposal. This model cannot account for effects that are not phonologically based, such as the influence of semantic representation on short-term recall. On the other hand, a language processing view of ISR specifically predicts the finding of a contribution from all levels of representation. In order to sustain this proposal, however, more evidence for a specifically semantic contribution in normal participants is needed. Furthermore, the interaction between semantic and phono-articulatory factors such as phonological similarity and articulatory suppression needs to be examined. Hence, a demonstration of specific influences

from lexical and semantic representations to ISR and predictions as to how these are affected by phono-articulatory factors are highly relevant for both the interactive activation and the phonological loop accounts.

Also of interest is the effect of LTM representations on ordered recall across serial position, as the pattern of results obtained can be used to specify in a more precise manner the mechanisms under which linguistic representations come into play when ordered recall is performed. The interactive activation account predicts that lexico-semantic effects will be greater at the beginning of the serial position curve because earlier items, through spreading activation, have more time to strengthen other levels of representation such as the lexical and semantic levels. Empirical support for the proposition that lexical influence is most important in the primacy portion of the serial position curve was provided by studies using frequency in normal serial recall tasks. In a study using 8-item sequences, frequency was found to affect the recall of items early in a sequence (Watkins & Watkins, 1977). Other studies involving aphasic patients with phonological processing impairments have found effects from imageability, on items early in the serial position curve (N. Martin & Saffran, 1997; Saffran & N. Martin, 1990). These findings are interpreted as additional evidence that semantic representations support the recall of items at the beginning of an input string.

In contrast, Hulme et al. (1997) have made different predictions about linguistic effects as a function of serial position in the context of a reconstruction hypothesis (Hulme et al., 1991; Roodenrys et al., 1994; Schweickert, 1993). This proposal assumes that when the phonological trace of an item is degraded, a reconstruction mechanism called redintegration is automatically called upon. It is

assumed that redintegration will be more effective with high-frequency words than low-frequency words because their phonological word form in LTM is more accessible. The redintegration process will thus be more contributory when the trace is more degraded (Schweickert et al, 1999). Hulme et al. argue that degradation of the phonological trace increases with serial position due to longer output delays for later items in a string (Cowan, 1992; Cowan, Day, Saults, Keller, Johnson, & Flores, 1992). Thus, Hulme and collaborators predict that lexical effects would increase across serial positions. In support of this, they provided data showing effects of frequency that increased with serial position (except for the terminal item). Similar predictions for semantic effects can be made assuming that semantic factors provide an additional cue which facilitates redintegration.

In summary, the goal of the present study is to present further evidence of a specific contribution from lexical and semantic representations to ISR performance, as predicted by the language processing view of memory. We also propose to separate the semantic influence from lexical contribution and to examine how these linguistic effects are affected by experimental manipulations which reduce the efficiency of phonological representations. For this purpose, normal participants were tested on recall of items that varied according to the linguistic representations they contained. Immediate serial recall performance was compared for three types of word categories: Abstract content words, function words, and non-words. Abstract words were used rather than concrete words so that the contribution of the semanticity factor be assessed independently of imageability which has already been reported. Non-words were used in order to evaluate the lexical influence separately from the semantic contribution . This was done by comparing non-words recall to function

words recall. Furthermore, to evaluate the suggestion that semantic influences are masked by efficient lexical and phonological representations, we manipulated access to phonological influences by evaluating participants in both silent and articulatory suppression conditions. The predictions are straightforward: Based on a language processing view, there should be worse recall for non-words than function words (and content words) and the latter should be more poorly recalled than content words. Articulatory suppression should produce increased semantic effects if the suggestion that access to phonological levels of representation can mask semantic influences is true. Finally, if lexical and/or semantic contributions are found, they will be tested against the two opposing accounts of linguistic effects on serial position presented above (Hulme et al., 1997 vs. N. Martin &Saffran, 1997).

Experiment 1

Method

Participants. At total of 24 French-speaking volunteers (12 women) living in the community participated in the experiment. Participants were an average age of 25.08 years (SD = 4.03; range = 19-32) and had an average education level of 13.44 years (SD = 2.04). Their general verbal performance was assessed using the French version of the Mill Hill Vocabulary Test (Gérard, 1983). The mean score on this test was 32.88/44 (SD = 4.72), which is within normal range (Deltour, 1993). The average word span was 4.83 words (SD = 0.92; range = 4-7) indicating a normal verbal STM capacity (Brener, 1940).

Materials. French stimuli were presented visually on a Macintosh computer screen. Each item was presented at the center of the screen in lower case letters with a Times 36 font. Two sets (A/B) of six items were created from each of the 3

following word categories: content words (e.g., *délai*; in English, delay), function words (e.g., *sinon*; in English, otherwise) and non-words (e.g., *chadin*). All six sets were matched on the basis of the number of syllables, phonemes, letters and digram frequency. Care was taken to ensure that words within the sets were not phonologically and semantically related. For content and function words, sets were also matched for word frequency (Baudot, 1992). All of the content words were abstract. Since there were no imagery or concreteness values available for these French words, we used English indices when available (Friendly, Franklin, Hoffman & Rubin, 1982; Paivio, Yuille & Madigan, 1968). For each word category, one set of words (e.g., A) was used in the silent condition and the other set (e.g., B) was employed in the articulatory suppression condition. Words from each set were used to construct ten six-item lists. Each list was created by drawing items randomly from a set without replacement so that the words from each set were presented in a different order over the ten lists.

Procedure. The participants were tested individually in a single session. Each trial began with the presentation of a visual cue in the center of the screen, followed by the six-item list. The items were presented individually at a rate of one every 2 sec, each item remaining on screen for 1.5 sec. At the end of the list, when a question mark appeared, the participant attempted to recall the words. Recall was written on a response sheet containing six lines placed in a vertical column. Participants were asked to write down the entire item to be remembered (not only the first letters), from top to bottom, on the line that corresponded to the serial order of the item in the list. Participants crossed out a line when they could not remember an item. To ensure the correct pronunciation of all the items, and particularly of the non-words, a

familiarization period always preceded the recall of each new set of words. During this period, the participant was required to read aloud at his own pace, the visually presented items, one by one on a sheet of paper.

All participants were assigned to both the silent and the articulatory suppression conditions; half of them received the silent condition with set A and articulatory condition with set B. The other half received the silent condition with set B and articulatory condition with set A. Articulatory suppression was performed during both the presentation and the recall of the items. This was achieved by instructing participants to count repeatedly from one to eight when the cue appeared, and continue counting until the last item was recalled. The three word categories and the two articulatory conditions were ordered according to a Latin square. Prior to the experimental session, a practice trial took place at the beginning of both conditions.

Results

The results are reported in the following manner: Preliminary analyses are presented first to evaluate effects of (1) word set (A or B) for each word category, (2) fatigue or practice effects and (3) order of a word category within the Latin square. Second, an ANOVA on the mean proportion of items recalled in the correct order, pooled across serial position, is reported. In order to provide statistical evidence that the findings can be generalized to language in general, and thus beyond the sample of stimuli chosen (Clark, 1973), separate ANOVAs were performed by participant and by item. Finally, subsidiary analyses (by item only) using mean proportion of correct recall as a function of serial position are presented.

A preliminary ANOVA was conducted on word sets and given that no significant effects were found, results from both sets were pooled together for each

word category in the subsequent analyses. Other preliminary analyses found no effect of fatigue or practice, or of order of word category in the Latin square.

Table 1 (p. 62) shows the mean proportion of items recalled in the correct order, pooled across serial position. Both ANOVAs by participant (p) and by item (i) contained the variables of Suppression (without vs. with) and Word Category (content vs. function vs. non-words) which were repeated measures factors in the analyses. The main effect of suppression was significant, F_p (1, 23) = 194.90, $p < .0001$, MSE = .0123; F_i (1, 11) = 195.89, $p < .0001$, MSE = .0061 indicating that recall was better without suppression than with suppression. The main effect of word category was also significant, F_p (2, 46) = 34.41, $p < .0001$, MSE = .0116; F_i (2, 22) = 43.08, $p < .0001$, MSE = .0046. Interestingly, the interaction between the two variables was significant in both analyses, F_p (2, 46) = 5.29, $p < .01$, MSE = .0075; F_i (2, 22) = 6.34, $p < .01$, MSE = .0031.

Simple effects for the silent condition indicated a word category effect, F_p (2, 46) = 34.18, $p < .0001$, MSE = .0093; F_i (2, 22) = 41.85, $p < .0001$, MSE = .0038. Newman-Keuls analyses by participant and by item showed that the recall of function words was greater than recall of non-words, indicating a significant lexical effect ($p < .01$). Other comparisons were not significant. For the articulatory suppression condition, a word category effect was also found, F_p (2, 46) = 12.32, $p < .0001$, MSE = .0098; F_i (2, 22) = 15.21, $p < .0001$, MSE = .0040. In addition to a lexical effect ($p < .01$), recall of content words was reliably higher than recall of function words, indicating a semantic effect ($p < .05$).

Supplementary analyses were performed using the mean proportion of correct serial recall as a function of serial position. A repeated-measures ANOVA was

conducted with Suppression, Word Category and Serial Position as variables. In addition to the effects already presented above, the main effect of serial position, Fp (5, 115) = 131.39, p < .0001, MSE = .0378, was significant. The Suppression X Serial Position, Fp (5, 115) = 4.96, p < .001, MSE = .0374, and Word Category X Serial Position, Fp (10, 230) = 2.30, p < .05, MSE = .0175, interaction effects were qualified by a significant three-way interaction, Fp (10, 230) = 4.66, p < .0001, MSE = .0168.

The three-way interaction was further explored by examining recall for each suppression condition. Figure 1a (p. 64) shows the recall performance in the silent condition for each word category at the six serial positions. The Word Category X Serial Position interaction was not significant, F(10, 230) = 1.36, p = .1997, MSE = .0189 and Newman-Keuls analyses confirmed the lexical effect reported previously. Figure 1b (p. 64) shows the recall performance for the suppression condition. Interestingly, the Word Category X Serial Position interaction, F(10, 230) = 6.04, p < .0001, MSE = .0154 was significant. As indicated in Figure 1b, the interaction is due to both a lexical effect that decreases across serial positions and to a semantic effect that is absent on Position 1, strong on Position 2 and then diminishes with serial position.

Comments

This experiment attempted to provide further evidence for distinct contributions from lexical and semantic representations to ISR performance. The results obtained support this view. First, an advantage for function words over non-words was found in both silent and articulatory suppression conditions. These results suggest a specific contribution from lexical representation to serial recall

performance. Additionally, a better recall for content words over function words was found in the articulatory suppression condition, indicating an influence from semantic representation to ISR. In contrast with many studies involving language materials, statistical analyses by item were provided and these indicated that the results are not restricted to the sample of items chosen, but can be generalized to the entire French language.

The supplementary findings on serial position revealed distinct patterns depending on whether rehearsal of the items was or was not prevented. In the silent condition, the results indicated that recall was affected by lexical representation to the same extent across serial positions. Results in the articulatory suppression condition showed a lexical effect for early items in the serial position curve. This was also found for the semantic effect except for Position 1. Both these effects decreased across serial positions. It should be noted, however, that data for later positions (4 and 5) skirt with the floor.

Experiment 2

The finding of a semantic influence to ISR in the articulatory suppression condition solely, appears to support the suggestion made by Saffran and N. Martin (1990) which links phonological deficiencies to reliance on semantic information to support recall performance. To further explore this relation, we used the well established effect of phonological similarity (e.g., Baddeley, 1966; Conrad & Hull, 1964). It is known that ISR performance is hindered by phonologically similar items (e.g., *b*, *v*, *t*, *d*) compared to phonologically distinct ones (e.g., *f*, *h*, *k*, *m*). Hence, by using word-sequences that rhyme, we are assuming that the phonological representation will be less reliable and will need to be supported by semantic

representation via the lexical level of representation. In addition, performance under articulatory suppression was compared to a condition where the participant was free to rehearse in order to assess whether the semantic effect would be further exacerbated.

In Experiment 2, participants performed an immediate serial recall of a series of *rhyming* abstract content words, function words and non-words. These items were presented auditorily, under a silent or an articulatory suppression condition. Since the phonological trace was reduced in both the silent and articulatory suppression conditions by using rhyming words, lexical and semantic effects should be found in both conditions; however, if semantic influences can be masked by the interaction of phonological and lexical representations, a larger effect would be expected in the articulatory suppression condition. Because numerous criteria were used to match the stimuli, it was impossible to create different lists for each articulatory condition. As we wanted to limit as much as possible the number of times each item was presented, the experimental design was modified from a within-subject design (Experiment 1) to a between-subject design in this experiment.

Method

Participants. Forty-eight French-speaking students, who did not participate in the previous study, volunteered for this experiment. They were divided equally into two groups according to the articulation condition. The silent condition group (22 women) were an average age of 21.29 years (SD = 2.17; range = 19-26) and had an average level of education of 14.90 years (SD = 1.83). Their mean score on the Mill Hill Vocabulary Test was (Gérard, 1983) was 35.54/44 (SD = 4.01). The articulatory suppression group (20 women) were an average age of 20.71 years (SD = 1.23; range

= 18-23) and had an average level of education of 14.19 years (SD = 1.21). Their mean score on the Mill Hill Vocabulary Test (Gérard, 1983) was 34.38/44 (SD = 4.16). No significant differences in age, t (46) = 1.14, $p < .01$, formal education, t (46) = 1.58, $p < .01$, or Mill Hill Vocabulary Test scores, t (46) = 0.99, $p < .01$, were found across groups. Performance level on the Mill Hill Vocabulary Test was within normal limits in both groups (Deltour, 1993).

Materials. All stimuli were presented auditorily on a tape recorder through headphones and were read by a female voice. A set of six rhyming items was created from each of the 3 word categories: abstract content words (e.g., *santé*, *idée*; in English, health, idea), function words (e.g., *ainsi*, *hormis*; in English, like this, except) and non-words (e.g., *vuima*, *hupras*). The actual rhyme, however, changed from one word category to another. Ten six-item lists were constructed from each set. Each list was created by drawing items randomly from a set without replacement and items within a list were presented in a different order over the ten lists. All stimuli were matched according to the same criteria utilized in Experiment 1.

Procedure. The participants were tested individually in a single session with word lists belonging to each of the three word categories. Each trial began with the presentation of an auditory cue, followed by the six-item lists. Each word was presented at a rate of one item per second. At the end of the list, the participant attempted a written response as in Experiment 1. A practice trial and familiarization period preceded the recall of a new category of words as described for Experiment 1. Finally, the articulatory suppression procedure was the same as the one used in Experiment 1. The order of the three word categories was determined by a Latin square.

Results

Two preliminary analyses were performed on the mean proportion of items recalled in the correct serial position. First, a split-plot ANOVA was conducted to evaluate the effects of practice or fatigue for each word category. Thus, performance on the first five trials of a word category was compared to performance on the last five trials. Results indicated a main effect of trial suggestive of a practice effect for the last lists. However, this factor did not interact with either suppression, word category, or both factors combined.

Another preliminary analysis was performed to assess the effect of the order of a given word category in the Latin square. A 2 (Suppression: without, with) x 3 (Word Category: content, function, non-word) x 3 (Order: first, second, third) ANOVA was computed. There was no main effect of order and this factor did not interact with suppression (with $F < 1$, in both cases). However, the Order X Word Category interaction was significant, F (4, 84) = 4.71, $p < .01$, MSE = .0064. A simple effects analysis showed an order effect for the function words, F (2, 42) = 3.21, $p = .05$, MSE = .0174. Performance with function words was significantly improved when it was preceded by the recall of words from another category. However, there were no order effects for the content words, $F < 1$, and the non-words, F (2, 42) = 1.30, $p = .2829$, MSE = .0099. The absence of a significant three-way interaction is noteworthy, $F < 1$. Because the Latin square design does not allow for a complete counterbalancing of the orders, a given word category is preceded by words from another category in two out of three cases. Hence, it is possible that a carry over effect might have influenced performance when function words were recalled. As further evidence of this, only the function words were affected by

preceding words from another category. This is compatible with the fact that function words establish their meanings within the context of a sentence, and thus from other words. To examine recall performance without any influence from preceding word categories, a subset of the data was used which included only responses from a word category presented first in the Latin square. Hence, analyses for a given word category were based on eight participants instead of all 24 participants in each condition. Since there were three word categories, the total number of participants in the subset for each suppression condition was 24.

Table 2 (p.63) shows the mean proportion of items recalled in serial order for a subset of the data where each word category was presented first. Both ANOVAs by participant (p) and by item (i) contained the variables of Suppression (without vs.with) and of Word Category (content vs. function vs. non-words) where the last variable is a repeated-measures factor in the analysis. The main effect of suppression was reliable, $\underline{F}\ p\ (1, 14) = 69.5526$, $\underline{p} < .0001$, $\underline{MSE} = .0107$; $\underline{F}i\ (1, 10) = 47.05$, $\underline{p} < .0001$, $\underline{MSE} = .0119$ indicating that participants in the SILENT condition achieved a better recall performance than those in the articulatory suppression condition. The main effect of word category was also reliable, $\underline{F}\ p\ (2, 28) = 19.6226$, $\underline{p} < .0001$, $\underline{MSE} = .0090$; $\underline{F}i\ (2, 20) = 10.82$, $\underline{p} < .001$, $\underline{MSE} = .0122$. Newman-Keuls analyses by both participant and item indicated that the recall of function words was higher than that for non-words ($\underline{p} < .01$). Furthermore, an analysis by participant showed that content words were better recalled than function words ($\underline{p} < .05$). The absence of a Suppression X Word Category interaction is notable, $\underline{F}\ p < 1$; $\underline{F}\ i < 1$.

Again, subsidiary analyses by participant only were performed using the mean proportion of correct serial recall as a function of serial position on the subset of the

data. A split-plot ANOVA was conducted in which the repeated-measures variables were Word Category and Serial Position, and the between-group variable was Suppression. In addition to the effects already presented above, the main effect of serial position, F (5, 70) = 104.88, $p < .0001$, MSE = .0190, was significant. The Suppression X Serial Position, F (5, 70) = 1.74, $p = .1370$, MSE = .0190, and the Word Category X Serial Position, F (10, 140) = 1.67, $p = .0944$, MSE = .0210, interactions were not significant. However, the Suppression X Word Category X Serial Position, F (10, 140) = 2.26, $p < .05$, MSE = .0210, interaction was significant in this analysis.

The three-way interaction was explored by examining recall in each suppression condition. Figure 2a (p. 65) presents recall performance for each word category at the six serial positions for the silent condition. The Word Category X Serial Position interaction was not significant, $F < 1$, and showed the previously reported lexical effect. Figure 2b (p. 65) shows recall performance for each word category at the six serial positions for the suppression condition. The Word Category X Serial Position interaction, $F(10, 140) = 3.03$, $p < .01$, MSE = .0210, was significant. As can be seen in Figure 2b, the form of the interaction is due to decreasing effects from both lexical and semantic representations across serial positions, in the primacy part of the curve.

Comments

The present experiment replicated previous results by finding distinct influences of lexical and semantic representations on ISR performance. In both the silent and articulatory suppression conditions, function words were better recalled than non-words, indicating a lexical effect. More interesting, however, is the finding

of an advantage for content words over function words not only in the articulatory suppression condition, but also in the silent condition where the trace of the phonological representation had been "weakened" by phonological similarity. Analyses by items allows for generalization of results to the entire French language.

Results on serial position again reveal distinct patterns depending on the articulation condition used in a manner similar to that reported in Experiment 1. In the silent condition a lexical effect was found to affect the recall of items at all serial positions to the same extent. In the articulatory suppression condition, both lexical and semantic effects were found in the primacy portion of the serial curve and decreased with serial position. However, floor effects clearly limit the interpretation of these data.

General Discussion

First, the goal of this study was to provide evidence of a distinct contribution from lexical and semantic factors to ISR and to examine how these effects are accounted for by current theoretical propositions. Second, this study wished to explore the relation between these linguistic contributions and phonological factors known to affect ISR performance. For that purpose, items that varied according to whether they had lexical or semantic representations were used in two experiments. Following Saffran and Martin's (1990) suggestion that semantic effects may be masked by efficient use of phonological representation, an articulatory suppression condition was employed to reduce phonological coding by preventing rehearsal. The phonological similarity of the items to be recalled was also manipulated as this factor has been shown to be detrimental to ISR performance (Conrad & Hull, 1964).

The findings providing evidence for linguistic influences on ISR were

straightforward. First, in both experiments recall for function words was better than that for non-words. It is assumed that function words have little or limited semantic representation when presented in isolation although, unlike non-words, they possess a lexical representation. Thus, the advantage of function words over non-words can be specifically attributed to the lexical level of representation. These results are compatible with our own results from a previous study which reported a lexical contribution using a similar paradigm (Caza & Belleville, 1999) or with other studies that manipulated frequency while controlling for semantic factors such as imageability and concreteness of the items to be recalled (Hulme et al., 1997; Hulme et al., 1995; Roodenrys et al., 1994).

Additionally, the results from both experiments showed that recall for content words was better than for function words. Given that content words have more semantic representation than isolated function words, as assumed by ease of predication (Jones, 1985), these results are interpreted as evidence for a specific semantic contribution to ISR performance that is distinct from the lexical contribution. Our findings are thus compatible with a number of studies which have previously demonstrated a semantic contribution to short-term recall in either a silent or an articulatory suppression condition or both (e.g., Bourassa & Besner, 1994; Caza & Belleville, 1999 Tehan & Humphreys, 1988; Poirier & Saint-Aubin, 1995; Walker & Hulme, 1999). The experimental manipulations on phonological similarity and suppression generally increase the influence of these linguistic contributions. Before discussing these effects, we will first discuss how two current models of ISR can account for the general finding of a lexical and semantic influence on ISR.

The Phonological Loop Account

Overall, these findings provide strong evidence for the claim that lexical and semantic representations make distinct contributions to STM performance. The demonstration of a contribution from both of these levels of representation presents a challenge to the phonological loop proposal. In order to account for the growing evidence of a lexical influence on immediate serial recall, proponents of the phonological loop hypothesis have revised the original proposal. Baddeley, Gathercole and Papagno (1998) proposed that the phonological store interacts with the phonological form of a word (or lexical representation) in LTM. Although this may generally account for some lexical effects reported in the literature, this addendum is not sufficient to account for our finding of a lexical contribution under articulatory suppression when stimuli are presented visually (Experiment 1). According to the recent version, articulatory suppression should abolish the lexical effect in the visual modality, since the phonological word forms in LTM can only be accessed via the STM phonological store.

Our demonstration of an influence from semantic representation is also problematic for the revised version of the phonological loop proposal, which can only account for LTM influences that are phonological in nature. Although it was suggested that the central executive might play a role in semantic effect on serial recall, the exact underpinnings were not provided (Baddeley, 1996).

The Language Processing Account

The language processing account presented here assumes that the different levels of representation in language processing are also involved in ISR performance

(N. Martin & Saffran, 1997). Thus, effects from both the lexical and semantic levels of representation obtained here are generally congruent with a language processing account. However, our finding concerning the differential pattern of lexical and semantic effects relative to the articulatory and phonological similarity conditions deserves further explication with regard to this model.

Semantic effects were not found when participants had full access to a phonological representation, whereas lexical effects were demonstrated in all experimental conditions. The interactive activation account assumes that linguistic representations are accessed serially. The phonological level is accessed first followed by the lexical and semantic levels when input is auditory. Thus, when participants rehearse, it is assumed that earlier levels of representation are continuously reactivated (i.e., become the most primed) and are the most important determinants of ISR performance, to the detriment of later levels such as the semantic one. This would explain the finding of only a lexical effect only in the silent condition. However, when activation from the phonological representation is compromised by articulatory suppression or phonological similarity, the phonological and lexical representations would rely more heavily on spreading activation from the semantic level of representation to maintain its activation. This would yield semantic in addition to lexical effects on serial recall.

The absence of a semantic effect in the silent condition of our study (Experiment 1) is not consistent with the results found in other studies. A possible explanation relates to the nature of the stimuli used, more specifically the type of content words. Other studies reporting effects from semantic factors have used either imageable words (Bourassa & Besner, 1994) or concrete words (Walker & Hulme,

1999). In our study, we used *abstract* content words to minimize the contribution from visual semantics or imagery and so assess the unique contribution of verbal semantics. Furthermore, when controlling for imageabilty, Bourassa and Besner (1994, Exp. 2) used 5-item sequences instead of the somewhat longer sequences typically used in studies that reported semantic effects (e.g., Baddeley & Ecob, 1970; Bourassa & Besner, 1994; Caza & Belleville, 1999; Poirier & Saint-Aubin, 1995; Tehan & Humphreys, 1988). It is possible that the use of shorter sequences facilitated the task and made phonological and/or lexical representations sufficient to support recall performance. Thus, it might be worth exploring in a more systematic manner the interaction between list-length and LTM factors. Finally, it should be noted that some caution must be exerted relative to the conclusions that can be drawn from a null effect.

Of particular interest was the finding that the lexical and semantic effects were not differentially affected by articulatory suppression when recalling phonologically similar items (Experiment 2). A legitimate assumption was made that, preventing participants from rehearsing would render the phonological trace even less useful for supporting recall. Consequently, a larger semantic effect was expected in the articulatory suppression condition compared to the silent one. This was not the case. The semantic effect was comparable in both conditions. Hence the effect of phonological similarity on lexico-semantic factors appears to be independent of whether or not items are rehearsed.

The Effects of Lexical and Semantic Representations on Serial Position

The ancillary analyses on serial position were conducted to provide data

relevant to the understanding of the mechanisms underlying the contribution of lexical and semantic representations to ordered recall within a language processing view. Unfortunately, floor effects in Experiment 2 forced us to limit our interpretation to data from Experiment 1 only.

A lexical effect across serial positions was clearly demonstrated in both conditions of Experiment 1. A different pattern of results was found depending on whether participants engaged in rehearsal or not. In the silent condition, the lexical effect was similar for all serial positions. The presence of a ceiling effect is notable, but was limited to the first serial position. This finding thus conflicts with both accounts of serial position.

The interactive activation model (N. Martin & Saffran, 1997) predicts a larger lexical effect for earlier items. This view assumes that linguistic representations of items at the beginning of a sequence have more time to strengthen their lexical representation via spreading activation than later items. This leads to a lexical influence in word retrieval. Conversely, Hulme et al.'s (1997) suggestion assumes that lexical representations will increasingly affect recall performance across serial positions because of increasing degradation with longer output delays for later items. However, results concerning the effect of frequency (i.e., lexical effect) on recall across serial position are far from consistent A study by Watkins & Watkins (1977) reported greater effects of frequency for early items compared to late ones. In a study involving aphasic patients, Saffran and N. Martin (1990) found a frequency effect for terminal items. Furthermore, in a study using mixed-frequency lists, Gregg et al. (1989, Exp. 2) demonstrated that high-frequency words affected span performance equally in the first and second half of the list.

In the articulatory suppression condition, the results revealed a lexical effect for items at the beginning of the serial position curve, that decreased across positions. This latter finding appears to support the interactive activation view. However, data for later positions (4 and 5) skirt with the floor and thus calls for caution. A semantic effect was found in the suppression condition only. The semantic effect was found for earlier items except item 1, and slightly decreased with serial position. Although this finding is generally consistent with the interactive activation view (N. Martin & Saffran, 1997), data for later positions is again close to floor and should be interpreted cautiously. Overall the experimental conditions, provide no evidence of an increasing effect from either lexical or semantic representations with serial position. Thus, these results challenge Hulme et al.'s (1997) suggestion, which assumes that both lexical and semantic representations will increasingly affect recall performance across serial positions because of increasing degradation with longer output delays for later items.

Other studies exploring LTM influences such as frequency, concreteness and semantic similarity as a function of serial position have failed to find increasing effects across serial positions as predicted by the output delay proposal (Poirier & Saint-Aubin, 1995; 1996; Saint-Aubin & Poirier, 1999; Walker & Hulme, 1999). A notable difference between some of these studies and Hulme et al.'s study is the language that was used. Hulme and collaborators used English words in all their experiments, whereas studies not showing the increasing effect of LTM factors (including ours) used French words. Although there is no obvious reason why the nature of the language would alter the presence of this effect, this difference is worth noting. Another difference between our study and Hulme et al.'s study concerns

response modality. We used written recall as did Walker & Hulme (in Experiment 2) instead of an oral response. However, written responses probably introduce even longer output delays than oral responses. Thus, if length of the output delay was the determining factor, increasing effects from LTM representations with serial position should have been found in our study. Furthermore, Poirier and Saint-Aubin, and Walker and Hulme used both oral and written responses and failed to find increasing semantic effects with serial position. Finally, it is worth pointing out that the various studies used different paradigms to investigate the semantic effect. For example, there were comparisons of words with low, medium, and high frequencies in Poirier and Saint-Aubin's study, comparison of frequent and very rare words in Hulme et al.'s study, comparison of concrete and abstract words in Walker and Hulme's study, and comparison of function words and non-words in our study. The impact of these methodological factors on the data remains to be elucidated.

In sum, the data presented here provide convincing evidence for distinct influences from lexical and semantic representations in ISR. These findings clearly support a language processing view of STM. Such a conception of STM is appealing because it can account for semantic and lexical effects on ISR performance. Furthermore, a language processing view of STM can explain the finding of residual capacities in patients with STM impairments. Indeed whereas immediate recall performance is greatly reduced in patients with a phonological loop deficit (e.g.,Vallar & Baddeley, 1984; Belleville, Peretz & Arguin, 1992), it is never completely abolished. These patients can usually recall two or three items and rarely is short-term recall capacity completely abolished. This supports the view that ISR performance is determined by multiple factors. It is likely that these patients used

other levels of representation to recall those items, a suggestion that is supported by their pattern of performance (e.g., Belleville et al., 1997; N. Martin & Saffran, 1997; R.C. Martin et al., 1994).

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Table 1

Mean Proportion of Words Recalled in the Correct Serial Position

Presentation and recall condition	Word category			Effect	
	Content	Function	Non-word	Semantic	Lexical
Silent	.70 (.13)	.70 (.14)	.50 (.12)	0	.29
Suppression	.44 (.15)	.39 (.15)	.30 (.13)	.11	.23

Semantic Effect: Content - Function / Content

Lexical Effect: Function - Non-word / Function

Values in parenthesis represent standard deviation

Table 2

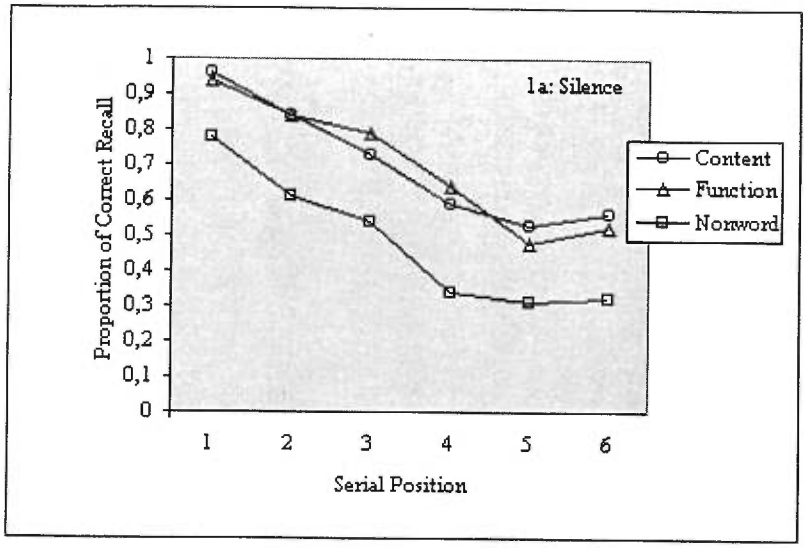
Mean Proportion of Words Recalled in the Correct Serial Position from the Subset of Data

Presentation and recall condition	Word category			Effect	
	Content	Function	Non-word	Semantic	Lexical
Silent	.63 (.12)	.57 (.14)	.41 (.09)	.10	.28
Suppression	.38 (.04)	.29 (.10)	.19 (.06)	.24	.34

Semantic Effect : Content - Function / Content

Lexical Effect : Function - Non-word / Function

Values in parenthesis represent standard deviation



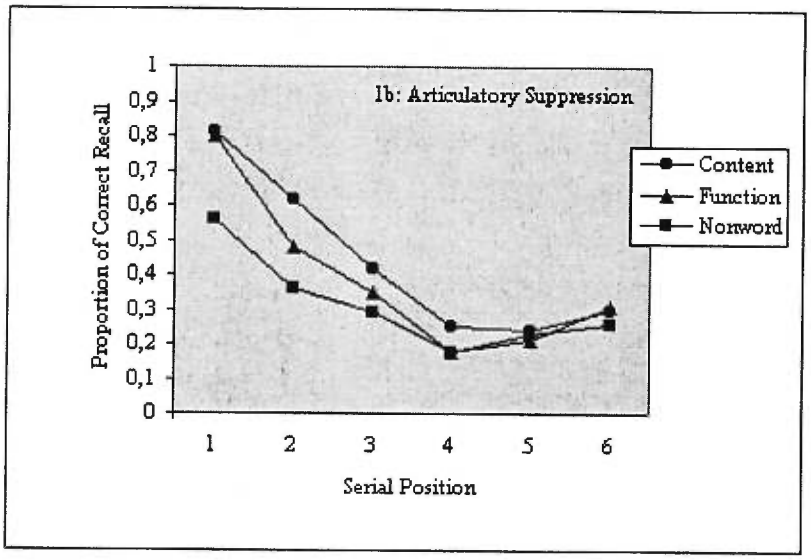
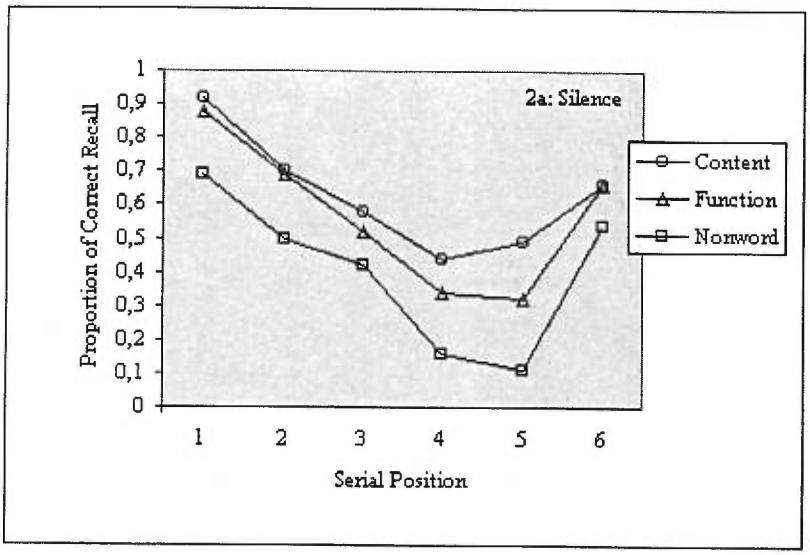


Figure 1 : Mean proportion of correct recall as a function of serial position and word-category in a) the silent condition and b) the articulatory suppression condition in Experiment 1



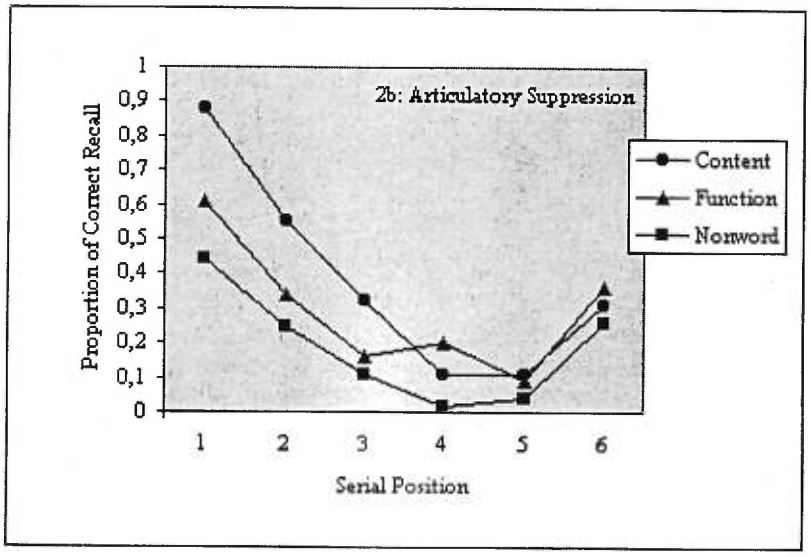


Figure 2 : Mean proportion of correct recall as a function of serial position and word-category in a) the silent condition and b) the articulatory suppression condition in Experiment 2

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Article no 2

Semantic Contribution to Immediate Serial Recall Using an Unlimited Set of Items: Evidence for a Multi-Level Capacity View of Short-Term Memory

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ABSTRACT

The purpose of this study was to assess the respective roles of lexical and semantic levels of representations in immediate serial recall, by testing participants with items that varied on both these dimensions. Contrary to most studies where a small fixed set of words are repeated over trials, the current items were tested once by sampling them from an unlimited set of items without replacement. Participants recalled 3 classes of words under articulatory suppression: nonwords, function words and content words. Results indicated an advantage for function words over nonwords, confirming a specifically lexical contribution to immediate serial recall. Additionally, content words were more frequently recalled than function words, confirming a semantic contribution. These results imply that non-phonological factors influence immediate serial recall and are consistent with a multiple-level capacity view of short-term memory.

INTRODUCTION

Performance in immediate serial recall of short verbal sequences has traditionally been recognized as a measure of verbal short-term memory (STM) capacity. Though it is widely used, researchers still do not fully understand the underlying mechanisms involved in this task. Two important theoretical conceptions have guided a large number of studies concerned with this issue. One very influential proposal is Baddeley's (1986; Baddeley & Hitch, 1974) phonological loop model. According to this view, verbal STM is essentially determined by a phonological store and a rehearsal process, thus by phonological factors. Central to this model is the assumption that verbal STM is a distinct and independent cognitive subsystem. An alternative view assumes that the processing of any type of information involves different but interactive domain-specific subsystems, each having a temporary storage capacity (Craik & Lockhart, 1972; Monsell, 1984; Crowder, 1989; N. Martin & Saffran, 1997; R. C. Martin, Shelton, & Yaffee, 1994). Accordingly, verbal memory is seen as having common underlying mechanisms with language processing, rather than construed as an isolated memory system. Since most theories of language assume the existence of different representational levels, such representations are further assumed to be reflected in the immediate serial recall performance of verbal information.

The debate between these two theoretical conceptions has currently been revived by recent research showing that immediate serial recall performance is influenced by long-term memory (LTM) information. Indeed, several researchers have reported lexical effects on immediate serial recall tasks (Besner & Davelaar,

1982; Gregg, Freedman & Smith, 1989; Hulme Maughan & Brown, 1991; Hulme, Roodenrys, Brown, & Mercer, 1995; Roodenrys, Hulme, Alban, Ellis & Brown, 1994; Tehan & Humphreys, 1988). Within the context of Baddeley's theory, a LTM influence must be independent of the phonological loop. These lexical effects have been obtained under articulatory suppression and found not to be mediated by differences in speech rate. These LTM effects are attributed to the knowledge participants have of the phonological form of the words stored in LTM, thus to the lexical level (word level) of representations.

The observation of a LTM contribution to immediate serial recall tasks has different implications for the above two theoretical proposals. In the case of Baddeley's framework, a lexical effect from stored phonological forms of words cannot be accounted for without modifying his current model. In a recent paper, Baddeley, Gathercole and Papagno (1998) proposed a new version of the phonological loop model in order to accommodate the growing evidence of a LTM contribution. The authors suggest that the phonological store interacts with the phonological form of words stored in LTM. This new version can thus account for lexical (or LTM phonological form) effects that indicate LTM contributions of a phonological nature.

Contrary to the original phonological loop proposal, evidence of a LTM contribution to immediate serial recall is quite compatible with the multi-level capacity approach. As mentioned before, this proposal assumes that different levels of representations will be reflected in the recall performance. According to most theories of language, linguistic comprehension and production require the processing of phonological, lexical, syntactic and semantic representations. However, since

participants performing an immediate serial recall task must produce a list of discrete words, and not complete sentences, it is assumed that the levels of representations implicated exclude syntactic knowledge. Hence, a multi-level capacity approach to immediate serial recall would predict not only a phonological effect on immediate recall, but also lexical and semantic contributions.

In the studies mentioned above, the LTM contribution has been attributed to lexical representations. However, in two of these studies (Besner et al., 1982; Hulme et al., 1991), a LTM contribution was inferred by finding a difference in performance between words and nonwords. Since words usually convey meaning, they posses semantic representations in addition to lexical representations. Therefore, one cannot be sure that the effects found were solely mediated by the lexical knowledge: the semantic representations might also have contributed to producing the effect.

The issue of whether the LTM contribution is arising from lexical or semantic levels of representations is not trivial. Implications stemming from the two theoretical conceptions are quite different. In the latest version of the phonological loop model (Baddeley et al., 1998), only a lexical contribution could be accounted for. Unless some modifications are made, evidence for a semantic contribution to immediate serial recall cannot be explained by this new version of the phonological loop model. On the other hand, the multi-level capacity view specifically predicts that semantic representations are used in immediate serial recall. However, convincing evidence for such a contribution is required in order to support this view. Because these two models make distinct predictions regarding the role of semantic representations in immediate serial recall, we believe that this issue is of important theoretical relevance.

A review of the literature suggests that few attempts have been made to separate out the semantic and lexical effects on immediate serial recall. Tehan and Humphreys (1988) indirectly provided a first demonstration when they compared recall performance across three classes of words; nouns, adjectives and function words (e.g., articles, prepositions, conjunctions). It is assumed that, since function word meanings are better established within the context of a sentence, function words have less semantic content than nouns and adjectives when presented in isolation. Tehan and Humphreys (1988) showed that nouns and adjectives were better recalled than function words and interpreted this, as suggesting a semantic contribution to immediate serial recall. However, this conclusion was later challenged by Bourassa and Besner (1994), who controlled for the imageability value of the test items. In this later study, no advantage was found for content over function words.

Unfortunately, some methodological problems were noted in both these studies. First, neither experiment used lists of nonwords. When compared with nonwords, function words can reflect the specific contribution of lexical representations, independently of semantic knowledge. Additionally, there is a methodological issue related to the size of the pool of items used. Given that all but one of the studies mentioned previously were based on the use of small fixed sets of items, it is possible that participants learned more rapidly certain fixed sets of items. For instance, the repetition of small sets of items may result in facilitating the recall of words over nonwords, thus contributing to the exaggeration of lexical effects. Indirect evidence for this was obtained in a study by Lapointe and Engle (1990), who found differences in word-length effects in span tasks when comparing small fixed

pools of repeated words with large unlimited sets of items sampled without replacement.

The experiment reported here was designed to explore the respective involvement of semantic and lexical levels of representations in immediate serial recall, as expected by the interactive multi-level capacity approach. For this purpose, items that differ according to their LTM representations were compared. Abstract content words were used to counter possible imageability effects. Words were chosen without replacement from an unlimited set so that no item was presented more than once. If immediate serial recall is mediated by the different subsystems involved in processing verbal information, performance should be better when items possess both lexical and semantic representations than only lexical representations, and these latter items should be better recalled than those lacking lexical (and semantic) representations. Participants were evaluated under articulatory suppression so that any effect found could not be attributed to the phonological loop.

Method

Participants

Twenty-one French-speaking students voluntarily participated in this experiment. Participants (12 women) had an average age of 21.67 years (SD = 3.01; range = 18-28) with an average level of education of 14.29 years (SD = 2.08). Their mean score on a French version of the Mill Hill Vocabulary Test (Gérard, 1983) was 24.43/34 (SD = 3.91) which is within normal range. Their average word span was 4.81 (SD = 0.75; range = 4-6), which indicates normal verbal STM capacity.

Material

All stimuli were presented visually on a Macintosh computer screen. Each word was presented at the center of the screen in lower case letters using a *Times 36* font. Three sets of 40 items were constructed such that each set contained content words, function words and nonwords. Eight lists of five items were created by drawing items randomly without replacement from each word-class set. In some lists, words were either phonologically or semantically related. In those cases, words were exchanged from others lists. It should be noted that, unlike English function words (e.g., then, that, thus), French function words are not phonologically similar. All 24 lists were matched according to number of syllables, phonemes, letters and digram frequency. For content and function words, lists were also matched for word frequency (Baudot, 1992). The content words were abstract. Since there was no imagery and concreteness values available for these French content words, we used English indices when available (Friendly, Franklin, Hoffman & Rubin, 1982; Paivio, Yuille, & Madigan, 1968).

Procedure

The experiment was conducted during a single session. Each trial began with the presentation of a visual cue (3 stars) in the center of the screen, followed by the five-item sequence. The items were presented individually at a rate of one every 1500 ms, each item remaining on screen for 1250 ms. At the end of the sequence, when a question mark appeared, the participant attempted to recall the words. Recall was written on a response sheet containing five lines placed one under each other. Participants were asked to write down the entire item to be remembered (not only the first letters), from top to bottom, on the line that corresponded to the serial order of the item in the sequence. Participants crossed out a line when they could not

remember an item. Articulatory suppression was performed during both presentation and recall of the items. To do so, participants were instructed to count repeatedly from one to eight when the cue appeared, and continue counting until the last item was recalled. The order of presentation of the different word-classes was counterbalanced across participants according to a Latin Square design. Prior to the memory task, participants received a practice trial.

Results

An analysis of variance was performed on the proportion of items correctly recalled. Responses were scored according to a strict serial recall criterion. Preliminary analyses were first performed to assess the effect of position in the Latin Square design and of fatigue or practice within a given word-class. No such effects were found.

The table (p. 82) shows the mean proportion of words recalled in the correct serial position for each word-class. Both content and function words yielded better recall than nonwords. Furthermore, content words were better recalled than function words, although this advantage is of smaller magnitude than that between function words and nonwords. A repeated-measures ANOVA including the Word-class factor confirmed that the main effect was reliable, $F(2, 40) = 131.696$, $p < .0001$, $MSE = .00255$. A Newman-Keuls analysis ($p < .05$) indicated that recall for the nonwords was reliably lower than the recall for function words, and that these later items were less well recalled than content words.

Discussion

The recall advantage of function words over nonwords is interpreted as a lexical effect given the lexical difference between these two word-classes. Given the

semantic difference between content and function words, the recall advantage of content words over function words is interpreted as a semantic effect. Since these effects were obtained under articulatory suppression, they are also interpreted as being independent of the phonological loop. Since items were not repeated, the results may not be attributed to a learning effect.

The observation of a lexical and/or semantic contribution to immediate serial recall not mediated by the phonological loop has previously been demonstrated in several studies involving normal participants (Gregg et al., 1989; Hulme et al., 1997; Roodenrys et al., 1994; Tehan et al., 1988). Although the present results are consistent with theses studies, our study establishes the independence of a lexical contribution from semantic representations by using items that are devoid of semantic properties (function words).

The results also show a semantic effect on immediate serial recall. This is consistent with a recent study by Poirier and Saint-Aubin (1995) which demonstrated an advantage for homogenous semantic category word lists over heterogeneous category word lists, providing indirect evidence for the involvement of semantic representations in immediate serial recall. Neuropsychological studies have also provided some converging evidence for the existence of a semantic influence on immediate serial recall in brain damaged patients unable to use phonological codes (Belleville, Peretz, Fontaine, & Caza, 1997; N. Martin et al ., 1997; R. C. Martin et al ., 1994).

The latest version of the phonological loop (Baddeley et al., 1998) can now account for lexical contributions to immediate serial recall by postulating that the phonological store interacts with a phonological long-term system. However, this

proposal has two important inconsistencies with our findings. The first problem concerns how a lexical or LTM phonological contribution obtained under suppression in the visual modality could be accounted for by the phonological loop model. According to this model, when items are presented visually, articulatory suppression blocks access to the loop. LTM effects could not be mediated via this system. However, an alternative account provided by Baddeley (1996) postulates that the central executive is involved in holding and manipulating verbal information from long-term memory. Unfortunately, it is unclear how this relates to immediate serial recall. A second inconsistency stems from the fact that the phonological loop model makes no prediction concerning the contribution of semantic representations to immediate serial recall.

On the other hand, the demonstration of lexical and semantic effects on immediate serial recall is consistent with the multiple-level capacity view. This proposal assumes that the different subsystems responsible for processing these representations also have storage capacities and are thus contributing to their recall. The finding of a lexico-semantic contribution to immediate serial recall in brain-damaged patients, has led N. Martin and Saffran (1997) to propose a theoretical framework based on a model of language production (Dell et al., 1992, N. Martin, Dell, Saffran & Schwartz, 1994). Dell and O'Seaghdha's (1992) model is particularly relevant because it assumes that word processing is temporally graded, where processing output needs to be stored until it's complete. However, Dell and O'Seaghdha's model is limited to single word repetition. N. Martin and Saffran (1997) further developed this model to provide an account of multi-word utterances.

The present study leaves some issues unresolved. The method of articulatory suppression was used in order to gather evidence for a LTM contribution that was independent of the phonological loop. However, it would be interesting to assess the effect of the different word-classes without suppression, when participants have complete access to the phonological level of representations, in order to evaluate the two models described above. Although an unlimited set of words was used to demonstrate LTM contributions, it would be of interest to show if the same effects would be found with smaller word-pools or if our semantic effect depended on using the current paradigm. Indeed, since smaller sets require repeated presentations, participants can focus more on the position of the items and less on their identity (i.e. meanings). Additionally, one should address the issue of why the semantic effect is smaller than the lexical effect. One possibility is that activation is faster for lexical than for semantic representations, which would favor lexical effects on immediate serial recall (in spite of the fact that an unlimited set of words was used). Obviously, the details to account for the complex processing of word sequences have not yet been fully worked through. Thus, further research concerning these issues is needed.

In conclusion, the stance taken here is that performance in immediate serial recall tasks at span or near span of verbal information may be seen as deriving from distinct representational levels involved in language processing. New evidence from normal participants has been provided to include semantic representations and also to establish the specific contribution of lexical knowledge.

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Table

Mean Proportions of Words Recalled in the Correct Serial Position

Word-class	M	SD
Content word	.405	.089
Function word	.367	.065
Nonword	.169	.061

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Article no 3

A Semantic Contribution to Immediate Serial Recall that is Distinct from Phonological Word Form Influences: A Neuropsychological Case Study

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ABSTRACT

We present HP, a patient who following herpetic encephalitis, lost the ability to understand some concepts while other concepts were preserved. Of particular interest is the fact that some words have retained their lexical status in spite of their loss of meaning. HP's immediate serial recall performance with meaningful and meaningless words was compared to assess the distinctive contribution of semantic knowledge without the confounding influence of phonological word form. The results reveal a clear advantage for immediate serial recall of meaningful over meaningless words, indicating a contribution from the semantic level of representations. Error analysis showed that phonemic errors were most common when semantic information was lacking. These findings support both the interactive activation model (N. Martin & Saffran, 1997) and the semantic binding hypothesis proposed by Paterson, Graham and Hodges (1994), which suggests that semantic knowledge helps stabilize phonological elements in word recall. In addition, we provide preliminary evidence that the recall of non-words might also be affected by semantic influences from words that share phonological elements with non-words. These latter findings, along with other neuropsychological data, favour a language activation account of short-term memory although other accounts are discussed.

INTRODUCTION

It is widely accepted that phonological representations contribute to performance on immediate serial recall tasks. However, a number of recent studies have investigated the effect of other stimulus characteristics (e.g., frequency, imageability) in normal participants on this type of task. The findings from these studies suggest that this view should be broadened to include other levels of linguistic representation, such as the lexical (or phonological word form) and semantic levels (Bourassa & Besner, 1994; Caza & Belleville, 1999; Hulme, Maughan, & Brown, 1991; Roodenrys, Hulme, Alban, Ellis & Brown, 1994; Tehan & Humphreys, 1988; Walker & Hulme, 1999). A convincing demonstration that other linguistic factors influence short-term serial recall is of theoretical relevance for models of short-term memory (STM), as a number of them do not provide a straightforward account of these effects (e.g., Baddeley, 1986).

The role of lexical or phonological word-form knowledge on immediate serial recall has been investigated by comparing the recall of words to non-words (lexicality effect) as well as the recall of high-frequency over low-frequency words (frequency effect). Numerous studies have demonstrated that both the lexicality and frequency effects of normal subjects in immediate serial recall tasks are reliable (e.g., Brook & Watkins, 1990; Gregg, Fredman, & Smith, 1989; Hulme, Roodenrys, Brown, & Mercer, 1995; Hulme, Roodenrys, Schweickert, Brown, S. Martin, Stuart, 1997). Theoretical accounts for such effects can be broadly divided into two classes, according to the type of relationship that is assumed between linguistic representations and memory function.

One approach proposes that there are interactions between lexical representations and immediate serial recall, but that these interactions occur relatively late in the recall process. These models also support a distinction between memory systems and language processing. The redintegration hypothesis accounts for lexical effects by assuming that the phonological word form in the LTM system can be used to support reconstruction or redintegration via a pattern completion process of the fading phonological trace stored in a STM system (Hulme et al. 1997; Schweickert, 1993). Another general class of theoretical accounts assumes that immediate serial recall depends on the activation of the representations involved in language processing. These frameworks lie within the scope of distributed processing models (e.g., Craik et Lockhart, 1972; Crowder, 1993; MacKay, 1987) whereby memory is seen as resulting from mechanisms that are also implicated in language processing. An example of such models is the interactive activation hypothesis (N. Martin & Saffran, 1997) which assumes that words in an immediate serial recall task are processed so that all linguistic representations including lexical ones, are activated via bi-directional connections between levels of representations, which in turn supports recall performance. In N. Martin and Saffran's model, lexical effects are proposed to occur during encoding and recall, as oppposed to only at recall. In spite of the differences in the proposed mechanisms involved, these two classes of models can account for the fairly robust lexical effects on immediate serial recall

Semantic effects in immediate serial recall have been investigated by manipulating word-class, concreteness, semantic category, and semantic similarity of the items to be recalled (Baddeley, 1966; Caza & Belleville, 1999; Poirier et Saint-Aubin, 1995; Tehan & Humphreys, 1988; Walker & Hulme,1999). Unfortunately, the

findings appear to be less systematic in normal subjects than those obtained with paradigms that involve lexical factors. For example, semantic similarity has been found to increase or decrease immediate serial recall (Baddeley 1966; Poirier and Saint-Aubin,1995). In one of our studies, when imageability is controlled, the effect of word class, or specifically the comparison of the recall of words with semantic content (abstract nouns) to the recall of words with little semantic content (grammatical words) is found only in conditions of articulatory suppression (Caza & Belleville, submitted). Some of these inconsistencies and difficulties in obtaining clear effects appear to result from experimental limitations, such as difficulties in selecting the proper criterion used to score performance or the lack of use of controls for confounding factors.

Brain-damaged patients with semantic deficits provide an alternative and unique opportunity to examine the contribution of semantic factors in short-term serial recall. This is particularly the case when patients exhibit selective semantic impairments, that is, impairments that affect only a subset of semantic concepts. Although such patients are uncommon, we have encountered one, HP, whom following herpetic encephalitis presents with a loss of semantic knowledge for specific concepts while other items are well preserved and meaningful. Most importantly, among the words that have become meaningless to her, some of them have retained their lexical status so that she is able to recognize them as words.

From a theoretical standpoint, assessing HP's recall performance with items that activate semantic and lexical representations (meaningful words) or mainly lexical representations (meaningless words) is highly relevant. It allows us to establish whether semantic representations affect performance in immediate serial

recall. It also provides an opportunity to distinguish the semantic contribution from the phonological word form influences that have been demonstrated in many studies. This can be achieved by comparing the immediate serial recall of words now devoid of semantic content with words that are meaningful in semantic content.

Assessments of a semantic contribution to short-term serial recall have been conducted previously in patients suffering from semantic deficits due to a dementing process (Knott, Patterson, & Hodges, 1997; Patterson, Graham & Hodges, 1994). In these studies, the immediate serial recall of words that were either known or unknown to the patients was compared. The results indicated an advantage for known over unknown items in all cases. Interestingly, these authors noted that patients made numerous phonemic errors when recalling items. To account for these errors, Patterson et al. suggested that two sources of binding or coherence aid normal word production. These binding effects are somewhat similar to the lexical and semantic influences that are assumed to support immediate serial recall performance in the interactive activation model (N. Martin & Saffran, 1997). They called this proposal the *semantic binding hypothesis*. According to this view, one of the sources lies within the phonological word form itself; it allows for the correct combination of phonological elements when a word is produced. The other source of coherence comes from semantic information about the word, which also helps the binding of sublexical elements in the word to be produced. The authors argue that when the phonological system is overloaded as is the case with recall of short word sequences, the absence of one source of coherence notably the semantic source in semantic dementia affects recall performance. Moreover, because semantic information is assumed to stabilize or help bind phonological elements together, the lack of semantic

binding gives rise to specific binding errors known as phonemic errors, that is, the misplacement of phonological elements.

However, studies involving patients with semantic dementia have not always found evidence supporting the idea that semantic information plays a role in immediate serial recall. In the first study to use the known/unknown paradigm, Warrington (1975), found similar performance for both known and unknown words in all patients. Similar studies also failed to find evidence for a semantic contribution to immediate serial recall (Funnell, 1996; McCarthy & Warrington, 1987).

It must be noted that several important methodological problems can account for the absence of a "known" or semantic effect in these studies (McCarthy & Warrington, 1987; Warrington,1975). First, the frequency of known and unknown words was not controlled. As mentioned previously, frequency effects are attributed to lexical processing and are known to affect serial recall performance. In addition, the performance with unknown words was close to ceiling in one of the studies (McCarthy & Warrington, 1987), leaving virtually no room for a potential difference between known and unknown words to be detected.

Methodological problems were also noted in the studies in which semantic effects were reported (Knott et al., 1997; Patterson et al., 1994). First, the patients' knowledge about the lexical status of the unknown words was not mentioned. Thus, it can be argued that the unknown words were like non-words to the patients. Since the recall of unknown words was not compared to the recall of non-words, the question of whether unknown items had a lexical status for the patients remains unanswered. This is of major importance because the semantic effect could be attributed to the lexical representation of the known words. As mentioned previously, lexical effects

appear much more robust and easier to account for within most models of immediate serial recall. If this were the case, the arguments for a semantic contribution to immediate serial recall would be much weakened. Indirect support for this has been found in other tasks which compared the recall of non-words to words chosen without regard to the patient's knowledge of them (Knott et al., 1997). The results revealed the absence of a lexical effect in one of the patients, indicating that these words did not activate the lexical level of representations. As this is consistent with an impairment of the lexical representations in this patient, it is possible that unknown words were devoid of both semantic and lexical status. They would thus not allow for the dissociation of the two levels representation.

A second important, and somewhat related, methodological issue is the absence of a control group to compare performance with known and unknown stimuli (Knott et al., 1997; Patterson et al., 1994; Warrington,1975). It is crucial that the memory equivalence of the known and unknown stimuli be demonstrated before attributing any difference in performance to the semantic level of representation. Observation of similar recall performances with known and unknown words in a group of control subjects provides such evidence.

Finally, as noted earlier, all of the patients in the previous studies were suffering from a progressive deterioration of semantic memory. Performing single case studies in patients suffering from a progressive deterioration always carries risks. Single case studies usually take place over a relatively long period of time. This is particularly problematic here, as the identification of known and unknown items is a crucial aspect of these studies. Since the disease usually evolves toward much wider cognitive deficits, it is always difficult to ascertain that other levels of representation

(for example, the lexical one) are not becoming gradually impaired, thus contributing to the pattern of performance reported.

Given the present state of theories of immediate serial recall, the resolution of whether a semantic contribution plays a crucial role in these tasks is fundamental. Data gathered thus far, both in normal and neurologically impaired persons, are not entirely convincing. Thus, we propose to assess the separate contribution of semantic representations on short-term serial recall in HP, a brain-damaged patient with a non progressive semantic deficit and a matched control group. As mentioned earlier, HP has lost some items while others are preserved, rather than the presence of a massive or general semantic deficit. Three types of items were presented for recall: Carefully selected words that are meaningful to HP, words that have become meaningless but have retained their lexical status, and non-words. If semantic representations contribute distinctly to short-term serial recall, HP's performance should be better with meaningful than with meaningless words. Based on the assumption that lexical representations influence immediate serial recall, meaningless words should be better recalled than non-words in both HP and matched controls.

Case Report

HP is a right-handed woman with a master's degree in social work who was working as a psychotherapist in a private office prior to the onset of the disease. At 42 years of age (September 1991), HP was hospitalized, presenting with drowsiness, confusion and a neuropsychological profile compatible with severe transcortical sensory aphasia. A Ct-scan revealed a hypodensity in the left fronto-temporal area

with a shift toward the median line and slight compression of the brainstem on the left side. A diagnosis of herpes simplex encephalitis was made and the patient was treated with mannitol and acyclovir. Once her medical condition became stable, HP was referred to a rehabilitation centre from which she was discharged at the end of January. Neuropsychological examinations performed between January and April 1992 revealed a substantial improvement in comprehension and oral expression and, to a lesser extent in long-term episodic memory. She was then referred to a nursing home, where she received help with her activities of daily living. During that period, HP was followed on an external basis for speech therapy, memory therapy and occupational therapy. By 1994, the patient had improved substantially: she lived alone and was able to take care of herself.

A recent neuropsychological evaluation was conducted in 1997-1998. HP was attentive and well aware of her deficit. The language profile was characterized by anomic aphasia. HP was fluent with logorrhea but evident word finding difficulties were observed with frequent circumlocutions. In conversation, her comprehension was not problematic. On formal language tests (Montreal-Toulouse 86B; Béland & Lecours, 1990; Béland, Lecours, Giroux & Bois, 1993; Table 1, p. 131), she was severely impaired in oral picture naming. Pauses and periphrases were frequent, however in most cases the target-word was provided with phonemic cuing. Written picture matching led to errors of the semantic type (2/5 for words and 7/8 for sentences). Her oral reading was moderately impaired, leading to phonemic paralexias that were most often spontaneously corrected. Writing to dictation was slightly impaired with occasional paragraphias of the literal type. In Semantic fluency (clothing and vegetable), HP's performance was significantly reduced (10 in both

cases, Normal Means: 21.2 and 16, respectively). However, in phonemic fluency (letters P, T and L), she scored within the normal mean range. She generated respectively 18, 18 and 13 words in 90 sec. (Normal Means: 19, 14.2 and 12.4 respectively). She made no errors in word and sentence repetition (30/30 for words and 3/3 for sentences). Oral comprehension (picture matching) was correct for words (8/9), simple sentences (6/6) and for long and complex sentences (29/32). Written comprehension, as assessed by a series of questions on a written text, was performed with no particular difficulties.

Intellectual efficiency was measured with the Ottawa-Wechsler I.Q. scale (1957, a French adaptation of the WAIS). She obtained the following scores: VIQ = 96, PIQ = 107 and FSIQ = 100. These results probably underestimate her pre-morbid intellectual functioning, considering her education level. Careful inspection of the different scores from the subtests (Table 2, p. 132) revealed that HP's performance was particularly depressed in three subtests, two of which solicit semantic knowledge (Information (4) and Picture Completion (4)). Results were also poor on the Arithmetic (5) subtest. HP scored 49/60 on the Raven Progressive Matrices, which places her close to the high range for her age group (90th percentile) and suggests that the patient has normal intellectual efficiency. There were no signs of object agnosia, visuospatial deficits, limb or constructional apraxias.

HP's executive functions were first evaluated with the Trail Making Test, which indicated a slowing in Part A of the test that was more marked on Part B (Table 3, p. 133). However, these results might also reflect a difficulty in recognizing some letters. Her performance on the Wisconsin Sorting Card Test was above average

on the identification of categories and perseverative errors were within the normal average range (Table 3, p. 133).

HP and matched controls were also evaluated on an updating task, a serial recall task which involves both the retention and manipulation of verbal material and is thus believed to tap executive functions. This task involves presenting long lists of letters known to HP (see letter span in Experiment 1) and asking participants to recall the last items of the lists without them knowing the list length in advance. As a result, the participants have to update continuously the content of their working memory. The number of items to recall corresponds to the participants letter span. Table 4 (p. 134) shows the mean percentage of items recalled in the correct serial order at each of the four list lengths by HP and controls. HP's results indicate a steady decrease in recall performance with increasing list length. Importantly, the patient's performance at all list lengths is within the range of matched controls, indicating normal capacities in tasks that involve executive control.

HP's memory Quotient on the Wechsler Memory Scale (1968, a French adaptation of the WMS) was 76, which indicated marked memory impairment. The details of the subtests are presented in Table 5 (p. 135). Notably, digit recall was preserved, as HP obtained a span of 6 in direct order and of 4 in reverse order in the Digit subtest. HP obtained 30/50 (Mean: 44.3, SD: 3.5) on Warrington's forced-choice face recognition test which suggests that episodic memory for non verbal material is also impaired. In daily life, HP was using different strategies to cope with her episodic memory problems, such as using a diary for appointments and making lists of things to do, to buy, etc.. Moreover, her life was well organized and based on routine activities.

The data presented here were obtained between early 1999 and mid 2000. No change in her performance level was noted during this time period. Unless otherwise stated, HP's performance was compared to that of four neuropsychologically intact control participants matched with her according to age, sex, and education. The controls were tested over a comparable period of time. This study complies with the APA ethical principles and was approved by a local ethics committee.

Experiment 1: Assessment of Immediate Serial Recall

Prior to investigating the semantic and lexical influences on short-term serial recall, Experiment 1 was conducted to examine HP's immediate serial recall on standard tests and materials typically found in the literature. The patient's performance on a classical span measure was assessed using different verbal materials, in both the auditory and visual modalities and compared with that of matched controls

Materials and Procedure

Unless otherwise stated, the general procedure for the span measures with all verbal materials was as follows. Two lists of two items were presented first. If on these lists, items were recalled in their correct serial order, the length of the next two lists was increased by one item. If an error occurred, two additional lists were presented at the same length. Span corresponded to the length of the longest lists recalled correctly on 50% of the trials provided at that length. Each list was constructed by drawing items randomly without replacement from a pool of stimuli. Span was measured in the auditory and visual modalities. In the auditory modality,

items were presented at a rate of one item per second. The rate of presentation was controlled by a computer. The examiner read each item from the computer screen, which was not in the participant's sight. In the visual modality, items were shown to the participant on a computer screen at a rate of one every two seconds. The rate of presentation was reduced as compared to the auditory modality to allow more time for processing the information. Within this range, the rate of presentation has not been shown to influence recall performance when participants are not prevented from rehearsing subvocally (Baddeley & Lewis, 1984). The responses were oral in all cases.

Digit span. This task was taken from the Côte-des-Neiges computerized memory battery (Belleville et al, 1992; Chatelois et al, 1993). Digits from one to nine were the stimuli used in this task. In order to ensure that HP had no difficulty producing the items, she was asked to repeat/read the nine digits, which were presented randomly. This was conducted in the auditory and visual modalities following the span task.

Letter span. HP's ability to correctly identify the letters of the alphabet was first assessed using (1) a naming task in which the 26 letters (in capitals) were presented randomly on a piece of paper, and (2) a writing to dictation task. Only consonants were used as stimuli in the letter span, and six were excluded (F, K, Q, W, X, Z) based on inconsistent performance in either the naming or the writing task, leaving a pool of 14 stimuli. Span measurement was then completed with the procedure described above in both the auditory and visual modalities of presentation. Following testing, HP was asked to repeat/read each item presented.

Word span. A set of eight concrete words were chosen to determine word span (bec, bijou, jus, oignon, ongle, piscine, pluie, vaisselle; in English, beak, jewel, juice, onion, nail, pool, rain, dishes). These words were carefully selected according to a procedure used to ensure that words were meaningful to HP (see Experiment 2). Prior to the span measure, HP was asked to repeat/read each item presented auditorily/visually for audibility/readability.

Results and Comments

Table 6 (p. 136) shows HP's span for verbal materials in both modalities, as well as the range of the matched controls. As shown in Table 6, HP has a normal span for materials that are familiar to her. This was found for all three types of material and in both presentation modalities. These results indicate that HP is able to perform normally in immediate serial recall tasks, provided that the material used is familiar to her.

Experiment 2: Effect of Semantic Knowledge on Immediate Serial Recall

This experiment was designed to assess whether an influence of semantic representations can be found independently of lexical effects in short-term serial recall performance. Thus, HP's recall performance was measured using words that are meaningful to her, as well as those that have become meaningless. Most importantly, the meaningless words can be recognized as words by HP, and have thus retained their lexical status. This allows for any advantage found for meaningful over meaningless words to be attributed specifically to semantic representations as

opposed to lexical or lexico-semantic influences. The matched controls should not exhibit recall differences between the two categories of words because these items have been matched in terms of all parameters likely to affect recall performance. HP's immediate serial recall performance of meaningless words was also compared in the same experiment to that of non-words with comparable phono-articulatory parameters. Based on the current literature, which indicates that phonological word forms influence short-term serial recall, both HP and the controls should be better at recalling meaningless words than non-words.

Finally, this experiment also enables predictions to be made regarding the possible extension of the semantic binding hypothesis to the recall of non-words. If loss of semantic coherence can affect *word* recall as proposed by Patterson et al. (1994), recall of *non-words* sharing many phonological elements with meaningless words might be hindered by the fact that top down influences from meaningless words cannot contribute to the stabilization of phonological representations. The non-words used in this experiment were created by changing letters in the meaningless words. Poor performance with non-words is thus expected in HP relative to controls. This would result in an exaggeration of the lexical effect.

Materials and Procedure

Two pools of French words were created for each of the two following conditions. The Meaningless (ML) condition was comprised of words for which HP was (1) unable to provide a definition to the written form of the word that she read herself, (2) unable to match the written word to a picture, (3) unable to name the picture representing the word but, (4) was able to make a lexical decision about the

word. The lexical decision task was presented twice, once with spoken items and once with written stimuli. Items had to comply with all four criteria in order to be used in the meaningless condition. The meaningful (MF) condition comprised words for which HP was able to (1) provide a definition to the written form of the word that she read, (2) match the written word to a picture and, (3) make a lexical decision about the word. The ability to name a picture was also assessed, but was not a mandatory criterion for a word to be included in the meaningful condition for two reasons. First, difficulty in naming a picture with adequate verbal definition may result from problem in activating phonological word form from intact semantics (Kay & Ellis, 1987). Furthermore, this allowed for a greater number of words to be included in the set so that more criteria could be used for matching items.

Two sets of 18 concrete words were constructed (6 monosyllabic, 12 polysyllabic in each set), one from each pool. A set of 18 non-words was created in most cases by replacing two letters from the words in the meaningless set. All three sets were matched on the number of syllables, letters, and digram log frequency. The meaningful and meaningless sets were also matched on word log frequency (Baudot, 1989) and concreteness level. All of the matching criteria for the stimuli are shown in Table 7 (p. 137). Because there were no French norms for concreteness, values were established separately by testing a group of 34 normal participants. They rated the concreteness of the words that were used in the different experiments of this study on a seven point scale, ranging from 1 (*concrete*) to 7 (*abstract*). Table 7 reports the concreteness values established in this manner for the set of items selected in this Experiment. Twelve lists at span length were created for each condition. Each list was created by sampling semi-randomly without replacement from the corresponding

word set. All items had to be included in a list before being drawn again and they were never presented in the same position twice.

The immediate serial recall of items was measured separately in both auditory and visual modalities. In the auditory modality, stimuli were presented individually at the rate of one item per 1.5 seconds. In the visual modality, items were presented at a rate of one every 2 seconds. Participants were tested at their span level in each modality as measured in Experiment 1. Thus, HP was tested with lists of four items in both modalities. The words that were used to measure span were comparable to those used in the experimental phase with respect to digram frequency and concreteness. Responses were given orally.

Results and Comments

Auditory modality. The mean percentage of items recalled in the correct serial position for HP and the controls is presented in Table 8 (p. 138). First, the controls performed similarly on both word conditions. This finding is compatible with the assumption that the two sets of words are equally known to the controls and were properly matched on dimensions that influence recall in normal participants. An advantage for meaningless words over non-words was also found, which is congruent with our predictions. In turn, HP performed better with words that were meaningful to her than those that have lost their meaning. In addition, items having a lexical status (meaningless words) were better recalled than non-words. These results are consistent with our predictions and indicate that HP's performance is influenced by both the semantic and the lexical content of the items to be recalled.

To compare the magnitude of the influence of these linguistic representations, a Semantic Effect Score [(Meaningful words - Meaningless words)/Meaningful

words] and a Lexical Effect Score [(Meaningless words - Non-words)/Meaningless words] was computed for both HP and Controls. These scores were also converted into z scores in order to allow for comparison with the control group. The effect scores, presented in Table 8 (p. 138), indicate a large semantic effect in HP and reveal a strong influence from semantic representations on immediate serial recall performance. HP also exhibited a large lexical effect and this effet was larger than that found in the controls. This finding reflects the contribution of lexical knowledge to HP's recall performance but also a depressed recall of non-words. As these non-words shared many phonological elements with meaningless words, this may reflect the detrimental effect of meaning loss on phonological recall, thus extending the semantic binding hypothesis (Patterson et al., 1994) to non-word recall.

Visual modality. The mean percentage of items recalled in the correct serial position for HP and the controls is presented in Table 8 (p.138).The controls showed a clear advantage for meaningless words over non-words, but no difference in performance was noted between meaningful and meaningless stimuli, as expected. As predicted, HP's performance was influenced by both the lexical and semantic content of the items, as recall is better for meaningful than meaningless words, and these latter items are better recalled than non-words. The Semantic Effect Score, shown in Table 8 , was again increased relative to the controls. However, the Lexical Effect Score remains within the range of that found in controls.

Error analysis. The semantic binding hypothesis (Patterson et al, 1994) predicts that a lack of semantic coherence leads to increased phonological errors in word production. The distribution of HP's serial recall errors with both meaningful and meaningless words was thus tabulated. Because HP was tested at span, the

number of errors with meaningful words was limited. Therefore, the results from both the auditory and visual modalities were pooled. The data represent the number of a particular type of error out of the total number of errors in each condition and are expressed as percentages (Table 9, p. 139).

As a first step, errors were classified as being either item or order errors.When calculated according to the method described above, meaningful items yielded a greater percentage of order errors than meaningless items (35% vs. 16%, respectively) whereas the reverse is true of item errors (65% vs 84%, respectively). Although the recall of order and item errors are often reported separately, they are intrinsically linked, as one cannot misplace a word that one does not recall. Consequently, dividing the number of order errors by the total number of errors may artificially inflate the proportion of order errors and make comparisons impossible if the total number of errors is not identical in all conditions. To account for such discrepancies, Murdock (1976) has suggested that order errors be divided by the total number of items recalled, regardless of their position. After adopting this procedure, the results revealed that meaningless words lead to slightly more order errors (16%) than meaningful words (8,43%).

Item errors were further classified as phonemic errors, semantic errors, omissions or other. HP's production was considered to be a phonemic error if more than half of the phonemes in the response were from the target word (e.g., ***écosse*** instead of **écorce**) or had migrated from any item in that sequence (e.g., ***pull*** instead of pyramide, in the sequence b**ul**be – dentelle – canard – **p**yramide). Consistent with the semantic binding hypothesis (Patterson et al., 1994), phonemic errors were the most frequent type of errors when semantic information was lacking. Errors with

meaningful words were of the phonemic type in 15% of the cases, whereas those with meaningless items were of the phonemic type in 40% of the cases. These results support the idea that semantic information about a word contributes to the recall of the item by stabilizing the phonological elements in that word, as proposed by Patterson et al. (1994).

As can be seen in Table 9 (p. 139), semantic errors were generally uncommon, but occurred more frequently with meaningful (10%) than with meaningless (2%) words. Within an activation view, semantic errors are believed to arise from the activation of other words which share semantic features with the target word. Assuming that meaningless words do not activate as many semantic representations as meaningful ones, semantic errors are less likely to occur with the former than the latter. Finally, there were a larger percentage of omission errors among meaningless than meaningful words (30% vs 10%, respectively)

Experiment 3: Effect of Semantic Knowledge on Immediate Serial Recall under Articulatory Suppression

The results from Experiment 2 indicate a semantic contribution to short-term serial recall that is independent of lexical or phonological word form influence. However, it is well known that the speed at which words can be articulated has a profound influence on immediate short-term recall. Items that are articulated more rapidly benefit more from active rehearsal and this is reflected by an increase in short-term recall. It has been shown that speed accounts for some of the lexical factors reported in the literature on immediate serial recall (Wright, 1979). Thus, it is

important to ensure that the semantic and lexical effects observed in the previous experiment are independent of the speed of rehearsal. This was achieved by comparing HP's recall performance under articulatory suppression. This procedure requires that the participant utters an irrelevant segment during the task, and is known to the block rehearsal of items. Hence, the use of articulatory suppression ensures that the effects are not mediated by differences in articulation speed.

Materials and Procedure

The Experiment involved the same lists of stimuli as those in Experiment 2. Again, the lists were presented in both the auditory and visual modalities. The procedure was identical to that of Experiment 2, except that during the presentation of the stimuli, participants were instructed to count repeatedly from one to eight.

Results and Comments

Auditory modality. Results for both HP and the controls in the condition of articulatory suppression are presented in Table 10 (p. 140). The level of performance for both word conditions was similar in matched controls and they showed an advantage for meaningless words over non-words. In contrast, HP showed a better recall for meaningful than meaningless words and for meaningless words than non-words. As indicated by the Effect Scores, the semantic and lexical effects were increased in HP relative to controls, thus replicating the findings of the previous experiment.

Visual modality. As shown in Table 10 (p. 140), the controls performed equivalently with both types of words and had a better recall for meaningless words relative to non-words. As expected, HP's performance indicates an advantage for meaningful words over meaningless words, and for meaningless words over non-

words. In this Experiment, the Semantic Effect Score was not increased relative to the controls, however, there was a relative increase for the Lexical Effect Score. The absence of a larger semantic effect in HP as compared to the controls may reflect the greater variability in the latter group, as indicated by the large range of performances. Overall HP's semantic and lexical effects under an articulatory suppression condition support the view that these linguistic contributions influence immediate serial recall performance independently of rehearsal.

Interestingly, the results from Experiments 2 and 3 yielded an exaggerated lexical effect in HP, as compared to the control group. This finding was not specifically predicted by the interactive activation model (N. Martin & Saffran, 1997). Thus, we wanted to determine whether the increased lexical effect was not due to methodological issues, such as the fact that the non-words were derived from meaningless words. A lack of semantic influences in meaningless words could be reflected in ISR of *non-words*. This is likely in the realm of activation models. A central assumption in Dell and O'Seaghdha 's (1992) model is that activation spreads to other representations that share elements at all levels (e.g., semantic features or phonological elements). Based on this principle, words that share many phonological elements with to-be-remembered non-words may influence their recall via activation from semantic and lexical levels of representations. Consequently, the absence of semantic representations in meaningless words should have a detrimental effect on the recall of non-words created from these meaningless items. This assumption was tested in the next experiment.

Experiment 4: Semantic Influences on Immediate Serial Recall of Non-words

To compare whether semantic information can indirectly affect the recall of non-words, we compared performance with non-words derived from either meaningful or meaningless words. Non-words were created by changing only *one* letter in the word to maximize the number of phonological elements shared between words and non-words. Hence, if semantic representations affect immediate serial recall performance, non-words created from meaningful words should be better recalled than those derived from meaningless items. Furthermore, based on the differential pattern of errors found between meaningful and meaningless words in Experiment 2, similar predictions were made for non-words. Hence, the recall of non-words derived from meaningless items should also lead to more phonemic errors than those constructed from meaningful stimuli.

Materials and Procedure

Two sets of 18 non-words were constructed from the sets of meaningful and meaningless words used in Experiment 2. The non-words were created by changing one phoneme in the target word. Both sets of non-words were matched on the number of syllables, letters, and digram frequency (Table 11, p. 141). Twelve lists at span length were created from each set of stimuli by sampling without replacement for each list. Across lists, items were never presented in the same position twice. Lists from each condition where given in alternation. Items were read by the examiner at the rate of one per 1.5 seconds. Participants responded orally.

Results and Comments

The mean number of non-words recalled in the correct serial order for both HP and the Controls is presented in Table 12 (p. 141). As can be seen in the table, the quantitative results indicate a similar performance regardless of whether non-words are created from meaningful or meaningless words. This result does not support our prediction. It should be noted, however, that performance with the non-words created from meaningless words might have benefited from the repeated presentation of the non-words used in Experiments 2 and 3. Although these were not the same non-words, they were constructed from the same set of meaningless words (by changing two letters rather than one letter). They thus shared some similarities.

Error analysis. Particularly interesting is the distribution of recall errors. Percent recall errors for both types of non-words are shown in Table 13 (p.142). Again, errors were sorted as either item or order errors and were calculated as the number of a particular type of error on the total number of errors in each condition. Order errors occurred about as frequently with meaningful (5%) than with meaningless words (0%). When order errors were divided by the total number of items recalled rather than total number of errors, similar results were found (meaningful 5,88%; meaningless, 0%).

Among item errors, phonemic errors were the most common errors for both "meaningful" and "meaningless" non-words. Consistent with the extended view of the semantic binding hypothesis, HP made more frequent phonemic errors with meaningless than meaningful non-words (75% vs. 55%, respectively). Target errors corresponded to cases in which the subject erroneously recalled the word that was used to create the non-word. These errors occurred about as frequently with

meaningful (25%) than with meaningless (20%) non-words. Conversely, omission errors were very infrequent with meaningful (5%) and meaningless non-words 0%).

Experiment 5: Semantic Influences in the Recall of Items from Different Grammatical Classes

Experiments 2 and 3 clearly demonstrated a contribution from semantic and lexical levels of representations to HP's immediate serial recall. The current experiment addresses the question of generality by using a different paradigm. Performance was measured with words from different grammatical classes. Recall was compared with rhyming items that varied according to whether they activate both semantic and lexical representations (content words), mostly lexical representations (function words such as prepositions), or no lexical or semantic representation (non-words). The variation between stimuli was consistent for both HP and the controls, as the items chosen were taken among those for which the patient knew the meanings. This task was selected because it has previously demonstrated a semantic and lexical contribution to immediate serial recall in normal participants (Caza & Belleville, submitted). Using this task, it is possible to determine whether typical semantic effects can be found when all items used are known to HP rather than using lost items which might have had a more general impact on HP's ability to use semantic information when attempting to recall items. Consequently, HP should have both a semantic and lexical effect, however, these effects should be the same as those found in the controls. We did not predict a depressed non-word recall in HP relative to the

controls. The reason for this is that the non-words used here were constructed from items that were not more degraded in HP than the controls.

Materials and Procedure

Three sets of six stimuli were created using (1) abstract content words (année, côté, degré, idée, privé, santé; in English, year, side, degree, idea, private, health), (2) function words (ainsi, ceci, hormis, ici, parmi, voici; in English, thus, this, but, here, among,here is), and (3) nonwords (ata, aupha, hupras, pobla, sola, vuima). In all lists, the number of syllables, letters, phonemes and digram frequency were controlled. Word frequency was controlled in both sets of words (Baudot, 1989). HP's knowledge of the content words was assessed with a definition task. A lexical decision task was also used to evaluate lexical knowledge of both the content and function words. Ten lists were created for each word class. Each list was created by sampling randomly without replacement. Items were presented in the auditory modality at the rate of one item per second and responses were given orally. Participants were tested at their auditory word span level as determined in Experiment 1.

Results and Comments

As can be seen from Table 14 (p. 143), both HP and the controls recalled abstract content words better than function words, and these latter items were better recalled than non-words. These results indicate that all participants benefit from additional semantic and lexical information when recalling items. Consistent with the assumption that content words activate similar semantic representations for both HP and Controls, the computed Semantic Effect Score [(Content words - Function words)/Content words] for HP is within the controls' range. However, contrary to our

predictions, the Lexical Effect Score [(Function words – Non-words)/Function words] was increased compared to controls. Since function words are assumed to activate similar representations in both HP and controls, the exaggerated lexical effect is attributed to poor performance with non-words in HP. A difficulty in recalling non-words might be indicative of an inability to use phonological representations to memorize items. Phonological processing difficulties may have gone unnoticed because HP's language assessment indicated no significant phonological deficits apart from occasional phonemic paralexias. The next experiment was performed to assess whether HP made use of phonological information to perform immediate serial recall tasks.

Experiment 6: Effect of Phonological Similarity on Immediate Serial Recall

It is well known that the phonological characteristics of items have an impact on immediate serial recall. This is exemplified in the phonological similarity effect. First described by Conrad (1964), it refers to the detrimental effect on recall of using items that are phonologically similar (e.g., b, t, d, v) as compared to items that are phonologically distinct (e.g., h, l, s, f). Although this effect can interpreted in different ways (e.g: Baddeley, 1986; Nairne, 1990) it is taken as evidence for the use of a phonological code in retaining verbal information. The phonological similarity effect was thus assessed in HP by comparing the recall of phonologically similar and dissimilar letters. The finding of a phonological similarity effect in HP's recall performance would suggest that she makes normal use of phonological information in immediate serial recall.

Materials and Procedure

Seven phonologically similar consonants (B, C, D, G, P, T, V) and seven phonologically dissimilar ones (H, J, L, M, N, R, S, T) were used as stimuli. These were all known to HP. Ten lists were created by randomly sampling items with replacement from each of the phonologically similar and dissimilar sets of stimuli. No item was repeated within a list. Participants were tested in both the auditory and visual modality with list lengths corresponding to their letter span in that modality, as determined in Experiment 1. In the auditory modality, items were read at a rate of one item per second. In the visual modality, items were presented on a computer screen at the rate of one item per two seconds. Phonologically similar lists were presented first, followed by the dissimilar lists. Participants were asked to recall items in the correct serial order and to respond orally. Prior to the experimental task, HP was asked repeat the letters presented individually.

Results and Comments

Auditory modality. The mean percentage of sequences recalled in the correct serial order by HP and the controls is reported in Table 15 (p. 144). In the auditory modality, recall of phonologically dissimilar items was better than that of phonologically similar material, as expected according to the phonological similarity effect. An Effect Score [(Dissimilar letters - Similar letters)/Dissimilar letters] was calculated for both HP and the controls in to compare the magnitude of the phonological similarity effect. HP showed a phonological similarity effect that was well within the controls' range.

Visual modality. As shown in Table 15 (p. 144), both HP and the controls exhibited an advantage for dissimilar letters over similar ones when tested visually.

The Effect Score indicates that HP was even more affected by phonological similarity than were the normal controls. This may be due to differences in performance level on dissimilar items. Although an attempt was made to equate performance level between HP and controls on dissimilar items by testing participants at span, it appears that this was not achieved in the visual modality. Had performance with dissimilar items been better equated, the difference between dissimilar and similar letters might not have been so drastic. Nonetheless, these results indicate that HP used a phonological code when performing immediate serial recall in both presentation modalities, and provide no indication that she has a phonological processing deficit.

Experiment 7: Delayed Repetition with Meaningful and Meaningless Words

This next experiment was designed to determine whether HP's capacity to maintain information at longer time intervals than those used in ISR was differentially affected by knowledge associated with the stimuli.

Materials and Procedure

Eighteen meaningful and 18 meaningless words from Experiment 2 were used in this experiment. The task involved presenting one item orally to the subject, followed by a delay in which an interference task was administered. During the interference task, the examiner stated a randomly selected number between 1 and 90. HP was asked to count aloud as quickly as possible starting from that number until the end of the delay. The delay was 2 or 5 seconds long, after which the patient was asked to report orally the previously presented item. There were 18 trials per condition. All conditions were tested in separate blocks using an ABBA design.

Results and Comments

The results for HP in both delay conditions and for both meaningful and meaningless words revealed a perfect performance. These findings are thus indicative of a normal trace decay in HP's capacity to retain both information that she understands and items that are now meaningless to her.

Experiment 8: Auditory Rhyme Judgment of Non-words

HP's phonological processing ability was assessed in a non-word rhyme judgment task which may be particularly sensitive to subtle phonological impairments.

Materials and Procedure

The rhyme judgment involved the use of 32 pairs of non-words; half of the pairs rhymed and half did not. All stimuli were disyllabic and orthographically legal. HP was asked to decide whether the stimuli in a given pair rhymed and there was no time limit in which to respond. Prior to the experimental task, a practice trial took place in order to ensure that the partient understood the nature of the task.

Results and Comments

The results for HP revealed only one error on the rhyme judgment involving non-words. These findings indicate normal phonological processing ability in a task known to be sensitive to phonological deficits.

GENERAL DISCUSSION

The main goal of the present study was to gather neuropsychological evidence for a semantic contribution that is distinct from lexical or phonological word form influences on immediate serial recall. To attain this objective, we manipulated the types of lexical and semantic representations activated by using carefully selected words from the vocabulary of HP, a patient with a non-progressive semantic deficit. We first demonstrated that HP's span performance using familiar information in both the visual and auditory modalities, was within the normal range of matched controls (Experiment 1). HP was also better at recalling words that are meaningful to her than items that have become meaningless (but have retained their lexical status), and these items were better recalled than non-words (Experiment 2). These results were also obtained under articulatory suppression, indicating that these findings are independent of rehearsal (Experiment 3). Error analyses indicated that HP made more phonemic errors when recalling meaningless than meaningful words. This was also found when non-words derived from meaningless items were used, but not when non-words derived from meaningful stimuli were employed (Experiment 4). However, her recall performance was equivalent in both non-word conditions. Semantic and lexical effects were also found in a different experimental paradigm that made use of familiar words for which the lexico-semantic content varies (abstract words, grammatical words and non-words, Experiment 5). Finally, HP's capacity to use and retain phonological information was shown to be normal in a phonological similarity task (Experiment 6), a delayed recall task (Experiment 7) and a non-word rhyme judgement task (Experiment 8).

The finding, in HP, of better recall for meaningful words over meaningless items is taken as evidence for a semantic contribution to immediate serial recall performance. Because both types of words had a lexical status but differed on whether they had meaning for HP, the semantic effect can be construed as independent of phonological word form influences. The finding of a semantic influence on immediate serial recall is compatible with studies involving normal participants that reported selective effects from imageability, grammatical class, semantic category and concreteness level on short-term serial recall performance, all of which have been attributed to semantic information about the stimuli (Belleville et al, soumis; Bourassa & Besner, 1994; Caza & Belleville, 1999; Poirier & Saint-Aubin, 1995; Tehan & Humphreys, 1988; Walker & Hulme, 1999). Our results are also in accord with neuropsychological data indicating that semantic factors such as imageability and word meaning affect the serial recall of patients with both normal and impaired phonological processing abilities (Knott et al., 1997;R.C. Martin, Shelton, & Yaffee, 1994; Patterson et al., 1994; Saffran & N. Martin, 1990).

Our finding of an advantage of meaningless words over non-words in HP's recall performance provides a further indication of a lexical contribution to serial recall. There is abundant evidence provided by both normal and neuropsychological data supporting phonological word form influences in serial recall. Because the stimuli used were devoid of semantic content, our data show a lexical contribution that is independent of the semantic one. More challenging to interpret, however, is the finding of a generally exaggerated lexical effect in HP's performances when comparing the short-term serial recall of either meaningless words to non-words (Experiment 2 and 3) or function words to non-words (Experiment 5). This issue will

be explored later in a discussion of how language-activation and redintegration proposals account for these semantic and lexical effects on immediate serial recall performance.

Interactive Activation View of Immediate Serial Recall

Because language-activation models specifically predict influences from all linguistic levels in immediate serial recall as items are processed, lexical and semantic effects come as no surprise within this view and are easily accounted for by it. According to the interactive activation model (N. Martin & Saffran, 1997), the lexical effect in Experiments 2, 3 and 5 are assumed to arise from an activation of knowledge about the phonological word form (lexical level) in some items relative to others. Similarly, the semantic effects are due to additional semantic information that gets activated via bi-directional connections between linguistic levels during word processing. It should be noted that the semantic level assumed in the interactive activation model refers to lexical or *linguistic* semantics and does not include *conceptual* semantics per se. However, within an activation view, the linguistic semantic level is connected to conceptual semantics and therefore, activation will spread to conceptual nodes. Although it is difficult to determine if linguistic semantics are intact when conceptual semantics have deteriorated, it can be assumed that the meaningless words in HP's vocabulary are the result of deterioration in both the linguistic and conceptual semantic levels. In any case, conceptual semantics have been shown to contribute to span performance (Potter, 1993).

The distribution of errors in Experiment 2 supports both N. Martin & Saffran's (1997) model and the semantic binding hypothesis (Patterson et al, 1997) which assume that influences from semantic information help stabilize phonological representations and contribute to better recall. The semantic binding hypothesis (Patterson et al.) specifically predicts that the absence of semantic binding will lead to more phonemic errors, and especially responses which include migrating phonological elements from other words in the list. Our results indicate that phonemic errors were the most common error type when semantic information was limited (meaningless words) and these errors were much more frequent when HP recalled meaningless than meaningful words.

Interestingly, the distribution of errors in the serial recall task involving non-words revealed that semantic representations can also influence the recall of non-words. Within an interactive and highly connected network, non-words which share many phonological elements with meaningful words will benefit more from semantic influences than non-words which share phonological elements with meaningless words. These influences are assumed to occur because during the processing of non-words, words with common phonological elements become activated via bi-directional connections between linguistic levels. The absence or limitation of semantic influences in meaningless words leads to less stable productions, which in turn give rise to greater migration of phonological elements from other items in the list. Our results support this type of error in non-words; phonological migrations were most frequent with recall of meaningless non-words than with meaningful non-words. Although preliminary, these findings are compatible with an interactive view of immediate serial recall.

We now turn to the finding of generally exaggerated lexical effects in HP's recall performance. Even when HP's performance level with function words (Table 11) was similar to (and even better than) that of controls, the lexical effect remained increased. Thus, it appears that poor performance with non-words played a major role in exacerbating the lexical effect.

One possible explanation for such an increase, as stated earlier, is that HP suffers from a phonological processing deficit in addition to a semantic one. Although we cannot completely rule out such a deficit, we do not believe that it can fully account for the increased lexical effects observed repeatedly. First, it was demonstrated that HP has a normal span performance with different verbal materials that she understands, in both presentation modalities. Patients with phonological processing deficits typically have a reduced span (Caplan & Waters, 1990). Second, a strong phonological similarity effect in both the auditory and visual modality was found in HP with material she understands. In cases where a phonological processing deficit is suspected, as with some short-term memory impaired patients, the phonological similarity effect is either absent in one modality (e.g., PV; Basso, Spinnler, Vallar, & Zanobio, 1982) or even reversed (e.g., IR; Belleville et al., submitted). Third, HP was able to make rhyme judgments with non-words, a task which relies heavily on phonological processing. Finally, HP's performance in recalling single meaningful and meaningless words after a 2 sec. and 5 sec. delay was excellent. Hence, if HP has phonological processing deficits, they are assumed to be very mild and would not be expected to lead to such exaggerated lexical effects.

A second possible explanation for her relatively low performance with non-words may be related to the fact that two of the three non-word tasks made use of non-words

derived from meaningless items (Experiment 2 and 3). Although non-words are generally thought of as being a "pure measure "of phonological processing, this may not be the case. Results from Experiment 4 indicated that non-words coming from meaningless or meaningful words gave rise to a differential error pattern between these two types of stimuli. Hence, the lack of semantic information in words used to create the non-words in Experiment 2 and 3 might have further depressed the recall of non-words, which gave rise to the exaggerated lexical effects. However, it is notable that HP's recall level did not differ for the two types of non-words, only the nature of errors differed. This was probably due to the fact that semantic influences on phonology should be very small in auditory ISR according to the interactive activation model (N. Martin & Saffran, 1997). In this case, phonological representations are activated first and are thus more contributory than semantic representations which become activated later and indirectly through feedforward/feedback cycles. Finally, HP also showed an exaggerated lexical effect when using non-words that were created from grammatical words that had no more semantic content to controls than to her. It is thus unlikely that the increased lexical effects were solely due to the use of meaningless items in creating the non-words. Hence, another deficient mechanism must be called upon to account for the poor performance in the recall of non-words.

It is plausible that additional hippocampal binding difficulties in HP, as recently proposed by distributed processing accounts of amnesia, may provide a more complete picture of H.P's difficulties. It is important to recall that HP shows signs of episodic memory deficits. Recent studies on HM, a famous amnesic patient (Scoville & Milner, 1956), reported word comprehension and production difficulties in this so

called "pure episodic memory deficit" patient (MacKay, Burke, & Stewart, 1998; Mackay, Stewart, & Burke, 1998). HM's language deficits were interpreted within a distributed-memory view, the node structure theory, which assumes that the strength of connections between neural units or nodes determines the ability to retrieve verbal memories via an activation process that is indistinguishable from that of normal language processing (Mackay,1987). New connections between phoneme nodes in a novel word or non-word (e.g., t – e – r – f – a – t) are weak and require input from the hippocampal system to maintain activation, whereas established connections between phoneme nodes in existing words (e.g., m – e – m – o – r – y) are stronger and more autonomous. This suggestion is not foreign to a proposal made by Hulme, Lee, and Brown (1993). To account for the absence of learning effects on the serial recall of repeated supra-span lists in patients with Alzheimer-type dementia, Hulme et al. proposed that " associative links between these phonological representations in long-term memory may also be created and may facilitate immediate serial recall" (p.170).

Thus, within a distributed processing view of cognition, poor performance on non-words by HP can be related to (1) loss of hippocampal binding, which normally aids the recall of novel items such as non-words by strengthening connections for subsequent recall, and (2) possibly loss of semantic activation from words that share phonemes with non-words and consequently reduces the binding, which may assist in the recall of non-words.

Redintegration Account of Immediate Serial Recall

The finding of lexical or phonological word form effect in this study can also be explained by the redintegration hypothesis (Hulme et al, 1997; Schweickert, 1993). According to this view, phonological features that define items held in phonological short-term memory are subject to degradation. When phonological features are fully available, items can be recalled from a direct readout of memory traces. If, however, the phonological trace is degraded, items have to be reconstructed via a "pattern completion" process. This reconstruction process is facilitated by representations stored in long-term memory. On this view, our finding of a better recall of meaningless words and function words over non-words can be attributed to knowledge about the phonological word form of these words, which aids in the reconstruction of the degraded phonological traces. Furthermore since "pattern completion can only occur for items that have pre-existing representations in the "long-term memory " of the speech recognition nets"" (Hulme et al , 1991; p.700) non-words should be recalled by using a direct readout from the STM store. Consequently, all non-words should be recalled equally well, assuming that there is no difference in ease-of-pronunciation. Our finding of a similar rate of errors in recalling non-words created from meaningful and those based on meaningless words supports this prediction.

Walker and Hulme (1999) have recently demonstrated that concreteness, a semantic variable, also affects immediate serial recall performance (concrete words are better recalled than abstract words). These authors suggest that a redintegration process similar to the one invoked for decaying phonological traces in STM, is called

upon to support semantic traces in STM. Walter and Hulme argued that "temporary semantic traces will be compared with permanent semantic representations" (p.1267). A similar view is proposed by R.C. Martin, Lesch and Bartha (1999) who propose the existence of temporary semantic traces distinct from those held in long-term memory. Hence, the redintegration hypothesis appears to account for both better recall of meaningful over meaningless words, and content over function words by postulating at least one additional 'store' holding semantic traces independent of the long-term semantic representations. Underlying this account is the assumption that some of the semantic features have degraded in this short amount of time. A priori, this latter assumption contradicts the literature on semantic effects, which generally assumes that the semantic code is more durable than the phonological code, as evidenced by the distinct effects of semantic and phonological factors in delayed recall.

The distribution of errors in HP's recall of meaningful and meaningless words appears less well accommodated by the redintegration view. Although it is suggested that both lexical and semantic representations stored in LTM and consulted upon retrieval of a degraded trace from the STM store, it is unclear whether interactions between these linguistic representations are assumed to occur in the LTM store. Some type of interaction would need to be postulated to account for our finding of a larger number of phonemic errors (blending of phonological elements from other words in the list) for meaningless vs. meaningful words. The model would also need to explain the finding of a differential phonemic error pattern between non-words from meaningful and meaningless words.

It was recently suggested that the reconstruction of degraded or incomplete memory traces for non-words uses phonotactic knowledge to support redintegration

(Gathercole et al., 1999). Differences in phonotactic information cannot be invoked to explain our results, as digram frequency was controlled in all of the stimuli used in this study. The redintegration model would need to postulate that semantic representations are also consulted during the recall of non-words. Similarly, this account would not predict an exaggerated lexical effect based on poorer recall of non-words by HP, because non-words have no LTM representations and must be recalled directly from the phonological STM store by both controls and HP.

Overall, both the language-activation and redintegration views can account to some extent for our general finding of a semantic contribution to immediate serial recall that is distinct from phonological word form influences. However, there are still fundamental questions that remain in light of HP's performance. The first relates to the role that semantic representations play in the recall of non-words. Our data appear to suggest a supporting role, however, this has never been addressed in the proposed models. A second question concerns the putative interaction between episodic memory and language processing. This is an important question as recent data, as well as those presented here, suggests a stronger interaction than once thought between the two components. Finally, the need to postulate short-term stores that are distinct from long-term stores must be addressed. We tend to support a more proceduralist position whereby language representations are not distinct from temporary memory traces (Belleville et al, submitted). Be this as it may, a major implication of our data at a general level is that it indicates that representations and memory systems are highly interactive and that pure memory dissociations may not be possible in the same way, as 'pure memory systems' may not exist (Allport,1995 Crowder,1989;1993, Nairne, 1990).

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Table 1

Scores on the Montreal-Toulouse 86B Subtests

Subtest	HP	Norms
Oral picture naming	14/31*	29.4 (1.67)
Word repetition	30/30	29.5 (0.67)
Oral word reading	25/30*	29.4 (0.12)
Dictation (words and sentences)	29/37*	35.3 (1.70)
Oral picture matching (words and sentences)	43/47	45.4 (1.85)
Written picture matching (words and sentences)	9/13*	12.7 (0.51)

Note. Values enclosed in parentheses represent standard deviations. Asterisks indicate performance at least 1.5 standard deviations below normal participants.

Table 2

Scaled Scores on the Subtests of the WAIS

Subtest	HP
Information	4
Comprehension	12
Digit span	11
Arithmetic	5
Similarities	11
Picture arrangement	14
Picture completion	4
Block design	10
Object assembly	11
Digit symbol	13

Table 3

Scores on Executive Tests

Test	HP	Normal
Wisconsin		
Categories	8	5.4 (1.3)
Perseverative errors	13	12.6 (10.2)
Trail Making Test		
Part A	28 sec.	75th percentile
Part B	92 sec.	25th percentile

Note. Values enclosed in parentheses represent standard deviations.

Table 4

Mean Percentage of Letters Recalled in Correct Serial Order as a Function of List Length

	List Length			
	+ 0	+2	+ 4	+6
HP	65.00	50.00	25.00	10.00
Matched Controls	62.39	48.86	32.96	30.5
	(36.00-85.00)	(24.00-80.00)	(8.57-45.00)	(2.86-70.00)

Note. Values enclosed in parentheses represent the range.

Table 5

Scores on the Subtests of the Wechsler Memory Scale

Subtest	HP	Norms
Information	3/6 *	5.91 (0.31)
Orientation	5/5	4.96 (0.24)
Mental control	6/9	6.63 (2.04)
Logical memory	6.5/23	10.15 (3.52)
Digit total	10/17	10.36 (2.14)
Visual reproduction	8/15	10.67 (3.20)
Associative learning	4/21*	16.25 (3.91)

Note. Values enclosed in parentheses represent standard deviations. Asterisks indicate performance at least 1.5 standard deviations below that of matched controls.

Table 6

Span Performance with Different Stimuli and Presentation Modalities

	Stimuli		
	Digits	Letters	Words
Auditory modality			
HP	6	5	4
Matched controls	5.5	5.75	5.25
	(5 – 7)	(5 – 7)	(4 – 6)
Visual modality			
HP	5	4	4
Matched controls	6.25	5.75	4.5
	(4 – 8)	(4 – 7)	(3 – 6)

Note. Values enclosed in parentheses represent the range.

Table 7

Values on Matching Criteria for the Different Word Categories

	Word Categories		
	Meaningful	Meaningless	Non-word
Word log frequency	1.29	1.30	
Concreteness	1.16	1.35	
Syllables	1.78	1.80	1.80
Letters	6.33	6.39	6.33
Digram log frequency	2.87	2.64	2.67

Table 8. Mean Percentage of Items Recalled in Correct Serial Order for Different Word Categories in Both Presentation Modalities

	Word categories				
	Meaningful	Meaningless	Non-word	Semantic effect (MF – ML/MF)	Lexical effect (ML – NW/ML)
			Auditory modality		
HP	77.08	56.25	14.58	27.02* [1.5]†	74.08* [5.8]†
Controls	88.16	84.90	48.47	4.83	43.80
	(73.61-95.00)	(54.17-97.92)	(26.39-58.33)	(-6.15-26.41)	(40.00-51.28)
			Visual modality		
HP	81.25	34.09	20.83	58.04* [4.0]†	41.07 [0.5]
Controls	80.76	82.29	56.86	- 4.68	32.10
	(45.83-96.67)	(56.94-100)	(26.39-73.61)	(-24.24-13.63)	(10.53-53.65)

Note. Values enclosed in parentheses represent the range; Asterisks indicate effect sizes out of the range of matched controls. Values enclosed in brackets represent the z score; Crosses indicate z scores of at least 1.5 standard deviations away from that of matched controls.

Table 9

HP's Error Types for Different Word Categories (shown in percentage)

	Word categories	
	Meaningful	Meaningless
Order (over errors)	35	16
Order (over correct)	8.43	16
Items	65	84
Phonemic	15	40
Semantic	10	2
Omission	10	30
Other	30	12

Table 10

Mean Percentage of Items Recalled in Correct Serial Order for Different Word Categories in Both Presentation Modalities under Articulatory Suppression

	Word categories				
	Meaningful	Meaningless	Non-word	Semantic effect (MF – ML/MF)	Lexical effect (ML – NW/ML)
			Auditory modality		
HP	47.92	16.67	4.17	65.21* [1.7]†	74.98* [2.7]†
Controls	61.56	54.55	31.28	11.79	39.47
	(55.56-65.00)	(38.33-85.42)	(25-39.58)	(-32.27-41.03)	(21.73-53.66)
			Visual modality		
HP	50.00	43.75	6.25	12.50 [0.9]	87.71* [1.9]†
Controls	50.76	55.38	31.70	-11.74	45.66
	(35.00-75.00)	(43.06-85.42)	(11.11-60.42)	(-42.86-20.51)	(25.82-74.20)

Note. Values enclosed in parentheses represent the range. Asterisks indicate effect sizes out of the range of matched controls. Values enclosed in brackets represent the z score; Crosses indicate z scores of at least 1.5 standard deviations away from that of matched controls.

Table 11

Values on Matching Criteria for the Different Non-words Derived from Meaningful and Meaningless Stimuli

	Stimuli	
	Meaningful	Meaningless
Syllables	1.78	1.80
Letters	6.33	6.33
Digram log frequency	2.74	2.67

Table 12.

Mean Percentage of Items Recalled in Correct Serial Order for Non-words Derived from Meaningful and Meaningless Stimuli

	Non-words derived from	
	Meaningful words	Meaningless words
HP	44.44	44.44
Matched controls	66.08	55.07
	(31.67- 85.42)	(30-69.44)

Note. Values enclosed in parentheses represent the range.

Table 13.

HP's Error Types with Different Non-words Derived from Meaningful and Meaningless (shown in percentage)

	Non-words derived from	
	Meaningful words	Meaningless words
Order (over errors)	5	0
Order (over correct)	5.88	0
Items	95	100
Phonemic	55	75
Target	25	20
Omission	5	0
Other	10	5

Table 14

Mean Percentage of Items Recalled in Correct Serial Order as a Function of Grammatical Class

	Grammatical Class				
	Content word	Function word	Non-word	Semantic effect (C-F/C)	Lexical effect (F-N/F)
HP	82.50	72.50	12.50	12.12 [-0.5]	82.76* [2.6]†
Controls	74.83	58.50	51.92	21.79	6.83
	(65.00- 90.00)	(36.67-68.33)	(45.00-70.00)	(0-43.58)	(-27.27-34.14)

Note. Values enclosed in parenthesis represent the range. Asterisks indicate effect sizes out of the range of matched controls. Values enclosed in brackets represent the z score; Crosses indicate z scores of at least 1.5 standard deviations away from that of matched controls.

Table 15

HP's Mean Percentage of Sequences Recalled Correctly in the Auditory and Visual Modalities as a Function of Phonological Similarity

	Material		Effect score
	Dissimilar	Similar	(D-S/D)
		Auditory modality	
HP	70.00	50.00	28.57 [0.5]
Controls	62.50	57.50	8.06
	(50.00-90.00)	(20.00-70.00)	(-40.00-50.00)
		Visual modality	
HP	100.00	60.00	40.00* [1.3]
Controls	67.50	60.00	13.33
	(30.00-100.00)	(20.00-80.00)	(-14.28-33.33)

Note. Values enclosed in parenthesis represent the range. Asterisks indicate effect sizes out of the range of matched controls. Values enclosed in brackets represent the z score; Crosses indicate z scores of at least 1.5 standard deviations away from that of matched controls.

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Article no 4

A Neuropsychological Argument For a Proceduralist View of Memory

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[Submitted]

ABSTRACT

This study examined the case of a brain-damaged patient, I.R., who exhibits the pattern of performance typical of persons with a selective short-term memory deficit. Part 1 reveals a dissociation in performance between impaired short-term memory and preserved long-term memory. Part 2 examines an alternative explanation of I.R.'s performance under a proceduralist view of memory that rejects the notion of dual stores. The results indicate that the patient's performance on immediate serial recall of short lists was influenced by the semantic properties of items. In contrast, the patient did not use phonological properties. A similar pattern was found in supra-span tasks, in which I.R. demonstrated excellent recall of lexico-semantic material but impaired memory for phonological information. These data suggest that there is a disruption of memory for phonological features with preserved memory for lexico-semantic features, irrespective of the short-term\long-term memory distinction.

INTRODUCTION

One classic characteristic of memory research involves the interplay between a temporary memory system (short-term memory or working memory) and a long-term memory system. A widespread theoretical position claims that these two systems occupy different locations in the brain and cognitive architecture and as a result, are independent (Baddeley, 1986; Baddeley & Hitch, 1974; Shallice, 1988; Shallice & Warrington, 1970). One of the most compelling arguments in support of the existence of two different stores is provided by studies of patients with brain damage. In neuropsychology, the observation of a double-dissociation between different cognitive systems supports the notion that the systems are distinct and independent. A double-dissociation refers to the finding that two patients exhibit the opposite pattern of performance on sets of tasks purported to measure two different processes. Such a double-dissociation has been reported with regard to short-term and long-term memory. For example, amnesic patients, following brain damage to the hippocampal formation, exhibit severe deficits on tasks reflecting long-term memory but show intact performance on tasks that measure short-term memory. The second aspect of the double-dissociation is provided in a description of four patients with brain damage who exhibited a selective impairment in short-term memory tasks with intact performance on long-term memory tasks (Basso, Spinnler, Vallar, & Zanobio, 1982; Warrington & Shallice, 1969; Warrington, Logue, & Pratt, 1971). Double-dissociation was used to support the dual-store model because it suggested that the two forms of memory were differentially affected by a lesion.

However, there are memory models that challenge the independence of short and long-term memory. These models are based on the premise that memory results from reinstantiation of information processing. This proceduralist approach (Crowder, 1993) proposes that storage and processing reside in the same neural units and that there are no separate stores into which information is placed for immediate or long-term retention (Allport, 1985; Cantor & Engle, 1993; Craik & Lockhart, 1972; Crowder, 1989; 1993; McClelland, 1994; McClelland & Rumelhart, 1985; McClelland, Naughton & O'Reilly, 1995; Squire, 1987). In Crowder's words, there is no such thing as 'pure memory'. Experience is thought to result in long-term changes in the nature of the units involved in the original experience. This idea is related to Hebb's proposal that reverbatory circuits underlie short-term memory, whereas long-term memory relies on long-term cellular modifications of these circuits (Hebb, 1949).

According to the proceduralist view, memory systems are defined as " different ensembles of information processing units - different codes - not different organisational or operational rules " (Crowder, 1993, Page 145, para 3). Codes refer to aspects of the world that are processed by specialized information processing systems. The visual, phonological or semantic properties of a word are examples of different codes processed by information processing units. Even if there were considerable overlap in the memory processes or codes involved in particular tasks, different tasks would vary according to the codes that they require for successful completion. Thus, the fundamental distinction between classic short-term memory *tasks* and long-term memory *tasks* can be accounted for by their requirement for a different combination of codes.

There is indeed a fundamental gap between tasks and processes, and even if the majority of researchers attempt to use relatively pure tasks there is a tendency to forget that tasks are a mere approximation of the underlying putative processes Aside from differing with respect to time scale, short-term and long-term memory tasks also contrast on a number of other dimensions. In this context, one can postulate that the phonological code is more involved than other codes in verbal short-term memory tasks due to their particular nature (e.g., recall is usually serial and follows a short delay) whereas the semantic code is more useful than other codes in long-term memory tasks (eg: recall is usually not serial and follows long delays). Thus, under this model, it is unnecessary to postulate the existence of different stores.

The proceduralist approach to memory has received some neuropsychological support from the discovery of a relation between impairment in short-term memory and language processing systems. Research has shown that aphasic patients can be sensitive to either the phonological or semantic characteristics of items when performing short-term memory tasks (N. Martin & Saffran, 1997; R. Martin, Shelton, & Yaffee, 1994; Saffran, 1990). Furthermore, this short-term memory pattern parallels the pattern patients exhibit in language processing tasks (N. Martin & Saffran, 1997; R. Martin et al, 1994). These data support models in which information activates various representational levels until a response is required (Dell and O'Seaghdha, 1992; Monsell, 1987). These representations are thought to be activated on different time courses. Hence, in repetition tasks phonological representations would be activated first, which accounts for their greater impact on recall with a short delay (N. Martin & Saffran, 1997).

Unfortunately, the proceduralist account has not been tested with patients with a so-called 'pure short-term memory deficit'. This is a crucial test for the proceduralist hypothesis for several reasons. First, patients with 'pure short-term memory deficits' are typically thought to have intact language capacities. This is in contrast to the patients reported above, all of whom are aphasic and may suffer from an association of symptoms that is due simply to the presence of a lesion that encompasses both the area involved in language processing and the one involved in short-term memory. A proceduralist view suggests that language should be slightly impaired in patients with a 'pure short-term memory deficit'. Indeed, Allport has observed that patients with 'pure short-term memory deficits' have subtle language deficits that are left undetected using the standard procedures (Allport, 1983). He proposed that patients with an impairment of the phonological processing system experience a deficit in performance on short-term memory tasks because these tasks are very demanding at the phonological level. Thus, it is essential to test patients with 'pure short-term memory deficits' using the paradigm employed with aphasic patients.

A second major issue is that there are few published data addressing the parallel between short-term and long-term memory. Thus, it is unknown whether the dichotomy between phonological and semantic codes is also observed in long-term memory tasks. Reports of patients with selective short-term memory impairment represent key evidence for the dual-store approach and pose a challenge to theorists who favor proceduralist models of memory. Thus, in light of the different memory models, it is essential to test these patients.

The goal of this work is to provide such data. Within a proceduralist framework, selective short-term memory impairment documented in neurological patients might be accounted for by an impairment of the processing system rather than impairment of a store. The most probable candidate is the phonological processing system, as classical short-term memory tasks rely heavily on a phonological code. Thus, brain damage could affect the phonological code in relative isolation. The interaction between the task demands on one hand, and the properties of the damaged system on the other hand, would yield an apparent short-term memory deficit. According to this view, the phonological code would decay rapidly, whereas the semantic code would be more durable (R. Martin & Romani, 1994). Thus, even if short-term memory patients' phonological codes were to fade very rapidly, they could quickly access semantic codes (see also Just & Carpenter, 1992). If lexico-semantic codes are intact in these patients, they could be used in short-term or long-term memory tasks. If this view is correct, brain damage leading to an isolated short-term memory deficit would spare most, but not all, of long-term memory as phonological memory would be impaired. Moreover, such damage would spare lexico-semantic effects in short-term memory, but would impair phonological effects in span tasks.

The present study reports the case of a patient, I.R., who shows the typical "selective short-term memory deficit" pattern of performance. It is proposed that the patient's pattern of memory performance is better accounted for within a proceduralist account than a dual-store approach to memory. In Part One of this study, we examine I.R.'s pattern of performance on typical short and long-term memory tasks. This was conducted to establish that I.R.'s profile is comparable to other individuals with so-

called 'pure short-term memory' deficits. In Part Two, we compare the effect of phono-articulatory and lexico-semantic factors on short-term memory and long-term memory tasks in a series of eight experiments. The findings revealed that I.R. uses lexico-semantic information but not phono-articulatory information to a normal extent, irrespective of task type.

Case Report

I.R. is a 39 year-old woman whom we have studied extensively over the last six years. Fifteen years after her brain accident, she continues to experience severe difficulties with music, despite her normal general intellectual abilities (Griffith et al., 2000; Patel, Peretz, Tramo, & Labrecque, 1998; Peretz & Gagnon, 1999; Peretz, Belleville, & Fontaine, 1997; Peretz, Gagnon & Bouchard, 1998). I.R.'s musical deficit has been documented elsewhere over the years, thus, only the most relevant aspects of her condition will be summarized here.

I.R. has 10 years of education, is right-handed, and is considered to be a non-musician despite being raised in a musical environment and having a brother who is a professional musician. I.R.'s major symptom of a musical deficit consists of an inability to sing and a severe recognition impairment for musical stimuli with which she was previously familiar (Peretz & Gagnon, 1999; Peretz et al., 1997). In contrast to her severe deficit in identifying music, I.R. is able to recognize the emotional tone of music, as far as happiness and sadness are concerned (Peretz & Gagnon, 1999). In fact, I.R. is able to use both mode (minor and major) and tempo (slow versus fast) in

music perception (Peretz et al., 1998b) for both emotional and non-emotional purposes.

The extent of I.R.'s lesion has been described previously in Patel et al.'s (1998) paper based on the results of a CT scan using 10 mm slices. Due to the presence of ferrous clips, an MRI scan of I.R.'s brain was not recommended. Therefore, in order to localize I.R.'s lesion more precisely, a second CT scan was performed recently using a high resolution spiral sequence producing 1.5 mm slices. The scan was linearly transformed into the standardized stereotaxic space of Talairach and Tournoux [see also Griffiths et al., in press, for identification of damage to the auditory regions of the temporal lobe with special attention to the Heschl's gyri).

All or most of the superior temporal gyrus (STG) in the left hemisphere is infarcted. Heschl's gyrus has been completely destroyed, along with the anterior portion of the planum temporale (PT), however, the most posterior portion of the PT appears to be spared. The lesion in the temporal lobe extends inferiorly into the middle temporal gyrus (MTG). The lesion extends superiorly into the parietal operculum (supramarginal gyrus). The damage extends anteriorly into the pre- and post-central gyrii, also destroying the posterior half of the insula. There doesn't appear to be any damage to the inferior temporal gyrus or to the medial temporal lobe structures, such as the parahippocampal gyrus, hippocampus, or the amygdala.

In the right hemisphere, any damage to the temporal lobe appears to be confined to the most anterior and superior portion of the STG near the pole. Heschl's gyrus is entirely spared, as is the PT behind it. In this hemisphere, the anterior portion

of the insula is infarcted, and the lesion encroaches medially into a small portion of the putamen. There is also a large frontal lobe lesion including most of the precentral and inferior frontal gyrii, as well as the white matter underlying them. Damage also encroached on small regions of the lateral orbital frontal and middle frontal gyrii.

I.R. underwent extensive examinations in audiology, speech pathology and neuropsychology, the results of which are described below. I.R. showed normal audiometry. In terms of language, she is fluent at a conversational level (See Peretz et al., 1997 for language assessment). Spontaneous language contains neither phonemic, lexical or semantic anomalies in spontaneous conversations. She has moderate articulatory disorders and a bucco-facial apraxia. A standardized language assessment was conducted using the Token Test (DeRenzi & Faglioni, 1978), French-adapted subtests of the Boston Diagnostic Aphasic Examination (Goodglass & Kaplan, 1972) and the Montréal-Toulouse 86ß (Béland & Lecours, 1990). As shown in Table 1 (p. 202), the results were normal on the majority of the tests. The only anomalies detected were a minor dysgraphia, writing deficits and difficulty repeating long sentences. Additional linguistic tasks were used (taken from Béland, Bois & Seron, 1999; see Peretz et al., 1997). I.R. had no difficulty recognizing auditorily presented words in a lexical decision paradigm. She scored perfectly on a picture-to-auditory-word matching task. Repetition and reading aloud of phonologically simple and complex words was normal. I.R. showed no difficulties in phonological discrimination (same-different judgment of auditorily presented words and syllables). She was able to derive phonology from word reading, as demonstrated by normal results in a visual rhyme judgment test (e.g.: ROYAUME - FANTÔME) and a visual homophony judgment task (p. ex., PAIN - PIN; Belleville, Peretz & Arguin, 1992).

Finally, her performance on a picture-to-written word matching task was in the normal range.

An examination of cognitive functions (Table 2, p. 203) indicated a fairly normal mental status. I.R. has a normal I.Q. (global = 94; verbal = 98; performance = 95) and a memory quotient compatible with her intellectual capabilities (M.Q. = 99). However, a remarkable aspect of her performance was a very low score on the "digit" and "arithmetic" sub-tests, which may be related to a short-term memory impairment. Consistent with this observation, one of I.R.'s major complaints was an inability to repeat long words and sentences, as well as problems organizing her ideas when there were many things to process simultaneously. Again, this is compatible with a short-term memory disorder. Visuo-perceptual processing was normal. I.R. showed no constructive or gestural apraxia. Finally, executive functions were intact in spite of a general slowing on both the Trail A (1'10") and Trail B (1'46"). I.R.'s performance on the Tower of London was normal and she obtained seven categories in the "Wisconsin card sorting test", which also corresponds to a normal performance.

After a period of withdrawal, I.R. experienced marked improvements in her psychosocial adjustment to her brain accident. She now lives an autonomous and active life: she drives her car, takes care of her house and of her family and is involved in a large number of social activities. Since 1993, I.R. has performed in the theater. She also became involved in volunteer activities in her son's school, in particular with the Newsletters, for which she wrote many articles. Nevertheless, her condition did not allow her to return to a normal professional occupation.

I.R.'s memory was tested between 1995 and early 1999. No modification in her performance level was noted during this period. Unless otherwise mentioned, I.R.'s performance was compared to that of 4 neurologically intact control subjects matched with her according to age, sex, and education and tested over a comparable time period. This study complied with APA ethical principles.

Part 1: The Short-term Memory/Long-term Memory Distinction

Results from the clinical assessment suggested that I.R. displayed the pattern of performance typical of persons with an isolated short-term memory deficit. She failed tests that were sensitive to short-term memory deficits and her complaints were indicative of an impairment at this level. In contrast, I.R. does not have any particular long-term memory problems in her daily life. She remembers the names and identities of the different clinicians and examiners that she meets, has excellent prospective memory as she never misses appointments, and easily learns new roads and procedures. In addition, I.R.'s performance on the verbal and non-verbal long-term memory subtests of the Wechsler-Memory Scale is in the normal range, if not above, that of normal subjects in her age range. The first part of this paper was designed to confirm this clinical impression with laboratory tests typically used to measure short-term memory (span for various material, Experiment 1) and long-term memory (free recall and cued recall, Experiment 2).

Experiment 1: Short-term Memory Span

To verify and delineate I.R.'s short-term memory impairment, we assessed the patient's span with verbal material (digits, words and letters) presented in the auditory and visual modalities. To assess whether I.R.'s reduced span was limited to verbal material or encompassed retention of non-verbal information, she was also tested with three visuo-spatial span tasks (face span, location sequential and location simultaneous).

Materials and Procedure

The general method consisted of presenting sequences of items, commencing with two items and increasing the length of the sequences by one item every four trials. No item was repeated within a sequence. Subjects were required to recall each sequence in order immediately after presentation. A sequence was judged as correct if all of the items comprising it were reported in their correct order. The length of the sequences was increased until the subject was unable to report at least 50% of the sequences (i.e. two out of four) at a given length. Span was determined for each stimulus set and corresponded to the longest sequence for which recall was correct on 50% of the trials or greater. These tasks were taken from the computerized Côte-des-Neiges memory battery (Belleville et al., 1992; Chatelois et al., 1993).

Digit span. Subjects were required to recall sequences of digits drawn randomly from the numbers one to nine. These digits were presented auditorily in one

condition and visually in the other condition. In the auditory modality, the digits were presented at a rate of one item per second by the examiner, who read them aloud as they appeared on the screen of a Macintosh Quadra that was hidden from the subject's view. This enabled a standardization of the presentation rate. Immediately after presentation, subjects were required to reproduce the sequence orally.

In the visual modality, the digits were presented one at a time at a rate of one item every two seconds on the screen in front of the subject. The rate of presentation was decreased relative to the auditory presentation to allow enough time for the subjects to process the items accurately. Within these limits, research has shown that a decrease in the rate of presentation does not significantly modify span performance (Baddeley & Lewis, 1984). Immediately after the visual presentation of each sequence, the nine digits were shown on the screen in a 3 by 3 array, and subjects were required to point immediately to the presented digits in the order in which they had been shown.

Word span. The stimuli used were drawn from a pool of nine monosyllabic, concrete and frequent (Baudot, 1992) words (pain, jupe, sac, tuile, chien, corde, fleur, jambe, gare; in english, bread, skirt, bag, tile, dog, rope, flower, leg, train station) that differed from one another phonologically as well as semantically. Word sequences were presented either auditorily or visually. The procedure was the same as that used for digit span with the exception of the visual modality, in which subjects responded orally and not by pointing .

Letter span. The stimuli used in the letter span task were nine consonants (F, J, H, K, R, M, L) chosen according to the criterion that they were monosyllabic (for

example, the letter w was not used) and there was no rhyming among them. Span was tested in both the visual and auditory modes and the presentation was the same as described above for words.

Location span. Sixteen squares were distributed randomly on the screen of a Macintosh Quadra. Each square was white with a black contour and measured 18mm by 18mm. Squares were presented on a white surface. In a first condition (sequential location span), a random series of squares was darkened sequentially at the rate of one item per second, starting with short sequences of two squares. Immediately after the presentation of each sequence, the sixteen squares were darkened for 250 msec to reduce the influence of iconic memory. This also indicated to the subject that she had to provide her response, which was made by pointing to the squares that had been shown in the same order. In a second condition (pattern location span), the squares of a series were darkened simultaneously rather than sequentially as in the previous condition. The subject's task was to point to all the squares that had been darkened in any order.

Face span. A face span procedure was also used to assess the visuo-spatial sketch-pad. The stimulus set consisted of six black-and-white pictures of male faces. Each picture was taken on the same background, and under identical luminance conditions and angle (three-quarter). The pictures did not contain any cues that could be used to facilitate recall, such as glasses or mustaches. All men were dressed in the same black t-shirt. Faces were presented on a Macintosh Quadra with a high-resolution screen. Random sequences of faces selected from the stimulus set were presented to the subject, and the sequences were of increasing length. Immediately

after the presentation, subjects were presented the complete set of faces and required to indicate, in the proper order, those that had been presented.

Results and Comments

Table 3 (p. 204) indicates the span performance of I.R. and the corresponding range obtained in the matched controls for the different span tasks used in the first experiment. The span sizes obtained by the control subjects were within the range of those reported in the literature for normal subjects (Cavanagh, 1972). In contrast, I.R. exhibited a severe span reduction for stimuli that can be encoded verbally. Her span was well below the normal range for digits, consonants, and words. The modality of the presentation did not influence her span capacities for verbal items, as her span deficit was equivalent whether she was tested in the visual or auditory modality. In contrast, there was no span impairment when non-verbal visuo-spatial material was used. As shown in Table 3, her performance in both versions of the location span and in the face span task was within a normal range.

Experiment 2: Long-term Memory, Free and Cued Recall

A set of tests from the computerized Côte-des-Neiges memory Battery (Belleville et al., 1992; Chatelois et al., 1993) measured I.R.'s long-term memory for verbal material. I.R. was tested under two conditions. In the first condition, she was

asked to memorize words and to recall them without the provision of particular instructions or strategies. In the second condition, I.R. was oriented at encoding toward the semantic properties of the words. At recall, free recall with no cues was compared to recall in which semantic cues similar to those used at encoding were provided to the subject.

Materials and Procedure

Two 15-word lists were created, one to be used in each condition. Each word in a list belonged to a different taxonomic category. The same 15 taxonomic categories were used in each list. The words in the two lists were matched according to their frequency of occurrence and typicality. They were not among the three most typical words in each category to prevent correct recall by mere guessing in the cueing part of the task.

The procedure involved showing the 15 words in a matrix on the screen of a Macintosh computer. In the no orientation condition, the examiner read aloud a word from the list and the subject was asked to find and memorize it. This was done for each of the 15 words. The location of the whole set of words in the matrix was changed on each occasion so that location was not used to facilitate recall. After the list was encoded, a 60-sec counting backward period was used to empty the content of short-term memory and prevent the appearance of a recency effect. This was followed by a free recall period in which subjects were asked to recall all the items they could remember in any order. In the semantic condition, the second 15-word list

was presented in the same manner to the subjects. For this condition, the examiner oriented encoding toward the semantic properties of the items by asking subjects to indicate the word that corresponded to a given taxonomic category (for example, "show me the means of transportation, show me the vegetable" etc...). After counting backwards, the subject was asked to engage in free recall of the words and the taxonomic category was presented as a retrieval cue for omitted items.

Results and Comments

The results are shown in Table 4 (p. 205). Normal subjects made use of semantic orientation at encoding since they were better in the semantic orientation than the no-orientation condition. Recall also improved when subjects were given a semantic cue. I.R.'s results were comparable both quantitatively and qualitatively to those of normal controls.

Discussion

I.R.'s pattern of performance was comparable to that of patients with selective impairment of verbal short-term memory. I.R.'s span was reduced to about three items on tests of immediate serial recall of verbalizable items. This reduction was found regardless of whether the stimuli were presented auditorily or visually, and both with pointing and an oral response. In contrast, I.R. did not exhibit any deficit

when memorizing visuo-spatial items that did not lend themselves to phonological recoding. This is compatible with the pattern of performance typical of the patients, as the impairment is usually restricted to verbal material. I.R.'s long-term memory for supra span lists of words was normal when she was tested in conditions of free or cued recall and regardless of whether she was provided with cues at encoding. At first glance, I.R.'s memory deficit appears to consist of selective impairment on tasks that are classically used to assess verbal short-term memory. Furthermore, as is found in classical cases of short-term memory deficit, I.R.'s short-term memory defect is found in the context of normal linguistic capacities as measured with a relatively extended clinical assessment. Although tasks are different due to differences in language and time period, this particular combination, impaired short-term memory with normal language and long-term memory performance, matches the pattern observed in classic cases in the literature (K.F., Warrington & Shallice, 1969; J.B. and W.H., Warrington et al., 1971; P.V., Basso et al., 1982).

Part 2: Assessment of Semantic and Phonological Codes

The goal of part 2 was to assess whether I.R.'s performance can be accounted for by a proceduralist view of memory. If this is the case, a general disruption of phonological memory with preserved lexico-semantic memory (regardless of the short or long-term memory distinction) should be observed. To test this hypothesis, we assessed whether I.R. could make use of phonological information in both short-term and long-term memory tasks. Furthermore, we determined whether she made

use of semantic information when tested on either short or long-term memory tasks. Specifically, our study crossed code (semantic vs. phonological) with task (short vs. long-term memory tasks). If I.R.'s deficit resides at the level of an independent short-term memory store, the dissociation should not cross stores: she should perform at a normal level when learning phonological information in a classical long-term memory paradigm. On the other hand, if I.R.'s apparent short-term memory deficit is in fact due to the defective use of a phonological code, she should be impaired on tasks that involve the long-term learning of phonologically based information, but should perform normally on long-term memory tasks that rely on lexico-semantic properties of words. A similar pattern should be found in classical short-term memory tasks, in which she should be sensitive to the semantic but not the phonological properties of words.

Experiment 3: Effect of Phono-articulatory Parameters on Immediate Serial Recall

Immediate serial recall is largely determined in normal subjects by the articulatory and phonological properties of items. Span is typically better for short than long words and for phonologically dissimilar than similar items. The latter effect is related to the fact that features deteriorate over time in phonological short-term memory. If items of a series share many phonological features, there will be fewer features among which to distinguish at recall (Nairne, 1990; Schweickert, 1993). On the other hand, interpretation of the word length effect is more controversial. This effect is explained in part by the fact that long words take longer to articulate at

recall. A longer output delay accounts for part of the effect (Cowan et al., 1992). However, the effect is still obtained with a pointing response, thus suggesting the contribution of other factors. Some researchers have suggested that longer items take more time to articulate within an internal articulatory-based loop and are thus more susceptible to degradation (Baddeley, 1986; Baddeley & Andrade, 1994; Baddeley, Thomson, & Buchanan, 1975; Schweickert, 1993). Others have proposed a phonological explanation of the word-length effect: because longer words contain more phonemes, their phonological planning takes longer (Caplan, Rochon & Waters, 1992; Caplan & Waters, 1994).

In Experiment 3, the effect of phonological and articulatory parameters on I.R.'s immediate serial recall was investigated. The phonological similarity effect was measured by comparing immediate serial recall of rhyming and non-rhyming letters. The word-length effect was measured by comparing immediate serial recall of short and long words. In this as well as the following experiment, subjects were tested with series for which the length was individually adapted to span capacities. This procedure is required when one is interested in comparing the effect of a particular variable (for example, phonological similarity or concreteness) in normal subjects and span-reduced subjects. Using series of fixed length would yield either floor effects in I.R. (if using long sequences) or ceiling effects in controls (if using short sequences). Furthermore, the classical span procedure is not very sensitive. The first trials in a span procedure are very simple and are, in fact, well under the region in which interaction effects are likely to occur. Finally, the classical span procedure often attributes the same span score to subjects who actually recalled a different number of sequences. Testing the effects of experimental variables at each subject's span

capacity allows for the control of these factors. Moreover, this procedure has been used frequently in other studies and was shown to be valid (Belleville et al., 1992; Belleville, Peretz & Malenfant, 1996; Belleville, Rouleau & Caza, 1998; Waters, Rochon, & Caplan, 1992).

Materials and Procedure

Phonological-similarity effect. Immediate serial recall of twenty sequences of phonologically dissimilar (non-rhyming) letters was compared to the immediate serial recall of twenty sequences of similar (rhyming) ones. Dissimilar letters were chosen randomly among the consonants F-H-J-K-L-M-R-S and similar letters among the consonants B-C-D-G-P-T-V. The sequences were presented auditorily at the rate of one item per second. Immediately after the presentation of a sequence, subjects were asked to report all items orally in their correct order. Subjects were tested at their span for monosyllabic dissimilar words. Thus, I.R. was presented with sequences of three items. I.R.'s phonological similarity effect was tested in two different sessions. Half of the trials for each condition (ten dissimilar and ten similar) were presented in each session. To control for order effects, the order of presentation of the two conditions was reversed.

Word-length effect. Immediate serial recall of monosyllabic words was compared to immediate serial recall of long (four-syllable) words. Short words were the same as those used to measure word span. Nine long words were paired with the nine short words according to frequency of occurrence (photographie, anniversaire,

médicament, éducation, bibliothèque, décoration, automobile, adolescent, exposition; in English, picture, birthday, medication, education, bookcase, decoration, car, teenager, exposition). Twenty sequences were constructed in each condition by randomly selecting words in the respective stimulus set. For each sequence, care was taken to select words that were phonologically and semantically different. The same testing procedure was used as that for the phonological similarity effect.

Results and Comments

The percent recalled correctly for phonologically dissimilar and similar items, as well as for short and long words, is presented in Table 5 (p. 206). To appreciate the size of the effects in individual normal subjects and facilitate comparison with I.R., an Effect Score was also computed according to the formula [dissimilar - similar/dissimilar] for the phonological similarity effect and [short - long/short] for the word length effect. These scores were also converted into z scores in order to allow for comparison with the control group. The results, which are presented in Table 5, indicate that matched controls were sensitive to the phonological similarity effect. In contrast, I.R. failed to show better recall for phonologically dissimilar than similar items. In fact, her recall performance was better for similar items. This result is atypical, but has been found in other patients (Belleville et al. 1992). It has also been found in normal subjects following a 24-sec delay and different items on every trials (Nairne & Kelley, 1999). This was interpreted as arising from an increase in list discrimination relative to within-list discrimination and governed by other aspects of

long-term memory representations. Table 5 also indicates that I.R. had only a modest word length effect.

Experiment 4: Effect of Lexico-semantic Parameters on Immediate Serial Recall

To examine the effect of lexico-semantic representations on short-term memory, we assessed the influence of three parameters on immediate serial recall: frequency, concreteness and semantic similarity. The frequency effect was measured by comparing the immediate serial recall of frequent vs. rare items. The concreteness effect was measured by comparing immediate serial recall of concrete and abstract words. The effect of semantic similarity was measured by comparing immediate serial recall of items belonging to the same taxonomic category (semantically similar) with items belonging to different taxonomic categories. The frequency effects measure the influence of lexical parameters, whereas the concreteness and semantic similarity effects measure semantic parameters (e.g. Forster, 1976). Separating the two parameters is of theoretical significance if one assumes that short-term memory performance shares underlying mechanisms with language processing. In many language models, lexical and semantic levels of representation are separated (e.g. Dell & O'Seaghdha, 1992; N. Martin & Saffran, 1997; R.C. Martin et al.,1999). Thus, distinct influences from these representations can be expected and have been observed recently (Caza & Belleville, 1999; submitted).

Materials and Procedure

Frequency effect. Immediate serial recall was measured with a series of frequent vs. rare bi-syllabic abstract words. The items were taken from the Baudot directory (Baudot, 1992). The two sets were composed of nine words with an average frequency of 353.66 (299-439) and nine words that each had a frequency of one. The frequent words were recherche, million, service, conseil, moyen, mesure, affaire, histoire, ensemble (in English, research, million, service, advice, means, measure, business, history, whole). The rare words were idylle, foison, rechute, pagaille, afflux, césure, embauche, charisme, impair (in English, idyll, abundance, clutter, relapse, surge, caesura, vacancies, charisma, blunder). The procedure was similar to that described in Experiment 4 for rhyming and non-rhyming letters. The length of the sequences to be learned corresponded to the individual subject's word span. Thus, I.R. was tested with a series of three items. She received twenty different series from each material set. Finally, the presentation modality was auditory and the response modality was oral.

Concreteness effect. Two sets of words were created to measure immediate serial recall of concrete and abstract words. Nine concrete words (bol, train, poire, mèche, jambe, porte, source, clou, table; in English bowl, train, pear, wick, leg, door, source, nail, table) were matched to nine abstract words (cause, bruit, genre, truc, tort, perte, norme, tri, manque; in english, cause, noise, kind, trick, fault, loss, norm, sorting, lack) according to the number of syllables, syllabic structure and frequency of occurrence. Forty series (20 series for each material type) of randomly selected items were constructed to test I.R.'s immediate serial recall.

Semantic similarity effect. Two sets of words were created. One set (semantically similar) consisted of nine words belonging to the taxonomic category of

animals (pigeon, gazelle, fourmi, colombe, renard, lapin, taureau, vautour, baleine, in English, pigeon, gazelle, ant, dove, fox, rabbit, bull, vulture, whale). The other set (semantically dissimilar) consisted of nine words belonging to nine different taxonomic categories (balance, triangle, momie, lunette, sapin, chanteur, enclume, perdrix, volant; in English, scale, triangle, mummy, glasses, pine, singer, anvil, partridge, wheel). Words from the two sets were matched for frequency of occurrence and they were all bi-syllabic, concrete items. From these two sets of words, series of randomly selected items were constructed to test immediate serial recall according to the same procedure described previously.

Results and Comments

The results of the lexico-semantic manipulations are presented in Table 6 (p. 207). First, the findings for the normal subjects were minimally influenced by the concreteness and semantic similarity of the items. However, their recall was affected by lexical parameters, as they recalled more frequent than rare words. These findings are consistent with previous results using a similar paradigm which indicated that semantic parameters have small to non-existent effects in normal subjects when they are not utilized in a condition of articulatory suppression (Caza & Belleville; submitted).

Consistent with a proceduralist hypothesis, I.R.'s immediate serial recall was highly influenced by lexico-semantic parameters. The magnitude of the effects was much larger than that for the matched controls. These results indicate that when

performing a short-term memory task, I.R. relies largely on lexical and semantic codes and that she does this to a much greater extent than the normal controls.

The particular manipulations performed here were meant to dissociate lexical from semantic factors. However, the words that were chosen as rare had a very low frequency and it was noted that although they were familiar, the meaning of some of these words was unknown to our subjects. Thus, frequent and rare words might have differed both in terms of lexical and semantic content, which made it more difficult to distinguish between the two factors. Hence, the goal of the subsequent study was to differentiate clearly between the lexical and semantic influences on I.R.'s short-term recall.

Experiment 5: Grammatical Category Effect

In order to assess the distinct contributions of the semantic and lexical levels of representation, we measured the recall of items that belonged to two different grammatical categories (open-class and closed-class or function words) in addition to the recall of non-words. Although words from both grammatical categories have lexical representations, closed-class words are assumed to contain little or less semantic content than open-class words, as measured by the ease with which they give rise to a number of features or predicates (Jones, 1985). Evidence suggesting that influences from lexical and semantic levels of representation can be distinguished was obtained in our own studies of normal participants (Caza & Belleville, 1999; submitted). Immediate serial recall is better for closed-class words than for non-

words. Additionally, content words are better recalled than function words in conditions of articulatory suppression or when using phonologically similar items, both of which are conditions that reduce access to phonological representations. In the case of I.R., whom we propose has a phonological deficit, both lexical and semantic effects were expected to be found.

Materials and Procedure

Immediate serial recall was measured for the series of open-class words, closed-class or function words and non-words. Across conditions, items were matched according to number of syllables, number of letters, number of phonemes, and digram frequency. Furthermore, abstract and grammatical words were matched according to their frequency of occurrence (Baudot, 1992). All of the content words were abstract. Because there were no imagery or concreteness values available for these French words, we used English indices when available (Friendly, Franklin, Hoffman, & Rubin, 1982; Paivio, Yuille, & Madigan, 1968). Items were presented auditorily at the rate of one item per second and recall was tested orally. The open-class words were perte, année, moment, lieu, matin, idée; in English, loss, year, moment, place, morning, idea). The closed-class words were certes, ainsi, comment, mieux, selon, ici; in English, indeed, like this, how, better, according to, here). The non-words were surtes, insat, connint, miot, serun, imi.

Results and Comments

The results for I.R. and the control subjects are presented in Table 7 (p. 208). In addition to showing the raw data, the table indicates the size of the lexical effect (Closed-Class - Non-words/Closed-Class) and the size of the semantic effect (Open-Class - Closed-Class / Open-Class). These values were also converted into z scores in order to allow for comparison with the control group. The findings for the normal subjects indicate a large lexical effect and a very small to non-existent semantic effect. This is congruent with results previously published using a similar procedure (Caza & Belleville, 1999; submitted). In contrast, I.R. demonstrated both lexical and semantic effects at a large magnitude. Her lexical effect was within the range of that found in the matched controls. However, her semantic effect was much larger and clearly surpassed that of the matched controls.

Experiment 6: Long-term Memory for Lexical vs. Non-lexical Items

In this experiment, we compared long-term memory for phonological versus lexico-semantic material by contrasting I.R.'s learning of familiar pairs of words that were rich in lexical and semantic information with her learning of non-words that had neither lexical nor semantic representations and that required the retention of phonological aspects.

Materials and Procedure

Two lists of 8 pairs of words (word - word paired-associate task) were developed. In addition, two lists composed of 8 words associated with 8 non-words (word - non-word paired-associate task) were created (Dubord & Belleville, unpublished material). The words were bisyllabic, concrete and frequent (Baudot, 1992).Words were matched across lists in terms of frequency of occurrence. Words that made a pair were not semantically or phonologically related. The non-words were matched to the words according to their letter and syllable number, as well as their syllabic structure. All of the non-words obeyed the phonological and orthographic rules of French.

The procedure was similar for the two types of material. Subjects were first asked to read aloud the words and non-words that were written on a sheet of paper. This was done to familiarize them with the items and to ensure that they derived the correct phonology from print. They were then given one practice trial prior to each condition. The actual memory testing procedure involved the presentation of each pair on the screen of a Macintosh at a rate of five seconds per pair. At the end of a list, the first word from a pair was presented visually and I.R. was asked to recall the item that was paired with it. The correct answer was then provided in written modality. Three learning trials were given for each list. There were two different lists tested for each material type in sessions that were separated by at least one week. The data from the two lists of a given material type were averaged for the analysis.

Results and Comments

The average number of words recalled is presented in Table 8 (p. 209). I.R. performed well below the worst control subject in the word - non-word paired associate task. Her recall performance in the word - word condition was close to that of the matched controls. However, she performed slightly worse than the worst control on two trials of the word - word paired associate task. One possible explanation for this is that the normal controls took advantage of the long presentation rate to rehearse the words whereas I.R. could not do so. Furthermore, this version asked for immediate recall, and it is possible that normal controls took advantage of recency effects for the first one or two trials. Thus, a slightly different version of the same task was constructed to control for these possibilities.

Experiment 7: Long-term Learning of Lexical vs. Non-lexical Items with Delayed Recall

Materials and Procedure

The same procedure as in Experiment 6 was used with different word lists and with the exception of two modifications. First, the rate of presentation was reduced to 2 seconds per pair at encoding. Second, at the end of the presentation of a list, a 20-second counting backward period was used to eliminate the recency effect.

Results and Comments

Although there was variability in the performance of the normal controls, I.R.'s results were clearly within the normal range for long-term learning of words on the three learning trials and for the total number of words recalled (Table 9, p. 210). The recall of non-words was at a floor level on Trial 1 for normal subjects as well as for I.R. However, whereas the performance of the normal subjects improved on Trials 2 and 3 and for the total number of items recalled, I.R's performance remained severely impaired on these last trials. Thus, I.R. showed normal learning of lexical items (i.e., the words), but impaired learning of phonological material (i.e., the non-words). However, performance was generally low for non-word memory and it appears that the task was particularly difficult for all subjects. This observation is especially critical for I.R. in the non-word condition because her dysarthria may have resulted in a more difficult articulation of non-words. We thus re-tested subjects with a recognition procedure that did not require verbal output.

Experiment 8: Non-word Recognition

There is reasonable evidence that I.R.'s recall of lexical items is within a normal range and that she is relatively impaired in the long-term learning of items that depend on phonological traces, specifically non-words. In this experiment, we wanted to use a task that did not require subjects to speak aloud and that did not

involve actively reconstructing a phonological trace. This was done to maximize I.R.'s long-term phonological learning. We wanted to ensure that the impairment observed in the two previous experiments did not result from an output deficit. Thus, we used a recognition procedure.

Materials and Procedure

Twelve non-words were created. Each non-word was composed of digrams that are frequent in French (Arguin, personal communication). The non-words were read to the subject at the rate of one item every 2 seconds. After the first presentation of the non-words, the list was read again to the subject but with the items in a different order. Then, the experimenter read a list of 24 non-words composed of the 12 previously presented ones and 12 distractors of the same digram frequency. Of the 12 distractors, 4 started with the same syllable as a target, 4 ended with the same syllable as a target and 4 were entirely different. The subject's task was simply to indicate whether the item she heard had or had not been presented in the learning phase.

Results and Comments

Table 10 (p. 211) indicates the number of hits and false alarms on the non-word recognition task. The results reveal that I.R. experienced difficulty on the task.

Specifically, her hit rate was much lower than that of the matched controls. Furthermore, a score that takes into account both Hits and False alarms (H-FA) indicates impaired recognition in I.R. relative to the controls.

Experiment 9: False Recognition Effects

One theoretical account of I.R.s' long-term memory performance for words and non-words might propose that the phonological loop of WM is involved in the learning of new vocabulary (Baddeley, Papagno, & Vallar, 1988; Gathercole & Baddeley, 1989; 1990; Papagno & Vallar, 1992; Papagno, Valentine, & Baddeley, 1991). On this view, non-word learning would mimic the learning of new lexemes. It would thus be easy to reconcile I.R.'s data from non-word to word pair learning with a view that proposes a role for the phonological loop in the learning of new vocabulary. The goal of this experiment was to examine the dissociation between phonological and semantic material by avoiding a comparison of words and non-words. To achieve this objective, we took advantage of the false recognition effect. When presented with large lists of items that are semantically related to a lure, subjects tend to believe that the lure was shown previously (Deese, 1959; Roediger III & McDermott, 1995). This effect arises from the reconstructive nature of memory (Deese, 1959; Roediger III & McDermott, 1995) whereby subjects reconstruct events from memory according to existing schemas. The false recognition effect is interpreted as arising from a difficulty in discriminating items that were actually presented from items that were activated through connections in an associative

network. When subjects produce false recognition effects, they reveal their incapacity to distinguish whether or not the word actually occurred (Roediger III & McDermott, 1995).

In this experiment, we used two conditions to assess false recognition effects in I.R.. In the semantic condition, 21 lists of words were created, each of which were the closest semantic associate of the critical target. In the phonological condition, 21 lists of words were created, each of which started with the same syllable. The first syllable was chosen as a criterion because it allowed for the generation of more lists and longer sets of associates than do rhymes. Furthermore, the syllable is the relevant segmentation unit in French (Mehler, Dommergues, Frauenfelder, & Segui, 1981; Peretz, Lussier, & Béland, 1998b). Our hypothesis was that I.R.'s phonological system is degraded. In this case, elements should be less easily discriminated from one another in the syllabic condition, thus causing a larger number of errors and a larger false recognition effect. On the basis of the short-term recall data, we expected her to use semantic properties to a greater extent than phonological properties. Thus, she might be better able to discriminate items presented from those not presented when they are semantically related than when they share the same syllabic onset.

Materials and Procedure

We created 42 lists: 21 lists of 15 semantically related words and 21 lists of 15 phonologically related words. For each critical target from the semantic condition, the corresponding list was obtained by choosing the first 15 associated words listed in

Kent-Rosanoff word association norms in French (Freibergs, 1968, 1970). On some occasions, one of these words was replaced by the 16th associate because it was member or target of another list. The targets were chosen from the Roediger III and McDermott (1995) list. As in Roediger III and McDermott (1995), the list was presented in decreasing order of association to the target, starting with the one most associated to it. In the phonological condition, all words in a list started with the same syllable. The words were all selected from the Brulex frequency table such that targets in the phonological lists were of equal frequency as targets in the semantic list (11730 and 11604 respectively).

The recognition lists included 63 studied and 63 non-studied items. The 63 studied items were the words in position 1 (e.g.: for critical word king, queen), 9 (e.g.: for critical word king, throne) and 11 (e.g.: for critical word king, country), of each studied list. There were three types of non-studied items in the semantic recognition list: 21 critical words (e.g.: king), 21 weakly related words (e.g.: for critical word king, nobility) and 21 unrelated words (e.g.: for critical word king, tobacco). The weakly related items of the semantic condition were chosen from each association list among those that followed Position 15. The unrelated words were items that were unrelated to any of the target words. None of these belonged to any of the lists studied. The average frequency of the targets, weakly related items and unrelated items was equivalent. The recognition list of the phonological condition was also made of 21 critical targets (e.g.: mouche), 21 unrelated words (e.g.: jardin) and 21 related words (e.g.: musicien). The unrelated words started with a syllable completely different from any of the targets, the weakly related words shared only the first letter with the target. None of these words were part of the studied list and the

frequency was equivalent across types of non-studied items. Care was taken to avoid semantic similarities among words.

Subjects were instructed to listen carefully to many lists of words and told that their memory for the words would be tested subsequently. The two conditions were tested in two sessions separated by a few days. The lists were presented successively at the rate of one word every 1.5 sec. Lists were recorded and presented auditorily. After each list, subjects were asked to count backwards from 100 for 30 seconds. After the 21st list was presented, there was a brief conversation that lasted 3-4 min. Then, subjects' recognition was tested. The recognition list was also presented auditorily by audiotape. Subjects responded orally.

Results and Comments

The results for the semantic condition are presented in Table 11a (p. 212). Like the control subjects, I.R. exhibited the expected effect. Her recognition level of the critical target (highly related lure) was equivalent to that of the presented item in approximately the middle position of the list (Position 11). This is compatible with the data reported by Roediger III and McDermott (1995). Furthermore, recognition of the unrelated and weakly related lures was much below that of the critical target lure. The size of the False recognition effect (False recognition of Target - False recognition of Unrelated) found in matched controls was somewhat variable but still among the largest ones in the literature. Thus, our procedure was successful in eliciting the effect. In the semantic condition, I.R. clearly showed a false recognition

effect (T - U). However, it is important to note that it was of a smaller magnitude than that found in controls. This is also the case when using a score that takes into account the recognition level (Hit) of items at Position 11 ([T/11] - [U/11]).

The results were strikingly different in the syllabic condition (See Table 11b, p. 212). In this latter condition, control subjects exhibited small False recognition effects. Their recognition rate of the critical target was 11%, which is just below their recognition of weakly related or unrelated lures (10% and 19%, respectively) and well below their recognition level of the presented items (62% for position 11). Interestingly, however, I.R. clearly exhibited a False recognition effect in the syllabic condition. Her pattern of performance in this condition differed from that in the semantic condition: she presented a high rate of false recognition (52%) for the critical target lure, numerous false recognitions of the weakly related lures (48%) but rejected unrelated lures (19%). As a result, her False Recognition effect was of a much larger magnitude than that of the controls. Considering that the false recognition effect results from a difficulty to distinguish between activation in an associative network and events that actually occurred, I.R. revealed a better capacity than the controls to do this in her semantic network, but a worse capacity than controls to do it in her phonological or syllabic network.

Experiment 10: Reading, Repetition and Rhyme Judgment of Non-words

The proceduralist approach proposes that aspects of short-term memory correspond to aspects of language processing. As in other cases of so-called pure

short-term memory deficit, I.R. had normal linguistic processing capacities when tested with clinical language assessments. Furthermore, she did not experience any particular difficulties in typical communication, as is exemplified by her writing for her son's school newsletter. However, linguistic deficits are evident in I.R. when she is administered tests that rely heavily on phonological abilities. The focus of this paper was not on I.R.'s linguistic capacities, and clinical assessment has indicated that she has normal linguistic processing when words are used as test stimuli. Nevertheless, in this final experiment, we wanted to determine whether I.R.'s linguistic capacities would be impaired on test material that does not allow for the use of remaining lexical and or semantic capacities. To achieve this goal, reading, repetition and rhyme judgment were tested here using *non-words* as test stimuli.

Materials and Procedure

A task involving the repetition and reading of non-words varying in phonological complexity and length (e.g.: OPI; AFORTI) was used (Béland et al., 1999). There were 30 items per condition. The same items were used in both conditions and the conditions were tested one week apart. All items corresponded to French phonological rules. In the reading condition, I.R. was asked to read aloud the items at her own pace. In the repetition condition, the examiner read each item aloud and I.R. was asked to repeat each of them immediately. In both conditions, I.R.'s responses were tape recorded and the responses were written down immediately by the examiner. They were also scored from the recorded tape by an experienced

linguist naive with respect to the goal of the study. The rhyme judgment task involved the visual presentation of 32 pairs of non-words, half of which rhymed and half of which did not. For both the rhyming and non-rhyming pairs, half were visually similar (e.g. jomus-plamus, tolep-ralip) and half were visually dissimilar (e.g. dayon-billon, miffon-avier). All non-words were bisyllabic and orthographically legal. The subject's task was to judge whether the pair rhymed or not. One practice trial was provided prior to starting the task to ensure that the subject understood clearly the notion of rhyme. No time limit was imposed.

Results and Comments

I.R. correctly repeated 24/30 non-words (80%), a performance that was worse than that of controls (which ranged from 28-30). Reading of the same non-words was normal, as I.R. obtained a score of 29/30 within the range of normal controls (28-30). Her performance on the rhyme judgment task was slightly more impaired. She obtained only 24/32 correct responses (75%), whereas matched controls performed particularly well on this task, obtaining perfect or near perfect performance (ranging from 31-32). Thus, I.R. exhibited impairments of phonological processing of items that are devoid of lexico-semantic information. Her reading of non-words was normal. Her non-word repetition was impaired relative to controls, despite the fact that the magnitude of the impairment was modest. Non-word rhyme judgement was particularly compromised in I.R.. This was observed in conditions that minimized memory demand: only two items were compared and presentation was visual, thus

items were visible throughout judgment. Yet, impairment was particularly marked in this task. It is important to emphasize that the same task and procedure performed using lexical material (that is, word repetition and rhyme judgement on words) yielded perfectly normal performance levels in I.R. (see Language assessment).

Discussion

The results presented in Part 2 support a proceduralist view of memory. The findings suggest that I.R. does not use phonological properties of words in short-term recall, as she shows no phonological similarity effect and only a very small word length effect. The pattern of performance is parallel with respect to long-term memory. I.R. had difficulty on tasks that required her to memorize the phonological structure of items (i.e., non-words) but she did not have difficulty recalling words that have semantic content. This was demonstrated by comparing word - word to word - non-word associations in a manner that simulated the learning of new vocabulary. This finding was also obtained in a non-word recognition procedure on which I.R. was impaired. Furthermore, I.R. had greater difficulty discriminating items relative to controls when processing was directed toward the syllabic properties of items than when processing was directed toward the semantic properties, yielding a large false recognition phenomenon in the syllabic condition.

The current study also indicates that language processing was impaired on tasks that made use of items that were devoid of lexico-semantic content. In contrast, I.R.'s short-term recall was influenced by the lexical and semantic properties of

items, indicating that these are the properties upon which her recall relies. She showed heightened effects of concreteness and semantic similarity. Furthermore, her recall increased when items that possessed semantic content (open-class words) were used relative to material that lacked semantic content (closed-class words). Our studies also indicate that normal controls make use of lexical properties to the same extent as I.R.

GENERAL DISCUSSION

I.R. is an individual with brain-damage who displays the pattern of performance that is generally judged as typical of pure short-term memory deficit patients. Our initial strategy was to show that I.R.'s profile corresponds well with what is expected from pure short-term memory patients with tasks that are within the realm of a dual-store view, and to demonstrate subsequently that her performance could be envisioned in a completely different way with further testing. In Part 1, we obtained the classical dissociation between impaired short-term recall and normal long-term recall of verbal material. This was done with classical tasks: span for words, digits and images of well known objects for short-term recall, and supraspan lists of words for long-term recall. In Part 2, we found strong indications that the dissociation relies on the defective use of a phonological code, with other codes (in particular the semantic one) remaining functional. The impaired use of phonological information was found to cross the short-term/long-term memory distinction. Thus,

I.R.'s dissociation lies along the informational domain (e.g.: phonological vs semantic) rather than memory type (i.e., short-term vs long-term).

Implications for the Distinction between Short-term and Long-term Memory

The existence of a neuropsychological double-dissociation between a transient form of memory and enduring memory is the strongest argument for the distinction between the two systems. Patients with short-term memory deficits, together with amnesic patients, display the double-dissociation that implies the presence of two separate stores. Thus, our results have important theoretical implications for the debate. Prior to discussing the implications of our case within a proceduralist view, we will address whether models that distinguish short-term and long-term stores can account for I.R.'s pattern of results.

Better short-term recall of words over non-words and frequency effects indicates a contribution of lexical factors to short-term memory. This finding, which has been obtained by other researchers with normal subjects, is difficult to reconcile with a view whereby only phono-articulatory factors are involved in short-term recall. More recent models of working memory have accounted for this finding by proposing close interactions between phonological working memory and phonological long-term memory (Baddeley, Gathercole & Papagno, 1998). However, the presence of semantic effects in I.R. is more difficult to account for within a view that dissociates short and long-term memory. Indeed, there is no actual implementation of how and when semantic factors might come into play. One possibility is that the semantic

effects would be present in I.R. because it is the central executive component that is responsible for retrieving semantic information from long-term memory and bringing it into working memory (Baddeley, 1996). As the central executive is presumably normal in I.R., she would be able to use controlled processes to retrieve information from semantic memory. However, this explanation is ad hoc and rather vague as to how this process may actually occur. It is also particularly unparsimonious.

I.R.'s association between an impaired phonological store and impaired ability to learn non-words is not novel, and has been accounted for within the working memory model. For instance, P.V., a patient with a deficient phonological loop, has difficulty learning non-words as compared to words (Baddeley et al., 1988). Furthermore, children with difficulties learning new vocabulary also exhibit deficits in non-word repetition, this later task being interpreted as measuring the phonological loop (Gathercole & Baddeley, 1989; 1990). These results have been explained by the role of the phonological loop in new vocabulary (or non-word) learning. Thus, there would be an obligatory passage through the loop for non-words, but not for words.

However, it is also possible that both P.V. and children with vocabulary learning deficiencies exhibit the type of general phonological memory deficits found in I.R., which would represent a more parsimonious account of their associated decrement in phonological short- and long-term memory tasks. Furthermore, I.R.'s results on the False recognition paradigm are not easy to reconcile within a view that new lexical items rely on the phonological loop. Indeed, the task used to test False recognition effects differs from the word - non-word association task on a number of aspects and is not easily assimilated to the learning of new vocabulary activity as it implicates words, not non-words. The relevant factor in the False recognition

paradigm is the information domain, phonological or semantic, that the task promotes due to the relation shared by the words. The role of phonological short-term memory in vocabulary learning cannot be invoked to explain I.R.'s high false recognition rate in the syllabic condition. This can only be explained by suggesting that this information does not allow her to discriminate items from episodic memory.

Other arguments have been used in the literature to support the functional distinction between short-term and long-term stores. One is that it is intuitively sound to propose a short-term store that is distinct from a long-term store. Indeed, numerous cognitive activities require the on-line retention of information that may not need to be retained longer than the time to complete the task. For example, this is the case for mental calculation or comprehension. In these two cases, products of intermediary processing may have to be temporarily maintained but do not need to overload long-term memory. However, this could be well accounted for by models that do not postulate different storage space. For example, by proposing differences in the time course of different representations, it is unnecessary to suggest separate storage space.

A second group of arguments relies on experimental dissociation effects from empirical studies of normal subjects. For example, typical short-term memory and long-term memory tasks are not affected by the same experimental variables: semantic parameters influence long-term memory tasks more than short-term memory tasks while phonological and articulatory variables have major effects on short-term memory but very little influence on long-term memory tasks. However, this could easily be accounted for in a model that postulates that the activation of different information has different decay functions. Thus, phonological information would decay more rapidly than semantic information (N. Martin & Saffran, 1997). There are

numerous studies showing that this experimental dissociation is not as clear cut as once thought: lexico-semantic properties do affect short-term recall (Caza & Belleville, 1999; submitted; Hulme, Maughan, & Brown, 1991; Poirier & Saint-Aubin, 1995; Tehan & Humphreys, 1988) and phonological properties influence long-term recall (Papagno & Vallar, 1992; Papagno et al., 1991).

Furthermore, experimental dissociations between short-term and long-term memory have been found by using completely different procedures across memory types: serial ordered span task is the norm for short-term memory, whereas free recall tasks are typically used to assess long-term memory. Thus, it is possible that the ordered nature of the task interacts in particular ways with the phonological or semantic characteristics of the items. Phonological information is by nature ordered, whereas order is less relevant to semantic content. Thus, again, there may be no need to assume the existence of different storage space. As discussed in Crowder (1993), the fact that the short-term memory/long-term memory distinction overlaps with the phonological/semantic distinction is still a further argument to suggest that the distinction may very well be based on informational domain.

Implications for the Language Based and Proceduralist Views of Short-term Memory

Some models of memory propose that there is a close relationship between representations involved in language perception and production, and representations involved in short-term memory (Caplan et al., 1992; Hulme, Roodenrys, Brown et al. 1995; N. Martin & Saffran, 1997; R. Martin et al., 1999; Nairne, 1990; Schweickert,

1993; Schweickert, Chen, Poirier, 1999; Walker & Hulme, 1999). The theoretical position differs somewhat across researchers, however, some have proposed that span is based on the remaining activation of the representations implicated in language. The major prediction of these models is that deficits in language processing parallel deficits in short-term memory. Thus, such models predict that a patient with a phonological short-term memory deficit would also exhibit impairment in phonological processing. In contrast, because lexico-semantic processing is intact in I.R., the presence of lexical and/or semantic effects on short-term memory tasks is expected. I.R.'s pattern of results on linguistic and short-term recall tasks is compatible with these predictions. In particular, I.R.'s impairment in the non-word repetition and rhyme judgment task is notable. I.R.'s linguistic deficits have also been found in repeating anomalous sentences. This may have arisen due to the fact that the lack of semantic congruence of these sentences makes them more dependent on phonological representations.

Two findings are worth discussing in more detail in relation to previous data. The first is related to the different effects of semantic versus lexical manipulation on short-term recall in I.R. Indeed, the patient exhibited normal lexical effects in immediate serial recall but she was more sensitive than matched controls to semantic manipulations. This is a solid effect because it was found with three different manipulations: concreteness, semantic similarity and grammatical class. This pattern of results is consistent with some of our previous findings showing better short-term recall of abstract words over closed-class words in normal subjects, but only in conditions that limit phonological processing (articulatory suppression and/or phonological similarity; Caza & Belleville, 1999; submitted).

One explanation for these findings is that the impact of semantic representations is more visible when phonological representations are not present simply due to metric factors. When representations have strong effects on performance, other less important effects may simply be more difficult to observe due to lack of sensitivity of behavioral measures. In turn, it is also possible that the different representations have inhibitory effects on each other, as is the case in selection systems. Thus, when a representation level is weakened due to a lesion, other representations might be free from a certain level of inhibition and have larger effects on performance. Consistent with this proposal, the False recognition paradigm also indicates that I.R.'s semantic system is somewhat enhanced relative to controls. She demonstrated better item discrimination capacities than matched controls in long-term recognition in the condition that promoted semantic processing, whereas discrimination was decreased in the condition that required phonological processing. Thus, our data suggest that some representations normally function in opposing ways and that it is possible to release inhibition from these representation levels.

Taken at face value, the suggestion that memory relies on an activation of representations in processing systems is not meant to explain the phenomenon of amnesia. One obvious mistake would be to suggest that the only distinction to be made is that between phonological and semantic memory, the former corresponding to short-term memory and the latter corresponding to long-term memory tasks. Clearly, long-term memory tasks rely on a wide variety of representations, including contextual ones (McClelland, 1994; McClelland & Rumelhart, 1985; McClelland, Naughton & Reilly, 1995). Others have suggested that one must form episodic-specific links among original concepts (Potter, 1993). The hippocampus has also been

proposed to be involved in binding processes (MacKay, Burke & Stewart, 1998). Contextual or binding processes might be the relevant component impaired in amnesic patients. It is interesting to note that subtle semantic deficits were recently observed in H.M., the most famous amnesic patient (MacKay et al., 1998). This is thought to occur due to an impairment in the binding processes that chunk previously new connections to form complex linguistic representations. Here again, an intimate relationship is thought to exist between long-term memory and language.

In sum, our results are compatible with the conception of memory as consisting of activated parts of information processing modules in line with a proceduralist model. On this account, the distinction between short and long-term memory tasks is explained by their reliance on different features: phonological features are more largely required for immediate serial recall tasks whereas semantic ones are particularly useful on tasks that require long-term recall or recognition of well known words. In this context, there would be no independent short-term store.

On the contrary, short-term recall depends on a collection of domain-specific processes. Two independent arguments can be used to support this proposition. First, short-term memory deficits due to brain damage are always observed in the context of aphasia (Allport, 1983; 1985; Caplan & Waters, 1990). They occur either in patients who exhibit clear language deficits or in those who have shown language difficulties that have regressed. Thus, it is quite possible that short-term memory tasks represent particularly sensitive tests of phonological difficulty. Second, studies using imaging techniques of the neural basis of the phonological loop have determined localisations that correspond to those involved in language processing in particular, the left supramarginal gyrus and Broca's area (Paulesu, Frith, & Frackowiak, 1993; Smith,

Jonides & Koeppe, 1996). If the same sites are implicated in language processing and short-term recall, why would short-term memory as a storage site still be considered distinct from processing? Finally, because I.R.'s performance is relatively typical of that of short-term memory patients, it is conceivable that the same pattern of results would be observed in other patients. For example, P.V. also had difficulty learning non-words in comparison to words. It would be theoretically significant to determine whether she also exhibits the other aspects of I.R.'s performance. We surmise that this is the case, however, further research is necessary to examine this possibility.

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Table 1. I.R.'s results on standardized tests of language

	I.R.	maximum possible (or score limit)
Auditory comprehension		
word discrimination	5	5
Token test	56	62
Verbal command	7	8
complex sentences	24	26
Image naming		
nouns, verbs	31	(30)
animals	24	(15)
Oral reading		
words	29	30
sentences	3	3
Written comprehension		
word-image matching	5	5
sentences, paragraphs	8	8
Repetition		
words	28	(24)
well formed sentences	6	8
anomalous sentences	2	8*
Paraphasia		
neologism	0	0
verbal	0	0
literal	0	0
Automatic langage		
automatic sequences	8	8
Writing		
mechanic	3	3
image written naming	9	12
spelling	6	10
sentence dictation	1	3*
Songs		
melody	0	2*
rhythm	0	2*

Auditory lexical decision	77/80
Word-to-picture matching task	95/95
Word repetition	66/66
Word reading	63/66 (Controls: 63-66)
Auditory word matching	36/36
Auditory non-sense syllable matching	38 /40
Visual word rhyme judgment	23 /24
Visual word homophony judgment	10/10
Oral-written non-word matching	30/30

* indicates that I.R. is impaired

Table 2: Examination of cognitive functions

Visuo-spatial perception	
Benton Judgment of line orientation	21/30
Benton visual discrimination test	28/30
Benton Facial recognition test	43 (Score limit = 41)
Hooper test	28/30
Ideo-motor praxia	Normal
Construction praxia (Rey Figure)	Normal
Frontal task	
Tower of London	Normal
Trail A	1'10''
Trail B	1'46''
Wisconsin Card Sorting Task	Normal
Music perception	Impaired
Memory	
Memory Quotient, MQ	99
(Wechsler Memory Scale)	
Information	5 (normal= 5,8)
Orientation	5 (normal= 4,9
Mental control	2 (normal= 7,2)*
Memory passages	13 (normal= 10,4)
Digits total	6 (normal= 10,5)*
Visual reproduction	13,5 (normal= 11,5)
Associate learning	21 (normal= 17,7)
Intellectual functioning	
Intelligence Quotient, IQ	94
Information	8
Comprehension	14
Digits	4*
Arithmetic	8
Similarities	14
Picture arrangement	8
Picture completion	10
Block design	7
Object assembly	12
Digit symbol	10

* indicates that I.R. is impaired

Table 3: I.R.'s short-term memory span a) verbal material presented in the auditory and visual modalities; b) non verbal material in the visual modality of presentation

	I.R.	Controls (range)
a) Verbal material		
Auditory Modality		
Digits	3*	6-8
Words	3*	4-5
Letters	2*	5
Visual Modality		
Digits	4*	5-8
Words	3*	4-5
Letters	2*	4-5
b) Non-verbal material		
Faces	4	3-4
Location sequential	4	4-6
Location simultaneous	6	5-8

* indicates that I.R. is out of the range of matched controls

Table 4: I.R.'s performance on list-learning with no cues at encoding or retrieval and with semantic cues at encoding only and at encoding and retrieval.

	I.R.	Controls (Mean and range)
No cues		
Free recall	6	7.8 (5-10)
Semantic cues		
Free recall	11	10.8 (10-12)
Cued recall + Free recall	15	13.5 (11-15)

Table 5: I.R.'s percent immediate serial recall for phonologically dissimilar and similar items and for short and long words. The effect score represents the percentage of loss due to material type: an effect score of zero means that there is no phonological similarity effect; a positive effect score denotes the presence of the effect; a negative score indicates that the expected effect is reversed.

	Material		
Phonological similarity effect	Dissimilar	Similar	Effect score (D-S/D)
I.R.	63.3%	90%	- 26.7%* [-4.3] †
Controls	83.778%	76%	12.5% (2.3-20)
Word length effect	Short	Long	Effect score (S-L/S)
I.R.	50%	43.3%	13.4% [-0.81]
Controls	96%	75.3%	21.5% (10.9-30)

* indicates that I.R. is out of the range of matched controls. Values enclosed in brackets represent the z scores; † indicate z scores of at least 1.5 standard deviations away from that of matched controls.

Table 6: I.R.'s percent immediate serial recall for frequent vs. rare items, concrete vs. abstract words and semantically dissimilar and similar words. The effect score represents the percentage of loss due to material type: an effect score of zero means that there is no effect due to change in material; a positive score denotes the presence of an effect; a negative score indicates that the expected effect is reversed.

	Material		
Frequency effect	Frequent	Rare	Effect score (F-R/F)
I.R.	51.7%	16.7%	67.7%*[4.81]†
Controls	89.5%	71.1%	19.3% (5.7-38)
Semantic similarity effect	Dissimilar	Similar	Effect score (D-S/D)
I.R.	70%	50%	28.7%*[3.92]†
Controls	72.6%	74%	-1.7% (-9.1-6.3)
Concreteness effect	Concrete	Abstract	Effect score (C-A/C)
I.R.	73.3%	53.3%	27.3%* [1.9] †
Controls	82%	74%	10.2% (2-19.4%)

* indicates that I.R. is out of the range of matched controls. Values enclosed in brackets represent the z scores; † indicate z scores of at least 1.5 standard deviations away from that of matched controls.

Table 7: I.R.'s percent immediate serial recall for abstract (open-class) words, grammatical (closed-class) words and non-words. Two effect scores were calculated. One represents the percentage of recall loss due to memorizing grammatical over abstract words (A-G/A). The second score (G-N/G) represents the disadvantage in recall due to memorizing grammatical words over non-words. An effect score of zero means that there is no effect due to changes in material; a positive effect score denotes the presence of an effect; a negative score indicates that the expected effect is reversed.

	Material				
	Open-class	Closed-class	Semantic effect (O-C/O)	Non-words	Lexical effect (C-N/C)
I.R.	100	86.7%	13.3%* [2.2] †	60%	30.8%[1.3]
Controls	93.5%	92%	3.4% (0-8)	25.8%	76.4% (25-91)

* indicates that I.R. is out of the range of matched controls. Values enclosed in brackets represent the z scores; † indicate z scores of at least 1.5 standard deviations away from that of matched controls.

Table 8: I.R.'s long-term learning of word - word and word - non-word pairs in Experiment 6.

Word - word paired associate task

	Trial 1	Trial 2	Trial 3	TOTAL
I.R.	3.5 [-0.68]	5.5* [-1.9] †	7* [-3.5] †	16*[-1.76]†
Controls (range)	5.4 (3-8)	7.1 (6-8)	7.8 (7.5-8)	20.4 (16.5-24)

Word - non-word paired associate task

	Trial 1	Trial 2	Trial 3	TOTAL
I.R.	1 [-0.2]	1.5* [-2.02] †	4.5* [-2.35] †	7* [-1.87]†
Controls (range)	1.5 (0.5-2)	5.1 (3.5-7.5)	6.8 (5.5-7.5)	13 (10-16)

* indicates that I.R. is out of the range of matched controls. Values enclosed in brackets represent the z scores; † indicate z scores of at least 1.5 standard deviations away from that of matched controls.

Table 9: I.R.'s long-term learning of word - word and word - non-word pairs presented with delayed recall.

Word - word paired associate task

	Trial 1	Trial 2	Trial 3	TOTAL
I.R.	0.5 [-1.10]	3 [-0.84]	3.5 [-1.49]	7 [-1.20]
Controls (range)	2.6 (0.5-4.5)	4.5 (2.5-7.5)	6.6 (3.5-7.5)	12.5 (6.5-18.5)

Word - non-word paired associate task

	Trial 1	Trial 2	Trial 3	TOTAL
I.R.	0.5 [0.26]	1.5 [-0.42]	1.5* [-1.70] †	3.5*[-1.19]
Controls (range)	0.4 (0-1)	2.1 (0.5-4)	4.2 (2.5-6)	6.5 (4-10)

* indicates that I.R. is out of the range of matched controls. Values enclosed in brackets represent the z scores; † indicate z scores of at least 1.5 standard deviations away from that of matched controls.

Table 10: Recognition of non-words.

	Hit	False Alarm	H-FA
I.R.	6* [-7.51]†	2 [0.00]	4* [-7.51]†
Controls (range)	10.3 (10-11)	2 (1-3)	8 (8)

* indicates that I.R. is out of the range of matched controls. Values enclosed in brackets represent the z scores; † indicate z scores of at least 1.5 standard deviations away from that of matched controls.

Table 11: Recognition results for Experiment 9. Proportion of items recognized in the a) semantic condition and b) syllabic condition as a function of study status.

	IR	Matched controls
a) semantic condition		
Studied		
Position 1	.71	.76 (.52 -.90)
Position 9	.61	.61 (.43 - .71)
Position 11	.52	.63 (.52-.71)
Non-studied		
Unrelated lure	.28*	.07 (0.0 - .24)
Weakly related lure	.19	.24 (.14 - .33)
Critical target	.52*	.63 (.57 - .71)
False recognition effect (T-U)	24%* [-3.34] †	55.8% (43 - 66%)
False recognition effect (T/Pos.11) - (U/Pos.11)	46%* [-2.61] †	87.3% (64.2 - 100%)
a) syllabic condition		
Studied		
Position 1	.57	.60 (.24 - .86)
Position 9	.62	.57 (.14 - .81)
Position 11	.62	.62 (.29 - .86)
Non-studied		
Unrelated lure	.19	.19 (.05 - .38)
Weakly related lure	.48*	.10 (0 - .19)
Critical target	.52*	.11 (0 - .19)
False recognition effect (T-U)	33%* [1.79] †	8.5% (-4 - 28%)
False recognition effect (T/Pos.11) - (U/Pos.11)	54%* [1.76] †	15.7% (-5.6 - 45.2%)

* indicates that I.R. is out of the range of matched controls. Values enclosed in brackets represent the z scores; † indicate z scores of at least 1.5 standard deviations away from that of matched controls.

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Chapitre 3

DISCUSSION GÉNÉRALE

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Les travaux présentés dans cette thèse avaient pour objectif premier d'évaluer la contribution des représentations lexicales et sémantiques au RSI. Ces hypothèses sont issues d'une approche linguistique et vont à l'encontre de l'approche par store préconisée dans le modèle de la mémoire de travail de Baddeley (1986; Baddeley & Hitch, 1974), une des conceptions théoriques les plus répandues. Un deuxième objectif, complémentaire au premier, était de démontrer que l'approche procéduraliste peut rendre compte des apparentes dissociations rapportées chez un petit nombre de patients, entre les performances aux tâches de mémoire dites à *court* et à *long terme* selon l'approche par store.

Sommaire des Résultats

Les trois expériences présentées dans les Articles 1 et 2 ont évalué la contribution des représentations lexicales et sémantiques au RSI normal de courtes listes de mots. Le paradigme utilisé consiste à présenter des stimuli qui varient quant aux types de représentations linguistiques qu'ils possèdent (mots de classe ouverte, mots de classe fermée et pseudo-mots). Les résultats indiquent une influence distincte des représentations sémantiques et des connaissances lexicales lors du RSI. Ces effets appuient l'hypothèse voulant que les processus et représentations impliqués dans le traitement du langage soient intimement liés à ceux responsables de la capacité à maintenir brièvement l'information présentée. Les résultats obtenus par la manipulation expérimentale de la similarité phonologique et de la suppression

articulatoire (Article 1) suggèrent que les effets sémantiques sont particulièrement sensibles au degré d'intégrité de la trace phonologique, ce qui n'a pas été observé pour les effets lexicaux. Enfin, l'Article 2 montre que les effets lexico-sémantiques sont observés malgré le fait que les items ne sont jamais répétés. Ainsi, l'effet sémantique observé dans l'article 1 ne peut s'expliquer par le fait que les items sont répétés, ce qui aurait pu favoriser les mots.

L'article 3 compare le RSI d'une patiente (H.P.) présentant une perte de la connaissance de certains mots. Les résultats montrent clairement que les connaissances sémantiques et lexicales contribuent au maintien de l'information pour de courtes périodes de temps puisque le rappel des mots connus est supérieur au rappel des mots dont H.P. a perdu le sens. Ces données neuropsychologiques s'ajoutent aux résultats obtenus chez les sujets normaux et appuient l'idée voulant que des mécanismes communs sous-tendent le maintien de l'information à court terme et le traitement du langage.

Les modèles théoriques capables d'expliquer les résultats obtenus dans les travaux précédents s'inscrivent dans une approche procéduraliste. Ainsi, de manière complémentaire aux trois articles précédents, l'article 4 fait la démonstration que cette approche peut rendre compte de la dissociation classique MCT/MLT. L'existence d'une telle dissociation constitue l'un des arguments majeurs en faveur de l'approche par store qui distingue au plan fonctionnel, les systèmes responsables de la mémoire à court terme et à long terme ainsi que ceux liés au traitement du langage.

Implications Théoriques

Les données empiriques issues de cette thèse s'ajoutent au nombre grandissant d'études qui rapportent dans la littérature des effets provenant des facteurs lexicaux et sémantiques. L'ensemble de ces travaux appuie fortement l'idée d'une contribution sémantique et lexicale au RSI de courtes listes de mots.

Au plan théorique, l'influence de facteurs non-phonologiques au RSI va à l'encontre des hypothèses découlant du modèle de la mémoire de travail de Baddeley (1986; Baddeley & Hitch, 1974). Par conséquent, les tenants de cette approche ont adapté le modèle original afin de tenir compte de certaines de ces influences. La version révisée du modèle postule l'existence d'une interaction entre l'information maintenue dans le registre phonologique et la forme phonologique des mots en MLT. Cette modification au modèle permet de rendre compte des effets associés à la contribution des facteurs lexicaux (ou forme phonologique des mots) mais ne tient pas compte des influences sémantiques. Selon le modèle de Baddeley (1986), les représentations sémantiques appuyant le RSI pourraient être « recrutées » via l'administrateur central qui chapeaute notamment la boucle phonologique (Baddeley, 1996). Selon cette dernière hypothèse, les patients ayant une atteinte de l'administrateur central devraient montrer une absence ou du moins une réduction des effets sémantiques. Or, des résultats préliminaires auprès de patients atteints de démence de type Alzheimer qui présentent typiquement une atteinte de l'administrateur central, indiquent que tel n'est pas le cas (Caza & Belleville, 2000). Au contraire, ces patients présentent des effets sémantiques accrus lors du RSI.

Quoique préliminaires, ces données vont à l'encontre de l'idée voulant que l'administrateur central soit responsable des influences sémantiques dans le RSI.

En revanche, le modèle d'activation interactive (N. Martin & Saffran, 1997) permet de rendre compte des effets lexicaux et sémantiques observés dans les différentes expériences de cette thèse. Selon ce modèle, la présentation d'items verbaux, lors d'une tâche de RSI, activent les différents niveaux de représentations linguistiques de façon sérielle via des cycles de proaction/rétroaction. Dans ce type de tâche, les influences du niveau phonologique restent dominantes par rapport à celles des autres niveaux puisque les représentations phonologiques sont activées en premier. Ce modèle est intéressant car il explique à la fois les effets lexicaux et sémantiques mais aussi les effets phono-articulatoires. Ainsi, lorsque la suppression articulatoire est utilisée, la trace phonologique ne peut être réactivée par la répétition subvocale d'où la chute de performance au RSI. De la même façon, la similarité phonologique des items va être nuisible au RSI. Par exemple, les mots qui riment à l'intérieur d'une même séquence seront *tous* activés lors de la présentation d'un seul de ces items en raison des connections qui activent tous les mots qui ont des éléments phonologiques communs.

Par ailleurs, même s'il est raisonnable de supposer que le niveau sémantique représenté dans le modèle de N. Martin & Saffran (1987) active aussi le niveau de représentation conceptuel, ce dernier n'est pas explicitement inclus dans le modèle d'activation interactive. Ainsi certaines interrogations demeurent quant à la nature des influences sémantiques observées dans nos travaux. Notamment au plan fonctionnel,

il est difficile de déterminer avec précision si la patiente H.P. a une atteinte restreinte au niveau conceptuel ou si l'atteinte comprend également le niveau de la sémantique linguistique (qui correspond au niveau sémantique postulé dans le modèlde de N. Martin, 1997). De plus, l'influence des effets linguistiques en fonction de la position sérielle semble plus problématique pour ce modèle. En effet, il est postulé que les effets lexico-sémantiques seront plus importants pour les items en début de listes comparativement aux derniers items. Nos résultats n'appuient que partiellement ces hypothèses.

D'autres modèles ont été proposés pour rendre compte des effets linguistiques dans le RSI. Le modèle de R.C. Martin, Lesch et Bartha (1999) postule également que les processus et représentations servant au traitement du langage sont impliqués dans le RSI de listes d'items. Toutefois, ce modèle postule que des buffers ou stores permettent le maintien de l'information pour de courtes périodes de temps. Puisque l'approche procéduraliste rend compte des effets lexicaux et sémantiques sans postuler l'existence d'autres buffers ou composantes, elle nous semble plus parcimonieuse.

Enfin, l'intérêt de l'approche procéduraliste est qu'elle permet de rendre compte de d'autres dissociations rapportées dans la littérature, et notamment du syndrome amnésique. Des travaux récents ont montré que le célèbre patient H.M. (Scoville & Milner, 1958), montrant une « atteinte sélective de la mémoire épisodique », aurait également présenté des troubles au niveau de la compréhension et de la production du langage (MacKay, Burke, & Stewart, 1998; Mackay, Stewart, &

Burke, 1998). Ces résultats appuient l'approche procéduraliste qui proposent que les mêmes systèmes sont responsables des performances mnésiques et linguistiques. Si tel est le cas, les différentes dissociations rapportées dans la littérature seraient à revoir à la lumière de cette nouvelle approche.

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