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AGEING EFFECT ON

VISUAL SEMANTIC VERSUS

ASSOCIATIVE SEMANTIC

ENCODING

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BY

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CERTIFICATE OF ORIGINALITY

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DEDICATION

I dedicate this work to my family, who have fully supported me throughout my study for the

Master of Philosophy degree.

Abstract of dissertation entitled: *Ageing Effect On Visual Semantic Versus Associative Semantic Encoding,* **by Tang Kin Chung for the degree of Master of Philosophy at The Hong Kong Polytechnic University in January 2012.**

ABSTRACT

Memory function involves encoding, storage, and retrieval. It is important to recognize the essence of effective encoding in memory function. Visual semantic encoding is characterized by clearly identifiable visual features (Biederman, 1987; Tversky & Hemenway, 1984), while associative semantic encoding is characterized by associations with meanings and functions (Barsalou, 1991). The process of encoding can be explained as the perceived stimulus being able to be registered by the relevant existing neural network, hence activating the related cognitive units for initiating interconnection (Collins & Loftus, 1975). Ageing has been found to modulate the integrity of visual and associative semantic networks, which impedes older people's learning and hence their daily functions. Studies have revealed that the associative semantic network remains largely intact over the visual semantic network across the lifespan (e.g., Backman, Small, & Wahlin, 2001; Naveh-Benjamin et al., 2003). Other literature has reported inconsistent findings on the issue of whether ageing will affect both encoding processes (Ferguson, Hashiroudi, & Johnson, 1992; Rahhal, May, & Hasher, 2002; Rémy, Taconnat, & Isingrini, 2008). This study investigated the modulation processes by using visual and associative semantic tasks which had compatible priming and

target stimuli.   This largely ensured the validity of the between-task comparisons.

Sixty healthy subjects (29 older adults and 31 young adults) participated in the study. A category verification task was used in which the subjects judged whether the descriptor presented was related or not related to the preceding animal name.   The stimuli were Chinese characters of animal words and descriptors of animal visual features (visual semantic information) and associative characteristics (associative semantic information).   The degrees of encoding facilitation were measured by the reaction time and accuracy rate across conditions.   Three parameters were used and manipulated in the experiment: length of SOA (short versus long), type of encoding (semantic versus perceptual), and congruency (matched versus nonmatched).   It was hypothesized that compared to the young subjects, the older subjects would maintain a relatively more stable associative, rather than visual, semantic encoding network and that this would be reflected in the reaction time and accuracy rate on the tasks.

The results indicated that both the younger and older subjects had significantly longer reaction times in the visual semantic trials than in the associative semantic trials, suggesting that associative semantic encoding would be more facilitated in the experimental tasks.   Our findings concur with those of other studies (e.g., Guo et al., 2004; Walla et al., 2001) which

suggest a more extensive activation of the associative semantic network relative to the visual semantic one. Such superior effects appear to be maintained among the older subjects. The older subjects, when compared with their younger counterparts, consistently showed a decline in task performance, particularly a longer reaction time in the visual semantic conditions, both in the raw and normalized forms. The decline in performance was also reflected in the smaller differences between the congruent and incongruent trials. The results suggest that age-related decline would be due to less efficient access to the visual semantic network. The lower efficiency could be due to a decrease in attentional and regulatory function in which irrelevant information cannot be eliminated from the processing. It could also be due to the decrease in working memory which impedes the binding of relational information within the neural network. It is noteworthy that the age-related visual-associative differentiation was observed in the discrepancies in reaction times but not in the accuracy rate on the category verification tasks.

The results of this study reaffirm the modulation effect of ageing on the encoding process which is crucial in memory function. More importantly, they also indicate that the associative semantic encoding function appears to remain intact than visual semantic encoding function among older subjects. Our findings shed light on the reason behind the decline in memory and learning functions among older individuals. The visual-associative

differentiation is useful for developing remediation strategies for the older population or those with pathological changes resulting in a decline in encoding functions.

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CHAPTER I

INTRODUCTION

This chapter provides an overview of the present research study on the theoretical background of this study. It covers the cognitive processes and neural mechanisms related to visual and associative-based semantic encoding. It begins with an outline of the statement of purpose, followed by the background and justification of the study, and ends with an outline of the organization of the thesis.

Background and Justification

There are at least two distinct processes which are commonly used to process information in semantic memory: visual-based and associative-based (Caramazza & Mahon, 2003; Warrington & McCarthy, 1987). Individuals who employ a visual-based semantic process tend to initiate the process by retrieving the visual features of objects, such as facial features for faces and the appearance characteristics of daily objects (Biederman, 1987; Lambon Ralph et al., 1998; Tversky & Hemenway, 1984). In contrast, those who adopt an associative-based semantic process tend to retrieve meaning and contents from which they have previously built connections with (Barsalou, 1991; Kellenbach et al., 2000). These two differential processes can be interchangeably used by individuals in their daily life depending

on the context of the encoding and recall. It has been revealed that compared with other adults, older people are more inclined to use a visual-semantic based strategy for retrieval (Liu, 2004). Patient with dementia have been found to exhibit a relative higher preservation of associative over visual semantic concepts (Breedin et al., 1994; Srinivas et al., 1997). However, other studies revealed that poststroke patients have a better performance in processing visual over associative semantic information (Warrington and McCarthy, 1994; Hillis et al. 1990; Hollis and Caramazza, 1991). These findings suggest that information processing and retrieval strategy is possibly influenced by an individual's cognitive ability and preference.

With these findings in mind, it is interesting to further explore the reasons behind the shift towards reliance on a visual-semantic based strategy in memory recall. In particular, understanding the effects of ageing on the ability to use visual and associative semantic-based encoding strategies would provide useful insights into how memory recall could be influenced. A review of the literature indicates that little is known about the mechanisms of encoding and the possible implications of any impairment to the encoding process. Researchers in rehabilitation sciences are interested in studying how memory recall can be enhanced by means of modifying the ways that information can be encoded. More importantly, an encoding method can be matched with the residual brain functions and personal style of an individual. This study proposes to shed light on how ageing influences

visual and associative semantic encoding. The results will have implications for the design of interventions to enhance encoding functions and hence improve recall, which is the ultimate goal in the quest to maintain and improve memory functions among older adults and those suffering from neuro-degenerative diseases such as mild cognitive impairments and Alzheimer's disease.

Organization of Chapters

This rest of this thesis consists of five chapters. Chapter 2 reviews the literature on the current knowledge of visual- and associative-based semantic encoding processes related to category-related information and also summarizes the different factors, particularly ageing, that modulate encoding processes. Chapter 3 reports on the process of subject recruitment, the design of the category verification task, and the data analysis strategies. Chapter 4 presents the results, and Chapter 5 discusses the findings and relates these to those revealed in other studies. Finally, Chapter 6 presents the conclusion, which also covers the limitations of the study and recommendations for further research.

CHAPTER II

LITERATURE REVIEW

Introduction

This chapter introduces the connectionist model of semantic memory (Anderson, 1983), in particular the theory of spreading activation proposed by Collins and Loftus (1975). These two sets of theories were used to guide the design of the present study. Recent studies on visual and associative semantic encoding related to conceptual organization of memory are then reviewed. The potential effects of ageing and other factors modulating encoding processes are explained. The roles of category verification tasks in studying the imagery of sequential movement are also explained. The data analysis and the interpretation of the results are also described.

Memory and Encoding

Memory is an important brain function which augments the daily functions of individuals. Long-term memory is viewed as a collection of memories that can be divided into explicit and implicit memories depending on the type of information processed (Cohen & Squire, 1980). Explicit memory refers to the recollection of the type of information

which requires conscious effort, while implicit memory refers to the recollection of highly specialized information which does not involve conscious effort. Explicit memory is subdivided into episodic and semantic stores, with the former consisting of personal information involving a specific spatio-temporal context (Starns, 2012; Tulving, 1984). Memory function involves encoding, storage (rehearsal and consolidation), and retrieval (or recall) (Craik, 2011). An effective encoding process is crucial for the subsequent retrieval of the encoded information. An understanding of each of these processes is important for recognizing the essence of effective encoding in memory function. According to Baddeley (2002), encoding occurs at an early stage when information is registered. The encoded information is then stored and maintained for future retrieval. Retrieval is the ultimate purpose of a memory function in which information is accessed for recognition or recall. Encoding is therefore the prerequisite which is crucial to linking or relating new incoming information to existing knowledge (Craik, 2007; Hasselmo, 2007). It is the initial process in memory function and warrants more attention as it governs the quality and amount of information inputted into the system. An effective encoding process will greatly enhance the success of the subsequent retrieval of encoded information. The focus of this study is on the effect of ageing on the visual- and associative-based encoding of selected Chinese characters (or words).

Semantic Memory and the Organization of Sematic Knowledge

Semantic memory is generally conceptualized as nontemporally encoded world knowledge, knowledge of facts and things. It is often distinguished from episodic memory, knowledge of events that are temporally coded (Ankerstein, 2012). Episodic memory involves the storage and retrieval of specific past events characterized by what happened where and when (Tulving, 1972). A common paradigm used to investigate the episodic memory process is to ask subjects to judge whether an item presented is novel to them or has been previously encountered by them in the encoding phase (Tulving, 1993). In contrast, semantic memory refers to the storage and retrieval of general concept-based knowledge unrelated to specific experiences and contexts. It includes knowledge about concepts of various types, such as visual perceptual information (e.g. dog has four legs), functional association information (e.g dog is used for hunting). Semantic knowledge is organized as a complex network consisting of representations that are related through serial and/or parallel associations. Within the network, concepts share attributes in a different extent. Observations of individuals with acquired brain injuries have revealed deficits within circumscribed subcategories of words and objects. In particular, some patients display an uneven impairment for knowledge of living and non-living things (Capitani, Laiacona, Mahon, & Caramazza, 2003). This has led to the proposal that some objects and classes of objects are differently weighted in terms of their dependence on visual features versus associative

features within semantic memory (Warrington & Shallice, 1984). Similar to episodic memory, the testing of semantic memory adopts a recognition and recall paradigm (Herzman, 2011). In the recognition phase, subjects are presented with a series of knowledge items. The items previously learnt prior to the recognition phase are called "old" items. Subjects are presented with a randomized mixture of old and new items. New items are those which have not been presented for the subjects to learn. The subjects are asked to decide whether the item presented is old or new. In the recall phase, they are asked to generate the old items without a cue (free recall) or from a fragment of the item (cued recall). Recognition and recall tasks are different in that in terms of retrieval requirement, recall is more precise and difficult than recognition. However, both tasks require subjects to generate their own information about items that already exist in their memory. (Okada, 2012; Tulving, 1993)

Connectionist Models of Semantic Memory

The representation of words and their corresponding concepts is a classical case of semantic memory which taps separate but connected semantic networks (Anderson, 1983; Collins & Loftus, 1975; Davis, 2010; Seidenberg & McClelland, 1989). Collins and Loftus (1975) proposed an early model of semantic memory which stipulates that semantic concepts are connected to each other through learned associations. They argued that nodes of concepts reside in a semantic network which shares connections with other nodes of similar meaning. An alternative to this model is the parallel distributed processing model

(Rumelhart, Hinton, & McClelland, 1986), which describes semantic concepts as being connected in the form of a parallel array in addition to serial pathways.   In their model, units of a network are not the word but its meanings represented by simple and highly interconnected features.   The learning of a word (e.g., "cherry") is conceptualized as changes in the weights of the connections of the pre-existing features of the word.   The features representing the word "cherry" would be round, juicy, small, edible, and grows on trees.   The weights of the connections among these features will henceforth be changed after the word has been learnt.   In return, the features representing the word become the semantic concepts of the word (Raposo, 2012).

The Encoding Process in Formation of Semantic knowledge

The encoding of a visually presented word or object to form semantic knowledge involves several cognitive inputs including perception, attention, and executive processing.   The perception begins with the detection and capture of the visually presented word (Posner & Petersen, 1990). Attention plays an important role which enables the visual system to capture the features embedded in the visual image of the word.   The sensory information is temporarily stored within the iconic memory and working memory before being further processed for storage.   In Baddeley's (2009) model, the visual image of the word is stored in the visuo-spatial sketchpad.   The encoding process can be further broken down into different

sequential subprocesses. Event-related potentials (ERPs) associated with the encoding

process offer a detailed depiction of the subprocesses. McClelland (1988) suggested that

early ERP components elicited around 100 ms reflect incoming information beginning to

transform into visual sensory information for processing (i.e., the C1, P1, and N1

components). He further explained that the transformation process is mediated by attention

processes which elicit the N2 and N2pc components. The semantic encoding of words is

then represented by the N2/P3 complex, which has been found to associate with the

categorization of visual stimulus. This process was also found to involve updating in the

working memory (the P3 component). Other studies have further supported that the

categorization process associated with the semantic encoding of words (Brem, 2009; Gabrieli

et al., 1998; Thompson-Schill et al., 1997). In the study of semantic encoding proess, the

subjects were asked to make speeded response of living/nonliving judgments after showing a

series of pictures of objects. Retrieval of semantic information about each object was required

in order to make a classification decision. A negativity between the 410 and 800 ms time

window was elicited over the left inferior frontal region which was found to associate with

classification decision. Moreover, the neural activity   N400 or late negativity complex was

also found to associated associated with semantic judgments (Thompson-Schill et al., 1997).

Visual- versus Associative- Based Semantic Encoding

Previous studies have revealed that concepts are organized in networks according to the semantic features representing the concepts (Jackendoff, 2002; Saffran, 1999). Neuropsychological studies conducted on patients with specific knowledge impairments have been a useful source of data for addressing issues about the organization of conceptual–semantic knowledge in the human brain. Observations of individuals with acquired brain injuries have revealed deficits within circumscribed subcategories of words and objects. In particular, some patients display an impairment for knowledge of living things such as animals and fruits/vegetables, whereas knowledge of nonliving things is relatively intact (Capitani, Laiacona, Mahon, & Caramazza, 2003). This has led to the proposal that some objects and classes of objects are differently weighted in terms of their dependence on visual sensory features (e.g., an object's visual characteristics) versus functional associative features (e.g., an object's use) within semantic memory (Warrington & Shallice, 1984). According to sensory/functional theory (Warrington & McCarthy, 1983, 1987; Warrington & Shallice, 1984), organization of semantic knowledge could be divided into visual/perceptual knowledge (e.g. color, visual parts, surface properties, smell) and associative/functional knowledge (e.g. usage or purpose, symbolism). When semantic encoding involves visual/ perceptual information, an individual processes the sensory and structural of the stimulus. In contrast, associative/functional based semantic encoding involves processing the

non-sensory and abstract meaning of the stimulus. For example, the visual semantic encoding of the word "pigeon" would involve its physical properties, such as wings and two-legged, while the associative semantic encoding of the same word would involve representations and meanings such as peace and flying (Raposo, 2012).

Visual- and associative- based semantic encoding can respectively be organized in a subordinate and superordinate hierarchy (Raposo, 2012). Visual information encoded at a subordinate level is likely to display a low degree of generality and class inclusion (Biederman, 1987, Bermeitinger, 2011). It is characterized with relatively clearly identifiable and highly detailed features. In contrast, associative information encoded at a superordinate level displays a high degree of generality, the content of which tends to be abstract. An example is the concept of *Dog*. The subordinate visual feature may be "has four legs", while the superordinate associative content may be "is used for hunting" (functional), "likes to chase cats" (habitual), or "carnivore" (encyclopaedic) (Barsalou, 1991).

Following this line of thought, researchers proposed the sensory-associative hypothesis in an attempt to differentiate the mental processes involved in visual/perceptual and associative/functional encoding. Lesion studies on brain injury patients (Laiacona, 2005; Sacchett & Humphreys, 1992) and behavioural studies utilizing the semantic categorization task paradigm (Caramazza & Mahon, 2009; Vitkovitch et al., 1993) demonstrated that subjects differentially tend to encode visual representative features when presented with

living categories but more likely to encode associative meaning information when presented with nonliving categories. These studies further supported by observations that the encoding of semantic knowledge involves the motor cortex and surrounding areas. In contrast, the encoding of visual knowledge involves the occipital-temporal areas close to the visual cortices. Kiefer (2001) further argued that visual semantic knowledge is required to discriminate objects in the living categories, and this type of knowledge relies heavily on fine-grained visual attributes. Associative semantic knowledge is required to discriminate objects in the nonliving categories, in which appearance or visual features vary considerably. Nevertheless, other studies have revealed inconsistent results which do not support the sensory-associative hypothesis. In Miceli et al.'s (2000) study, the performance of patients with deficits in visual-perceptual knowledge in the living and nonliving categories was not found to be significantly different. In other words, the differentiation between visual and associative semantic encoding based on knowledge of living and nonliving objects is less convincing.

Encoding processes involve the selection and binding of the information being processed (Mangel, Picton, and Craik, 2001). The common processes between visual/perceptual and associative/functional encoding are attention and the binding of information; the latter has been found to be associated with blood oxygenation level-dependent (BOLD) responses in the left medial temporal cortex and the hippocampus

(e.g., Daselaar et al., 2003; Mangels et al., 2001; Otten et al., 2001). The potential difference between the two encoding processes is the type of information selected for manipulation and binding. The associative semantic encoding of words has been found to associate with stronger activations in the left inferior frontal cortex compared to visual semantic encoding (Kapur et al., 1994; Otten, 2001; Ragland et al., 2005). The left inferior frontal cortex has previously been revealed to relate to the manipulation and selection of the attributes of stimuli (Otten et al., 2001; Prince, Daselaar, & Cabeza, 2005; Ragland et al., 2005). In other words, the encoding of associative semantic information demands more manipulation and selection processes than the encoding of perceptual information.

Neural Processes Underlying Visual- and Associative-based Semantic Encoding

Researchers have proposed that visual semantic processes are used to encode information on objects in subordinate-level categories - more clearly identifiable and highly detailed visual features (Biederman, 1987; Raposo, 2012; Tversky & Hemenway, 1984;) – while associative/functional semantic processes are used to encode information on objects in superordinate categories – more general and abstract (Barsalou, 1991). Tanaka et al. (1999) founded that the presentation of objects from a subordinate category elicit a larger negative ERP N1 around 150 ms poststimulus than objects from a superordinate category. The N1

component has been found to associate with visual semantic encoding processing which

elicits a larger negativity when attention is paid to visual stimuli (Fu, S. et al., 2009; Mangun

& Hillyard, 1991). This further suggests that the processing of objects in a subordinate

category involves visual semantic processing (Jolicœur, Gluck, & Kosslyn, 1984). Tanaka et

al. (1999) found that a frontal positivity elicited around 300 ms poststimulus is associated

with the processing of objects in a basic-level category. Various neurophysiological studies

have concluded that such frontal positivity is associated with associative semantic processing

(Kiefer, 2001; Kiefer et al., 1998; Snyder et al., 1995). Furthermore, several functional

neuroimaging studies supported the modality-specific semantic memory model based on the

visual and associative processing. For example, Chao, Haxby, & Martin (1999) found that the

lateral posterior fusiform gyrus responds more robustly to living than non-living objects,

suggesting encoding visual properties of living objects is associated to specific brain regions.

Other studies have indicated bilateral activation of inferior occipital-temporal cortex for

visual encoding of natural objects. (Martin, Wiggs, Ungerleider, & Haxby, 1996; Cappa,

Perani, Schnur, Tettamanti & Fazio, 1998)

Spreading Activation and the Priming Effect

Spreading activation has commonly been associated with the learning of semantic

information. Collins and Loftus (1975) proposed that within an interconnected semantic

network, activation is spread along the paths of the network, resulting in the activation of the associated cognitive units and hence their memories.   In an experiment conducted by Neely (1991), faster responses to a target word were elicited if that word had followed a semantically related word rather than an unrelated word.   The beneficial effects of semantic priming are typically ascribed to an activation process whereby the presentation of a prime word activates semantic knowledge not only about that word but also about other semantically related words, typically through a process of automatic spreading activation. (Neely, 2010).   As a consequence, the recognition of nodes representing related words takes less time.   This is a fast-acting, automatic process which does not require attention or awareness and only makes minimal demands on resource capacity (Posner & Snyder, 1975; Shiffrin & Schneider, 1977).   The facilitating effect of spreading activation is supported by biological studies on the long-term potentiation (LTP) effect (Hasselmo, 2007). When a synapse has undergone LTP, subsequent stimuli applied to the presynaptic cell are more likely to elicit action potentials in the postsynaptic cell (Henneberger, 2010).   In cultured cells, applying a series of short, high-frequency electric stimuli to a synapse can strengthen, or potentiate, the synapse for minutes to hours.   Neurons connected by a synapse that has undergone LTP have a tendency to be active simultaneously.   The effect suggests that there is an increase in chemical synapses that lasts from minutes to several days.

Effects of Ageing on Cognitive Functions

A decline in cognitive functions, the encoding and retrieval of autobiographical events, is a hallmark of normal cognitive ageing. Among these functions, attentional control has been found to decline when older subjects are engaged in the encoding process (Lee et al., 2006; Wang, Li, Metzak, He, & Woodward, 2010). The literature also suggests that the speed with which semantic information is access and utilized, whether consciously or unconsciously, decreases significantly with advancing age. Salthouse (1996) has proposed that age-related slowing lowers the effectiveness of working memory operations and thus efficiency of cognitive processing, including memory encoding. Birren and Fisher (1995) suggested that older adults typically show slower response time in lexical decision, naming, categorization, and various verbal fluency tasks. Lee et al. (2006) further attributed the decline in cognitive functions to the slow processing speed among older adults. This slowness delays the suppression of irrelevant information (requiring attentional control) which interferes with the selection of relevant information for processing (Finnigan, O'Connell, Cummins, Broughton, & Robertson, 2010). This proposition was supported by Wang et al. (2010), who revealed that older subjects tend to recruit the default-mode-network (DMN) more than their younger counterparts in both the visual and associative semantic encoding processes. These findings seem to suggest that a decline in attentional control would affect both encoding processing alike. Studies have revealed that semantic

processing remains largely intact across the lifespan and that the semantic network is not qualitatively modulated by normal ageing processes.

A further review of the literature identified studies which reported inconsistent findings. These studies revealed no significant differences in visual or associative semantic encoding between younger and older subjects (e.g., Ferguson, Hashiroudi, & Johnson, 1992; Rémy, Taconnat, & Isingrini, 2008). Rahhal et al. (2002) observed that in visual perceptual encoding, older subjects appear to attend less to the details of visual features compared to their younger counterparts. Ferguson et al. (1992) and Rémy et al. (2008) found that older subjects perform worse than younger subjects in visual perceptual encoding only in the condition demanding more attentional control. These findings seem to suggest that older subjects retain their the overall semantic encoding ability but are more susceptible to a decline in attentional control, which affects their visual rather than associative semantic encoding.

Effects of Ageing on Visual and Associative- based Semantic Encoding

Besides attentional control, previous studies have reported the effects of ageing on the deterioration of the binding process associated with encoding (Naveh-Benjamin, 2000; Naveh-Benjamin, Brav, & Levy, 2007; Naveh-Benjamin, Guez, Kilb, & Reedy, 2004; Naveh-Benjamin, Hussain, Guez, & Bar-On, 2003; Ramponi, Richardson-Klavehn, &

Gardiner, 2004). Desalaar et al. (2003) further explained that deficits in the binding process are characterized by a decrease in the ability to merge an encoded event or stimulus into an existing representation; this was observed in older, but not younger, subjects. The decrease in ability has been found to be related to a decrease in the activities of the medial temporal lobe (MTL) in older subjects irrespective of the type of encoding involved (Prince et al., 2005). Yet, in their review, Friedman, Nessler, and Johnson (2007) concluded that the deterioration effects are likely to impact on associative semantic rather than visual semantic encoding as declining episodic memory, which is closely related to the binding of associative semantic information, has been commonly found among the older adult population. Hence, there are inconsistent findings on the age-related deterioration of the binding process between visual and associative semantic encoding. To further investigate the nature of encoding processes in older people, Thompson-Schill et al. (1997) utilized the object classification paradigm in which younger and older subjects study words under low and high selection conditions. The low-selection condition requires a decision as to whether a previously presented picture (e.g., a lion) matches the meaning of a to-be-remembered word (e.g., lion). In the high-selection condition, a decision has to be made concerning whether a previously presented adjective (e.g., heavy) describes a feature of the to-be-remembered word (e.g., feather). While both decisions necessitate the retrieval of a semantic concept, the high-selection decision requires the selection of specific semantic features from several

alternatives. This object categorization task design served as the basis for the design of the experimental task used in this study.

Factors Modulating the Encoding Process –

Attention Control and Stimulus Onset Asynchrony (SOA)

The encoding process can be modulated by the level and amount of attentional resources required in a task (Mangels, Picton, & Craik, 2001). For instance, processing information at a visual (physical or structural) semantic rather than associative semantic level has been found to impede recall in terms of the reducing the number of remembered items during recognition episodic memory. Researchers have further explained that this is attributable to the reduced resources allotted to the information when stimuli are processed perceptually (Rattat, 2011). The effect of attentional resources on encoding is further supported by neuro-anatomical studies (Moscovitch, 1991) and neurophysiological studies (Fu, 2009). Moscovitch (1991) proposed that reduction in attentional resources might interfere with the neural processes involved in episodic memory encoding. They founded that the sources of these interferences are located in the medial temporal lobe and the hippocampal complex with the allocation of the attentional resources regulated by the prefrontal cortex. The implications for the design of the experimental task for this study were that the stimuli and processes involved in the perceptual and semantic encoding tasks

would need to be highly comparable; otherwise, any between-task comparisons or between age-group comparisons would not be meaningful

Stimulus Onset Asynchrony (SOA) is another factor that can modulate the encoding process (Hutchison, 2001; Rattat, 2011). SOA is manipulated by means of the duration between the presentation of the priming and the probe stimuli. A shorter SOA will elicit an aftereffect which could induce a spreading activation which facilitates semantic encoding which is automatic in nature, while such a process would be less obvious with a longer SOA. For the latter, the encoding would be become less an automatic process and more a controlled process (i.e., expectancy). The dissociation between an automatic-based and a controlled-based priming has been demonstrated in studies. The common method used in these studies was to manipulate the time interval of the SOA, that is, the duration between the onset of the prime word (at which point an individual could start generating an expectancy) and the presentation of the probe word. There is, however, no uniform SOA which can differentiate anatomic from controlled processes. The time interval of SOA has been found to vary across tasks (Hutchison, 2001).

Under a shorter SOA condition, spreading activation dominates the encoding process. In studies conducted by Neely (1977) and Burke, White, and Diaz (1987), subjects were trained to expect items of a different category to the prime category. They founded that responses to the semantically related prime-target trials were faster than responses to the

semantically unrelated trials. The authors concluded that automatic spreading activation was the dominated processes occurred under a very short SOA condition. Neely (1991) suggested that under a longer SOA condition, at least two conscious controlled strategies could be employed by subjects. These strategies are expectancy and postlexical semantic matching. Expectancy involves the interpretation of the context provided by the prime leading to the active activation of the target and neighbouring regions of the network relevant to the target word. Differ from the automatic processes, expectancy requires attentional resources and executive control (Becker, 1980, Posner & Snyder, 1975). Other studies have revealed that the expectancy and postlexical semantic matching will not occur shorter than 500 ms poststimulus (De Groot, 1984; Neely, 1977). The postlexical matching strategy has been found to exist in the longer SOA condition for the encoding of words and nonwords (Neely, 1977; Neely, Keefe, & Ross, 1989). McNamara (2005) founded that a shorter SOA condition does not provide a time window wide enough to allow registration of the prime stimulus to support the semantic matching. Moreover, the presentation of the target stimulus could interrupt and interfere the matching process that is originally triggered by the prime stimulus.

In summary, three mechanisms are available in the existing literature to explain the possible processes involving in the encoding of stimuli. However, it is important to note that the majority of the content and evidence has been generated from overall semantic

processing. The extent to which these mechanisms can be applied to the visual- and associative- based semantic encoding process respectively is not certain. In general, spreading activation is one major process which will occur when the duration between the prime and the probe stimuli being presented is relatively short. This is a test of the related information (or the semantic and perceptual content of words) that exists within an interconnected network (or lexicon). Semantic matching can be a controlled process which occurs when the duration between the prime and the probe stimuli being presented is longer. Such processes involve postlexical integration processes requiring the conscious and active participation of the subjects.

Research Questions and Hypotheses

Previous studies using animate-inanimate discrimination task to dissociate of visual and associative semantic processes received a number of criticisms. First, the researchers made assumption with Sensory/Functional Theory that the ability to recognize living things depend on visual (sensory) semantic subsystem, while the ability to recognize nonliving things is assumed to depend on the functional/associative subsystem (Warrington and McCarthy, 1983, Humphreys and Forde, 2001; Crutch and Warrington, 2003). Second, subsequent analysis compares the composite feature profiles for living versus nonliving things, limiting interpretations to cross-domain differences. Thus, there is an automatic assumption of

within-domain homogeneity and cross-domain segregation. They further assumed that a dissociation of visual and associative subsystem should not be observed either within living or nonliving construct (Mahon & Caramazza, 2003). However, Ankerstein, C. A., Varleya, R. A. & Cowella, P. E. (2012) found significant cross-domain similarities and within-domain differences indicated that profile of visual and associative semantics were not determined simply as a function of the living and nonliving domain distinction. This important finding further supported a model of semantic memory with reduced salience for the "Animate-Inanimate" construct. Moreover, considerable amount of evidences supported that non-living categories also relied on visual sensory properties in the same way as living things and were therefore affected by damage to the visual semantic system (Sartori & Job, 1988; Basso, 1988; DeRenzi & Lucchelli, 1994). Stewart, Parkin & Hunkin (1992) found that when two categories were matched jointly for frequency, familiarity, and visual complexity, the category effect across domain disappeared. Moreover, the explanation of visual and association semantics using animate versus inanimate based on Sensory–functional theory has also been questioned on the grounds that the contribution of functional information to the concepts of living things has been underestimated as the result of an overly narrow definition of what counts as a functional property. For example, animals have important biological functions, such as running, breathing, eating other time visual outlook features. (Tyler & Moss, 1997). These led to our first question that is there any heterogeneity between visual

and semantic encoding within the same semantic subsystem?

There are several limitations in previous experimental design in studying the visual and associate semantic subsystem. For example, the validity of the feature generation task in providing a window on the underlying representations and structures of semantic memory has not been adequately explored. According to Ankerstein (2012), one limitation of feature generation tasks is that they may be biased for easily verbalized features, resulting in feature profiles for items that may not be representative of the multisensory representation in semantic memory. A further limitation of previous research on category-related semantic processing in healthy subjects is that naming and categorization latencies usually differ between artifacts and natural objects even if stimuli are matched for relevant variables such as name frequency, familiarity, and visual complexity (Kiefer, 2001; Lloyd-Jones & Humphreys, 1997a, 1997b). One way to overcome these limitations of feature generation design and animate-inanimate design as mentioned above and to assess visual and associative encoding process within semantic memory is via a semantic priming experimental design (Roediger, Weldon, & Challis, 1989). A semantic priming effect is observed when the primed target is responded to faster than the unprimed target, which is interpreted as indicating that the concepts are linked in semantic level. Using the primed semantic verification task, the participants are unaware of the prime, it is obvious that they would not be able to predict the target consciously nor derive any benefit from a controlled retrospective strategy (Neely,

Keefe and Ross, 1989). Moreover, Kiefer (2005) claimed that the benefit of using this technique is more sensitive to automatic processes, and less sensitive to strategic processes. In the present study, semantic verification task incorporating priming is used to unveil the visual and associative encoding process. Visual input (visual letter string), decision (''yes it is a word''), and motor response (button press with index finger) are identical for both processes. If neurophysiological priming effects (reaction time) vary as a function of encoding, these encoding-related differences must arise from differentially activated visual or associative semantic representations, reflecting of semantic memory organization and hence strengthen the multiple semantic systems account.

This study was designed to test the extent to which ageing impacts on visual- and associative- based semantic encoding using an object (animals) categorization task. The experimental task made reference to the tasks used by Thompson-Schill et al. (1997). Despite inconsistent findings, associative-based semantic encoding in general has been demonstrated to be less affected by the ageing process (e.g., Mangel et al., 2001; Bergerbest, 2009). Given that older individuals are more susceptible to attentional decline, which further hampers perceptual encoding, it was hypothesized that when compared with younger counterparts, older subjects would show a more significant decline in performance in visual-based than in associative-based semantic encoding. Given this, it was anticipated that

in the object categorization task, the response time would be faster and the accuracy rate would be higher in the associative semantic congruent trials than in the visual semantic congruent trials for both the younger and older groups. The index derived from dividing the response time of the congruent trials by that of the incongruent trials would reflect the regulation of the encoding process. It was hypothesized that the ageing process would have a more negative impact on the regulatory process. As the differences between congruent and incongruent trials would be less in visual semantic conditions than in associative semantic conditions, it was anticipated that the visual-associative discrepancy would be more significant in the older group than in the younger group.

Significance of Study

Memory function is mediated by extensive neural networks and is susceptible to an overall or specific change in the brain. An overall change in brain function can be due to ageing or other pathological changes, such as a cerebral vascular accident. Studies on the encoding process in relation to the retrieval process will shed light on the structure and dynamic of the memory system. A review of the literature indicates that little is known about the mechanisms of encoding, let alone the effects of ageing on the encoding process. The findings of this study will reveal the possible effects of ageing on modulating the encoding process - an initial and essential step before the storing and recall process of

memory function. It will enable us to further understand the relationships between an individual's age, encoding style, cognitive ability, and memory performance. The behavioural data obtained can further substantiate the notion that perceptual- and semantic-based encoding strategies involve different mental processes. The results will help our understanding of the potential encoding problems among the older population. They will also shed light on developing interventions for older adults and patients with brain pathologies, such as poststroke and brain injuries, to enhance their memory functions by tackling encoding rather than recall functions.

CHAPTER III

METHOD

This chapter describes the method and set-up of the study. It covers the sampling methods, study design, equipment, and instruments. The procedures for collecting and analysing the data will be elaborated.

Sample

A convenience sample of 60 subjects (29 older and 31 younger individuals) was recruited to participate in the study. The younger subjects were undergraduate students of

The Hong Kong Polytechnic University, while the older subjects were members of a community centre for older adults. The younger subjects were recruited by posting recruitment notices on student notice boards at the university. The purpose and a brief description of the study were provided in the recruitment notice. The older subjects were recruited using the following inclusion criteria: 1) aged 65 years old or above; 2) a minimum educational level of Primary 6. The exclusion criteria were as follows: 1) visual impairment that would impede perception of the stimuli in the study; 2) diagnosed with a cognitive impairment; and 3) diagnosed with a neurological or psychiatric condition. All of the subjects were screened using the Mini Mental State Examination (cut-off score of 24) and a Chinese reading passage pegged at Primary 6 level (not more than 10 words unrecognized). To protect their confidential information, each subject was assigned a code that was used throughout the experiment and in the data processing and analyses. The purpose of the research study was explained to the subjects and informed consent was obtained from them before the experiment began. Ethics approval was obtained from the Department of Rehabilitation Sciences, The Hong Kong Polytechnic University. Each subject received HK$100 as compensation for the time he or she spent completing the experiment.

Category Verification Task

The task used for this study was a category verification task in which the subjects were required to indicate whether or not a given animal name (e.g., pigeon) was related to a target visual feature descriptor (e.g., bark) or a associative functional descriptor (e.g., peace).

Stimuli

The stimuli consisted of a pool of 12 single-word animals as primes and 120 double-word descriptors as targets. Half of the targets belonged to visual categories (visual features from head, texture, extremities, size, and body part, respectively) and the other half were associative categories (locomotion, function, temperament, symbolic representation, and habit, respectively). Stimuli selected from this pool were organized into a sequence in which half of the animal names were followed by a related descriptor (called congruent) and half of the items were followed by a nonrelated descriptor (called incongruent) (Figure 3.1). All of the animal-descriptor pairs were then divided into two visual and two associative lists in such a way that an animal name that appeared as congruent (in a congruent condition) in one list would appear as incongruent (in an incongruent condition) in the other list. The stimuli in combinations of different descriptors and congruency were classified into four conditions: visual versus associative and congruent versus incongruent.

The animal names and their visual and associative features were selected based on two criteria: 1) the animals had been commonly used in previous studies (e.g., Spitzer et al., 1995; Warrington & McCarthy, 1987); 2) they were regarded as familiar by the subjects based on the reading criteria set out by Snodgrass and Vanderwart (1980) at the level equivalent to or below Primary 3 in the Hong Kong education system.

Design of Task

Beside the types of encoding and congruency, the stimuli were further divided into short and long SOA conditions (50:50 split). The SOA conditions were embedded in each of the four blocks of trials: two visual and two associative blocks. The shorter SOA condition involved a delay of 150 to 450 ms before a target stimulus was presented after the presentation of a prime stimulus; the long SOA condition involved an 800 to 1100 ms delay. This formulated a 2 (visual versus associative) x 2 (congruent versus incongruent) x 2 (short versus long SOA) design for the trials.

A typical trial began with the presentation of a fixation cross for 500 ms, during which time the subject was required to attend to it (Figure 1). The name of the animal for the trial was displayed in the middle of the screen for a varied period of time depending on the SOA condition. For a short SOA condition, the exposure time was randomized within 150 to 400 ms, while for a long SOA condition it was randomized within 800 to 1100 ms.

A target descriptor stimulus was displayed after the SOA, and the subject was required to respond by judging whether the descriptor matched with the name of the animal. The subject made his or her response by using the right index finger to press the "L" key on the keyboard for "yes" (match) and the left index finger to press the "A" key for "no" (nonmatch). The time allowed to give a response was 5,000 ms, after which the descriptor stimulus disappeared from the screen. The next trial was automatically loaded after the response was registered by the system. A blank screen was displayed for 500 ms, and this was followed by a fixation cross. The reaction time in response to the target descriptor stimulus and the accuracy of the "yes" or "no" response were recorded by the system. Each subject was instructed to perform as best as he or she could and to make a judgment as accurately and quickly as possible.

There were four task blocks: two visual and two associative. Within each task block, the orders of the animal-descriptor pairs and the SOA duration were randomized. Each block had 120 trials. The Latin square counterbalancing procedure was used to arrange the order of the four task blocks and subject assignment. The subjects were randomly assigned to one of the four task sequences: V1-V2-A1-A2, V2-V1-A2-A1, A1-A2-V1-V2, or A2-A1-V2-V1 (where A and V stand for associative and visual, and 1 and 2 stand for the first and second half of the trials in the block). This method was meant to control for progressive error caused by order effects because each experimental block condition occurred equally

often in each position.　　The entire task required about 2 hours to complete.

500 ms fixation cross		SOA 150-450 ms or 800-1100 ms				match or nonmatch response		500 ms
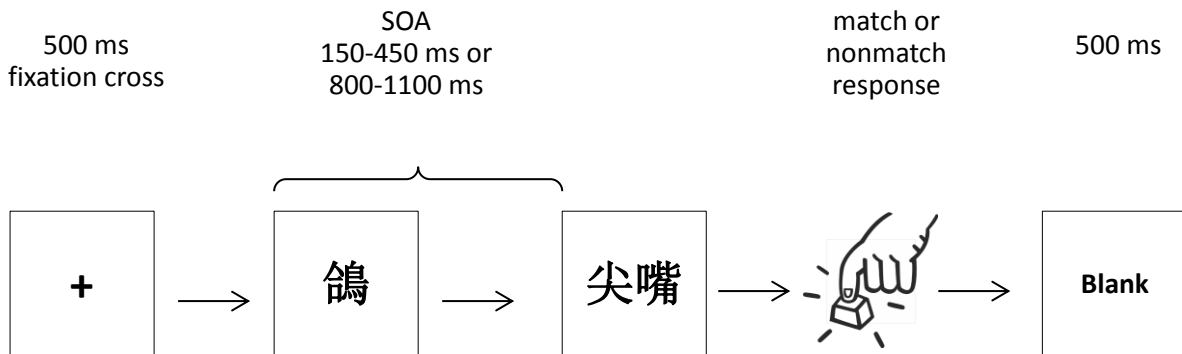
(A) A congruent animal name and target descriptor trial in a perceptual block.

500 ms fixation cross		SOA 150-450 ms or 800-1100 ms				match or nonmatch response		500 ms
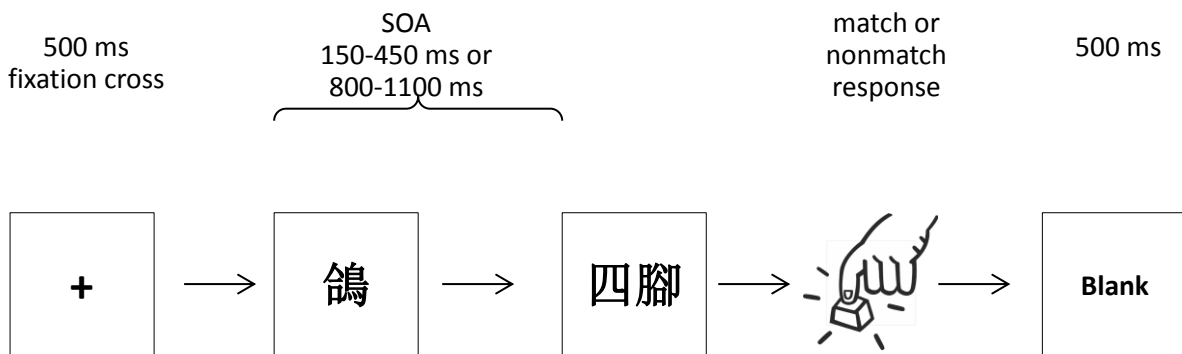
(B) An incongruent animal name and target descriptor trial in a visual block.

Figure 3.1. Design of a visual trial in the category verification task used in the study.

Experimental Set-up

A 13-inch IBM notebook computer for displaying the visual stimuli was placed at a distance of 65-75 cm from the subject; the viewing angle for the stimuli subtended about 38° horizontally and 18° vertically in front of the subject.　　The notebook computer was placed in a central position relative to the subject to allow the subject's index fingers to rest on the A and L keys, respectively (see Figure 2).　　The subject sat in an upright position in front of the

computer monitor on which the stimuli were presented, and his or her eye level was at the

centre of the screen**.**   The entire experimental session required about 2 hours to complete.

Figure 3.2. Subject completing the category verification task sitting in front of a table, upon which is placed a notebook computer.

Procedures

Before participating in the category verification task, each subject completed a

demographic questionnaire on age, sex, handedness, and educational level.   All of the older

subjects were screened for eligibility using the Mini Mental State Examination (MMSE) and

for reading literacy by reading a paragraph equivalent to Primary 6 reading level.   There

were four blocks in the task, each of which consisted of the five phases summarized below:

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┌─────────────────────────────────────────────────┐
│   Training phase (30 related animal-descriptor pairs)   │
└─────────────────────────────────────────────────┘
                        ⬇
┌─────────────────────────────────────────────────┐
│   Qualification phase (Recall with 90% of accuracy or   │
│                    above)                        │
└─────────────────────────────────────────────────┘
                        ⬇
┌─────────────────────────────────────────────────┐
│           Practice phase (20 trials)             │
└─────────────────────────────────────────────────┘
                        ⬇
┌─────────────────────────────────────────────────┐
│   Experimental phase (4 blocks in randomized     │
│            counterbalanced design)               │
└─────────────────────────────────────────────────┘
                        ⬇
┌─────────────────────────────────────────────────┐
│         Wash out phase (Digit-span test)         │
└─────────────────────────────────────────────────┘
```
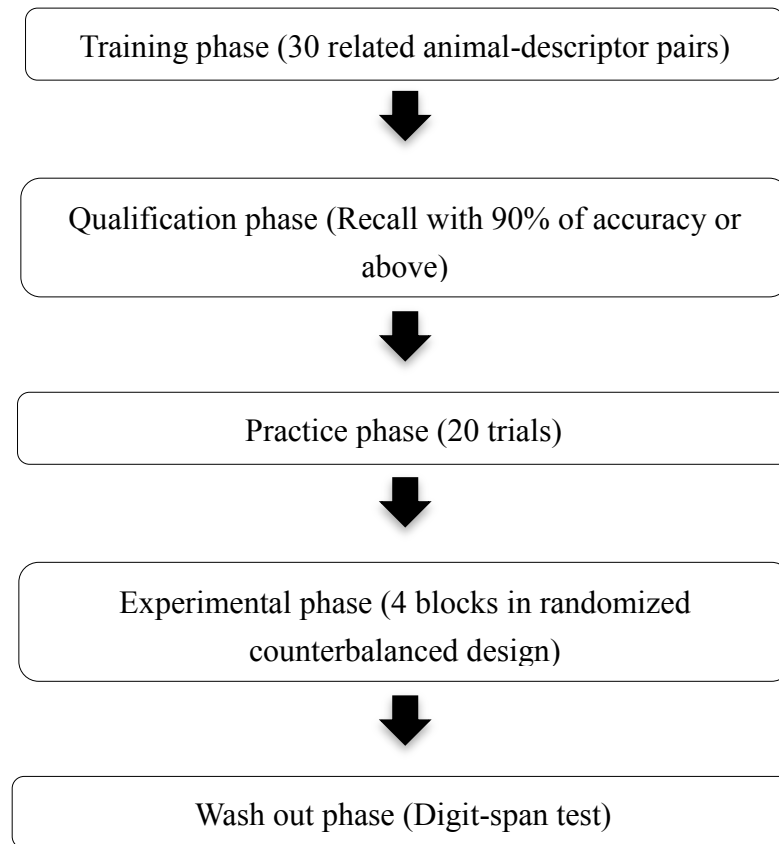
Training phase

The training was specific to the visual and associative condition blocks. Each subject was required to learn associating the animal name with the related visual-based or associative-based semantic descriptors (called congruent) before he or she proceeded to the testing phase (visual or associative block). The training session was self-paced; in the session, the subject was presented with 30 animal-descriptor pairs formed by six animals and five related descriptors for each of them. After the presentation of each pair, the subject was required to memorize the name of the animal and then the descriptor followed. Each

training session took 20 minutes to complete. It was conducted using a laptop computer with a slideshow presentation program. All of the animal-descriptor pairs in the training session were used again in the subsequent experimental block. The training was conducted in a self-paced manner so that the subject could proceed to the next pair in his or her own time. On the first slide of each training slideshow, it indicated whether it was a visual or a associative concept training session. The slide showed the definition of the visual or associative concept and then gave examples of a related animal-descriptor pair.

Qualification phase

This phase immediately followed the training session. The subject was shown the name of one animal and was asked to recall the descriptors associated with the name that they had learnt in the training session. The subject was required to attain 90% accuracy or above in the recall to qualify for the task. If the subject failed to pass the threshold, he or she had to redo the training and qualification session until the required accuracy was attained. The whole process of the training and qualification phases ensured that all of the subjects gained a comparable scope of knowledge (animal-descriptor pairs) so as to minimize the within-group differences in this study.

Experimental phase

Before a subject performed the task, he or she was presented with 20 practice trials.

This ensured that the subject was familiar with the experimental procedures and responses.

Wash out phase

The subject was required to complete the digit span test after completing one task

block.   This test served as a wash out which would alleviate the possible carry-over effect of

learning from engaging in the experimental task, particularly when shifting from a perceptual

to a semantic block or vice versa.   The digit span test involved attention (by forward digit

span) and working memory (backward digit span) and took 5 minutes to complete.

Statistical Analysis

The statistical analysis of the present study was divided into two major levels.   The

first level of analysis adopted a planned paired-samples t-test to test the three major aims of

the study: to examine 1) the differences in reaction time between short and long SOA

conditions under visual and associative conditions respectively across age groups; 2) the

differences in reaction time between the congruent and incongruent conditions across age

groups; and 3) the differences in reaction time between the visual and associative encoding

conditions across age groups.   The mean RT and accuracy of the trials under each condition

were computed.   Using the Bonferroni adjustment, all of the planned pairwise comparisons

were conducted on the significant effects by setting the p value as .05 divided by the number

of comparison pairs.

On the second level of the analysis, a post hoc two-way repeated measure ANOVA was conducted to examine the differences and the interaction effects between the encoding processes and age group conditions. Furthermore, a post hoc three-way repeated measure ANOVA was conducted to examine the differences and the interaction effects on the RTs between encoding processes, congruency, and age group conditions. All of the statistics were computed using SPSS 16.0. The significant level for all of the statistical tests was set at $p \leq 0.05$. For all of the within-subject effects in the repeated measures ANOVA, the Greenhouse-Geisser was reported to correct for the significance to compensate for the violation of sphericity.

To eliminate several confounding variables that exist in the ageing process in order to ensure a meaningful statistical comparison of the network encoding between the young and older adult age groups, we adopted stringent normalization procedures to generate two types of score – the "associative encoding efficacy score" and the "encoding facilitation score". The efficacy of the associative encoding process over the visual encoding process across age group was computed by taking the ratio of the difference in RT between the two types of trials:

$$\text{Encoding efficacy score (Associative)} = \frac{RT_{\text{Visual Congruent}} - RT_{\text{Associative Congruent}}}{RT_{\text{Associative Congruent}}}.$$

Moreover, the encoding facilitation score was computed to allow pairwise comparison on the encoding facilitation effect between the associative and the visual encoding process across age group. The calculation of the score was derived from the ratio of the difference between the associative incongruent trials and the associative congruent trials and the descriptive results:

$$\text{Associative Facilitation Score} = \frac{RT_{\text{Associative Incongruent}} - RT_{\text{Associative Congruent}}}{RT_{\text{Associative Congruent}}};$$

$$\text{Visual Facilitation Score} = \frac{RT_{\text{Visual Incongruent}} - RT_{\text{Visual Congruent}}}{RT_{\text{Visual Congruent}}}.$$

It was noted that in the initial section of the analysis of the contrast between the Short and Long SOA conditions, it was likely that confounded results would be identified in the Short SOA condition that may affect the interpretation of the encoding in the category verification paradigm. To further uncover the influences of the underlining confounded factors, a follow-up analysis was conducted in which the congruent trials were regrouped to form short-short SOA (SS-SOA) and long-short SOA (LS-SOA), respectively. The new grouping further improved the sensitivity of the comparisons. Therefore, in the latter parts of the data analysis, Long SOA was the main focus for the analysis and interpretations of the results because it was presumed to be free from the influences of the confounded factors that may exist in the Short SOA condition.

CHAPTER IV

RESULTS

This chapter reports the demographic characteristics of the subjects and their performances on the category verification task.

Demographic Characteristics of the Subjects

The younger group consisted of 31 right-handed university students, 15 males and 16 females (mean age = 21.3, *SD* = 2.4) (Table 4.1). The older group consisted of 29 right-handed older adults, 13 males and 16 females (mean age = 72.0, *SD* = 6.6). The younger adults were students recruited from The Hong Kong Polytechnic University, while the older adults were recruited from a community centre for older adults. The majority of the older adults had received a primary or secondary level education. All of the younger subjects were receiving a university level education. All of the subjects had no reported history of sensory or motor deficits or of musculoskeletal or neurological problems. They also had no signs or history of other psychological or psychiatric disorders.

Table 4.1.

Demographic Characteristics of Subjects (N=60)

	Younger Adults (n=31)	Older Adults (n=29)
Age		
Mean (SD)	21.3 (2.4)	72 (6.6)
Gender		
Female (%)	16 (51.6)	16 (55.2)
Male (%)	15 (48.4)	13 (44.8)
Educational level		
Primary	-	13
Secondary	-	12
Tertiary	-	2
University	31	2

Performance on the Category Verification Task

The performances of the subjects in the category verification task are summarized in Table 4.2. Among the younger subjects, the response times for the visual trials were, in general, longer than those for the associative trials. The congruent trials had longer response times than the incongruent trials. The effects of SOA were more obvious on the congruent trials than the incongruent trials, with the longer response times being associated with short but not long SOA. In contrast, the differences in the response time due to the short and long SOAs were minimal among the incongruent trials. The accuracy rates for the younger subjects were around 95% or above in all task conditions.

Among the older subjects, the response times for the visual trials were also longer than those for the associative trials.   In contrast to their younger counterparts, the response times of the older subjects in the congruent trials were shorter than in incongruent trials. The effects of SOA on response times were also different from those observed among the younger subjects.   Disregarding the type of encoding and congruency conditions, the response times were, in general, much longer in the short SOA trials than in the long SOA trials.   The accuracy rates for the older subjects were in general lower than those for the younger subjects.   They ranged between 87.4% (for visual, incongruent, and long SOA trials) and 92.8% (for associative, incongruent, long SOA trials).

The observed differences were tested with inferential statistics and reported in the next section.

Table 4.2.

Performances of Subjects on the Category Verification Task in terms of Response Time (RT) and Accuracy Rate (AC)

Stimulus			Visual				Associative			
Congruency			Congruent		Incongruent		Congruent		Incongruent	
SOA			Short	Long	Short	Long	Short	Long	Short	Long
Acronym[a]			VCS	VCL	VIS	VIL	ACS	ACL	AIS	AIL
Age Young		Mean RT	869.2	727.1	766.2	785.6	801.7	707.3	744.4	768.8
		(*SD*)	(146.9)	(124.8)	(135.8)	(147.6)	(122.1)	(120.0)	(87.0)	(120.8)
	Old	Mean RT	1682.3	1521.3	1842.4	1775.7	1484.2	1312.7	1791.5	1646.4
		(*SD*)	(585.2)	(574.2)	(741.5)	(672.4)	(586.4)	(549.8)	(907.2)	(717.8)
Age Young		Mean AC %	95.0	94.4	95.7	98.4	94.0	96.0	94.2	96.9
		(*SD*)	(4.8)	(4.2)	(5.0)	(3.0)	(5.1)	(5.4)	(5.0)	(3.6)
	Old	Mean AC %	91.6	91.6	90.0	87.4	89.8	93.1	88.8	92.8
		(*SD*)	(8.3)	(7.5	(10.0)	(12.0)	(8.4)	(9.5)	(9.9)	(6.8)

[a] The acronyms for the different conditions: the first letter denotes what network was being cued or primed (V for visual; A for associative); the second letter denotes the condition of congruency (C for congruent condition; I for incongruent condition); and the third letter denotes the SOA (S for short; L for long).

Contrast between Short and Long SOA Conditions

Visual conditions

The congruent trials were contrasted. The mean reaction time of the short SOA trials was found to be significantly longer than that of the long SOA condition for both the younger group ($t(30) = 7.09$, $p < 0.01$) and the older group ($t(28) = 2.82$, $p < 0.01$) (Table 4.3). For both age groups, no significant differences were revealed in the mean accuracy rate between the short and long SOA conditions ($p > 0.05$) (Table 4.4).

<u>Associative conditions</u>

Similarly, the mean reaction time was found to be significantly longer in the short SOA condition than in the long SOA condition for both the younger group ($t(30) = 4.74$, $p < 0.01$) and the older group ($t(28) = 2.47$, $p < 0.05$) (Table 4.3). However, for both age groups, no significant differences were revealed in the accuracy rate between the short and long SOA conditions ($p > 0.05$) (Table 4.4).

Table 4.3.

Comparison of Mean Reaction Times (RT) between Short and Long SOA Congruent Conditions

Process	Congruency	Age	SOA	Mean RT (ms)	*df*	*t*-value	*p*-value
Visual	Congruent	Young	Short	869.2	30	7.091	<0.001
			Long	727.1			
		Old	Short	1682.3	28	2.821	0.009
			Long	1521.3			
Associative	Congruent	Young	Short	801.7	30	4.738	<0.001
			Long	707.3			
		Old	Short	1484.2	28	2.465	0.020
			Long	1312.7			

Table 4.4.

Comparison of Mean Accuracy Rates between Short and Long SOA Congruent Conditions

Process	Congruency	Age	SOA	Mean Acc (%)	df	t-value	p-value
Visual	Congruent	Young	Short	95.0	30	.597	0.555
			Long	94.4			
		Old	Short	91.6	28	.000	1.00
			Long	91.6			
Associative	Congruent	Young	Short	94.0	30	-1.342	0.190
			Long	96.0			
		Old	Short	89.8	28	-1.257	0.219
			Long	93.1			

The results obtained from comparing the task performances between the short and long SOA were rather counterintuitive as the reaction times were significantly longer in the former trials than in the latter trials. The facilitation of SOA, if any, would have been manifested as faster response times for the shorter SOA trials. To further uncover the possible confounding factors embedded in the short SOA trials, a follow-up analysis was conducted in which congruent trials with a short SOA of 100 to 250 ms were selected and regrouped to form the short-short SOA (SS-SOA), while those with a SOA of 250 to 400 ms were grouped to form the long-short SOA (LS-SOA) (Table 4.5). This new grouping would further improve the sensitivity of the comparisons. The comparison of RTs between the SS and LS trials in the short SOA condition revealed that for both the younger and older subjects, the trials in the former subgroup had a significantly longer mean RT than the trials in the

latter subgroup (in perceptual conditions, Younger: $t(30) = 3.00$, $p < 0.01$; Older: $t(28) = 2.40$, $p < 0.05$; in semantic conditions, Younger: $t(30) = 2.24$, $p > 0.05$; Older: $t(28) = 2.43$, $p < 0.05$). The findings suggested possible de-facilitating effects exerted on the two encoding processes due to the short SOA. The plausible reasons behind these unexpected findings will be further elaborated in the discussion section. In the subsequent analyses, only the data obtained based on the long SOA conditions were used.

Table 4.5.

Comparisons of Reaction Times (RT) between Shorter and Longer Trials Within the Short SOA Conditions

Process	Age	Short SOA	Mean RT (ms)	*df*	*t*-value	*p*-value
Visual	Young	SS	910.5	30	3.00	0.005
		LS	827.8			
	Old	SS	1714.7	28	2.40	0.023
		LS	1649.9			
Associative	Young	SS	845.4	30	2.56	0.016
		LS	758.0			
	Old	SS	1551.5	28	2.43	0.022
		LS	1416.9			

Note. SS refers to the short SOA within 100 to 250 ms, while LS refers to the short SOA within 250 to 400 ms.

Testing of Encoding Process and Age Effects

The results obtained from congruent trials under the long SOA conditions were used in

the rest of the analysis testing the effects of the encoding process and age on subjects'

performances in the category verification task.   The main reason for this was that the long

SOA conditions appeared not to be affected by the unexpected de-facilitating processes

undergone in the short SOA conditions.

The results from a two-way repeated measure ANOVA on the mean response time of

the congruent trials revealed significant Process and Age effects (Process: $F(1,58) = 15.37$, p

$< .01$); Age: $F(1,58) = 49.72$, $p < .01$).   The Process x Age interaction effects were also

statistically significant ($F(1,58) = 10.51$, $p < .01$).

<u>Age effects</u>

The younger subjects were found to perform significantly faster on the congruent and

long SOA trials than the older subjects in both visual and associative conditions (Visual: $t(28)$

$= -7.93$, $p < .01$; Associative: $t(28) = -5.97$, $p < .01$) (Table 4.6).   The accuracy rates,

however, were not found to be significantly different between the two age groups ($p > .05$)

(Table 4.7).

Table 4.6.

Comparison of Reaction Times (RT) between the Younger and Older Groups in Congruent

Trials under the Long SOA Condition

SOA	Congruency	Process	Age	Mean RT (ms)	df	t-value	p-value
Long	Congruent	Visual	Young	732.2	28	-7.93	<0.001
			Old	1521.3			
		Associative	Young	708.9	28	-5.97	<0.001
			Old	1312.7			

Table 4.7.

Comparison of Accuracy Rate between the Younger and Older Groups in Congruent Trials

under the Long SOA Condition

SOA	Congruency	Process	Age	Mean Acc (%)	df	t-value	p-value
Long	Congruent	Visual	Young	94.5	28	1.86	0.074
			Old	91.6			
		Associative	Young x	95.7	28	1.90	0.067
			Old	92.8			

Encoding process effects

The older subjects had significantly shorter mean RTs on the associative encoding trials than on the visual encoding trials under the congruent condition ($t(28) = 3.5$, $p < 0.01$) (Table 4.8). No significant difference in mean RT between the two encoding conditions was revealed for the younger subjects ($p > 0.05$).

Table 4.8.

Comparison of Reaction Times (RT) between Visual and Associative Encoding Trials under

Congruent and Long SOA Conditions

SOA	Congruency	Age	Process	Mean RT (ms)	*Df*	*t*-value	*p*-value
Long	Congruent	Young	Visual	727.1	30	0.919	0.365
			Associative	707.3			
		Old	Visual	1521.3	28	3.745	0.001
			Associative	1312.7			

Testing of Encoding Process, Age, and Congruency Effects

The results obtained from a three-way repeated measure ANOVA on mean RT revealed significant Process ($F(1,58) = 9.56$, $p < .05$), Age ($F(1,58) = 57.24$, $p < .05$), and Congruency ($F(1,58) = 59.78$, $p < .05$) effects (Table 4.9). The interactions between the three main effects were significant for Congruency x Age ($F(1,58) = 26.12$, $p < .05$) and Process x Age ($F(1,58) = 6.19$, $p < .05$). Other interaction effects were statistically not significant. The main and interaction effects on the accuracy rates were all statistically not significant ($p > 0.05$).

Table 4.9.

Results of Three-way Repeated Measure ANOVA on Mean RT in Congruent Trials in the Long SOA Conditions

Effects	*Df*	*F*-value	*P*-value
Process	1, 58	9.56	0.003
Age	1, 58	57.24	<0.001
Congruency	1, 58	59.78	<0.001
Congruency x Age	1, 58	26.12	<0.0001
Process x Congruency	1, 58	1.18	0.282
Process x Age	1, 58	6.19	0.016
Process x Age x Congruency	1, 58	1.01	0.318

Congruency effects

The results showed that for both age groups, the mean RT for the congruent trials was significantly faster than that for the incongruent trials in both the visual encoding condition (Young: $t(30) = -3.36$, $p < .01$; Old: $t(28) = -4.39$, $p < .01$) and the associative encoding condition (Young: $t(30) = -3.80$, $p < .01$; Old: $t(28) = -5.60$, $p < .01$) (Table 4.10).

Table 4.10.

Comparison of Reaction Times (RT) in Congruent and Incongruent Long SOA Trials between the Visual and the Associative Encoding Conditions

Process	SOA	Age	Congruency	Mean RT (ms)	*Df*	*t*-value	*p*-value
Visual	Long	Young	Congruent	752.9	30	-3.355	0.002
			Incongruent	785.6			
		Old	Congruent	1521.3	28	-4.392	<0.001
			Incongruent	1775.7			
Associative	Long	Young	Congruent	707.3	30	-3.795	0.002
			Incongruent	768.8			
		Old	Congruent	1312.7	28	-5.598	<0.001
			Incongruent	1646.4			

Among the younger subjects, the mean accuracy rates were lower in the congruent visual trials than in the incongruent visual trials ($t(30) = -4.05$, $p < .01$); such differences were not observed in the associative trials ($p > .05$) (Table 4.11). No significant differences in accuracy rates were revealed in the other comparisons ($p > .05$).

Table 4.11.

Comparison of Mean Accuracy Rates between Congruent and Incongruent Long SOA Trials

in Different Encoding and Age Conditions

Process	SOA	Age	Congruency	Mean Acc (%)	Df	t-value	p-value
Visual	Long	Young	Congruent	94.4	30	-4.052	<0.001
			Incongruent	98.4			
		Old	Congruent	91.6	28	1.52	0.139
			Incongruent	87.4			
Associative	Long	Young	Congruent	95.0	30	-0.502	0.619
			Incongruent	95.7			
		Old	Congruent	93.1	28	0.170	0.866
			Incongruent	92.8			

Age Effects on Normalized Encoding Processes

The encoding efficiency (semantic) index was defined as the normalized RT differences between the visual and the associative encoding trials (based on semantic) in the category verification task. The results revealed that the age effect on encoding efficiency was significant. The encoding efficiency for the younger group was 0.039 (SD = 0.25), while that for the older group was 0.174 (SD = 0.17). The younger group yielded a significantly higher encoding efficiency (associative) than the older group ($t(30)$ = -2.47, p < .05). These results suggested that the RT differences between the visual and associative encoding conditions appeared to diminish in the older subjects.

The encoding facilitation index was defined as the extent to which congruent trials

would be facilitated by normalizing the RT differences between the incongruent and congruent trials (based on congruent) in the category verification task. For the younger subjects, the facilitation indices for the visual and associative encoding trials were 0.088 (SD = 0.13) and 0.098 (SD = 0.153), respectively. For the older subjects, the facilitation indices for the visual and associative encoding trials were 0.152 (SD = 0.128) and 0.250 (SD = 0.208), respectively. The associative facilitation index was found to be significantly larger than the visual facilitation index among the older subjects ($t(28)$ = -3.22, $p < .05$), while such differences were not observed among the younger subjects ($p > .05$). Between age-group comparisons indicated that the associative facilitation index for the older subjects was significantly larger than that for the younger subjects ($t(28)$ = -2.86, $p < .05$). The differences in the visual facilitation index were not statistically significant ($p > .05$).

CHAPTER V

DISCUSSION

Part I. Short SOA Confounded Performances in the Category Verification Task

It was hypothesized that subjects would have a shorter reaction time when encoding under short rather than long SOA conditions. The results obtained in this study did not support this hypothesis in that both the younger and older subjects were found to have significantly longer mean reaction times in the short SOA conditions than in the long SOA conditions (see Table 4.3). The findings were consistent for the visual and associative encoding tasks. The counterintuitive findings suggested that short SOA conditions would exert de-facilitating effects on the encoding processes. In contrast, the expected facilitating effects existed in the long SOA conditions. One plausible explanation for this de-facilitating effect is that the time taken to register the prime stimulus (i.e., the first animal word) was delayed and extended into the 100-400 ms time window originally set for the short SOA conditions. Such a delay was likely to be more significant in the first half of the 100-400 ms time window than in the second half. This postulation was supported by the reaction time for the 100-250 ms trials being significantly longer than that for the 250-400 ms trials under the short SOA conditions.

This phenomenon could be further explained by the stage model of encoding. The encoding of a visually presented word, as is the case in the presentation of the prime stimulus, involved successive stages of perception, attention, and executive control until it could be comprehended to elicit a response (match or nonmatch). As stipulated by Posner and Petersen (1990), the perceptual stage involves the registration of a visual stimulus and the transmission of the captured images for further processing via the visual system. The attention function enables the encoded images and visual sensory information to be temporarily stored within the iconic memory and working memory. Baddeley (2009) further suggested that encoded visual information will be stored in the visuo-spatial sketchpad. For the category verification task used in this study, the subjects needed to register the first animal word, which was the prime stimulus, and capture it in the iconic memory before encoding it for the subsequent match or nonmatch response. The time taken to complete this encoding process would need to be shorter than the time when the target stimulus (features or characteristics of the animal) was presented (i.e., 100-400 ms for the short SOA condition and 800-110 ms for the long SOA condition). In case that encoding of the first animal word took a time that was longer than the SOA, the subjects might have needed to actively maintain the partially encoded first animal word in the iconic memory and, at the same time, register the target stimulus for encoding. The comparisons and matching between the first animal word and the second feature/characteristic word would have tapped

their attentional and executive resources.   The parallel processing would have involved the subjects having to suppress or disengage from encoding the first word.   The suppression of or disengagement from encoding the first animal word might have resulted in a delay in the reaction time in the short SOA trials, particularly the short-short ones (100 to 250 ms) (Finnigan et al., 2010).   Other studies have investigated the processes of "postlexical matching" using an automatic versus a controlled priming paradigm (Bell, Chenery, & Ingram, 2001; Hartman, 1991).   The subjects in these studies examined the relationship between the target and the prime stimuli under different SOA conditions.   The results indicate that the suppression / disengagement processes tend to be conscious and controlled and reveal that these processes consume substantial attentional resources in the executive function subsystem.   These processes were reflected in the increases in response times in these studies' trials.   Gazzaley et al. (2005) further explained that the disengagement process would need to mobilize extra resources in the working memory to capture and process two or more pieces of information, resulting in a slower process.   However, the extent to which the delay would interfere with the active spreading activation of encoding is unclear as a category verification task cannot differentiate the time taken for each of the encoding subprocesses.

Our results indicate that both the younger and older subjects had longer reaction times in the short-short SOA trials (100-250 ms) than in the long-short SOA trials (250-400 ms) (refer to Table 4.4).   It is noteworthy that no significant differences were revealed in the

accuracy rates between these conditions (see Table 4.5).   These findings further suggest that

the shorter duration between the presentation of the first (animal name) and second (feature /

characteristic) words did not make the trials more difficult but did require a set time for

completing the encoding processes.   They seem to imply that a shorter or longer duration

within the short SOA condition is not likely to interfere with the cognitive processes of

encoding, as is evident from the nonsignificant speed-accuracy trade-off in both the younger

and older groups (87% or above) (Ober, 2002).

In the subsequent sections, the focus is on discussing the results generated from the

long SOA conditions which would avoid the possible confound revealed in the short SOA

conditions.

Part II. Effects of Ageing on Visual and Associative Encoding

<u>Effect of ageing on the encoding process</u>

The results of this study indicated significant interaction effects between visual and

associative encoding and age group on subjects' reaction times in the category verification

tasks.   The older subjects were found to perform significantly slower in the visual congruent

condition than in the associative congruent condition.   Such differences were not observed

among the younger subjects.   These findings support our hypothesis that ageing would have

differential modulation effects on the visual and the associative encoding processes.   Such

modulation effects appear to be more significant on the visual encoding process than on the associative encoding process. The modulation phenomenon observed in this study is consistent with that reported by Koutstaal (2003). Koutstaal further explained that the modulation effects are plausibly attributable to the decline in the ability to capture visual details and features, among older subjects. This decline in ability would reduce the priming effects acting on the visual semantic network. In contrast, younger subjects can maintain a high level of ability in capturing visual details during the stimulus registration phase. These details would, in turn, facilitate the subsequent visual semantic encoding process and hence the retrieval process.

<u>Decline in encoding-related cognitive abilities due to ageing</u>

Besides visualizing the visual-based semantic details, a general decrease in processing time due to ageing would perhaps contribute to the slowness in both the visual and associative semantic encoding processes, as was evident in this study from the significantly faster reaction times of the younger group compared to the older group in all task conditions. The effects of ageing in terms of bringing about a decline in processing time have been well documented in a vast number of studies. Lee et al. (2006) revealed that the slow processing speed among older subjects delays the suppression of irrelevant information at the beginning of the encoding process, resulting in undesirable interference with the processing of relevant information. It has also been shown that the slow processing time of older people also

impedes their attentional control during the encoding process (Lee et al., 2006; Wang et al., 2010).   Birren and Fisher (1995) reported that older adult subjects show slower response times in lexical decision, naming, categorization, and various verbal fluency tasks.

The general slowness of older subjects poses challenges to research seeking to make comparisons with their younger counterparts.   Other researchers have highlighted the importance of, and the ways to normalize, results obtained separately from younger and older subjects to allow meaningful comparisons to be made (e.g., Giffard, Desgranges, & Eustache, 2005; Ober, 2002).   In the next section, the findings based on the two indices derived in this study, namely the encoding efficiency and the encoding facilitation indices, will be discussed.

Effects of ageing on normalized task conditions

The three-way ANOVA model revealed significant Age x Process and Age x congruency interaction effects on subjects' reaction times in the category verification tasks. These findings further support our second hypothesis that ageing would modulate the encoding process.   Two ways were proposed to normalize the results so as to enable meaningful between-task and between-age group comparisons to be made.   The encoding efficiency (associative) index normalizes visual-based encoding by the associative-based semantic encoding process.   A large value would indicate a greater efficiency decline in the visual-based encoding process than in the referent associative encoding process.   Post hoc

analysis indicated that the older subjects had a significantly larger index value than the younger subjects. The results suggest that the likelihood that the older subjects had undergone decline in visual-based semantic encoding ability was more obvious than a decline in their associative-based semantic encoding ability. In other words, it is possible that the older subjects may have more deterioration in the visual semantic network than in the associative semantic network. The larger visual-associative encoding discrepancy in the older subjects may have been due to their reduced ability to attend to the visual details mentioned above. Visual details captured from external information would need to be transformed into images and meanings for processing. In contrast, associative information does not need to be transformed and can readily be utilized in the semantic network. Our proposition is supported by Rahhal et al.'s (2002) study, which revealed that older subjects attend less to perceptual details in visual semantic encoding compared to associative semantic information. Ferguson et al. (1992) and Rémy et al. (2008) found that older subjects perform less well than younger subjects in terms of visual information processing only if tasks manipulate the attention load to a high level. These studies concluded that a decline in the attention required for capturing details accounts for the poor performance of older subjects in visual encoding tasks.

Congruent and incongruent conditions in encoding

The results of this study indicated that, in general, the younger and older subjects had faster reaction times in congruent trials than in incongruent trials irrespective of the encoding conditions. These findings concur with previous studies on the priming facilitation effect. The faster reaction time for congruent responses can be explained by the spreading activity theory proposed by Collins and Loftus (1975). The faster responses are likely to be attributable to the strong or direct links that exist between the representations of words that are closely related in meaning (and hence produce congruent responses). Neely (1991) reported that faster responses were elicited when the target words were followed by semantically related rather than unrelated words. Therefore, the recognition of nodes representing related words takes less time. The differences in the reaction times between the congruent and incongruent conditions reflect the neurocognitive facilitation effect of encoding. The larger the differences, the greater the activation of the related neural network (Hasselmo, 2007). In our study, the presentation of the first animal word (i.e., prime stimulus) elicited an activation spread along the paths of an interconnected network which consists of associated concepts in the visual and associative semantic subnetworks. The faster reaction time for the congruent trials and the slower reaction time for the incongruent trials demonstrated the facilitation effects of the priming stimuli in both visual and associative semantic under the long SOA conditions. However, among the older subjects,

these facilitation effects appeared to be impeded more in the visual encoding process and less in the associative encoding process.

Visual and associative encoding processes in congruent conditions

The older subjects in this study had significantly longer reaction times in the visual encoding trials than in the associative encoding trials. These differences were not observed among the younger subjects. These results seem to suggest that the visual encoding process is more susceptible to decline in old age than the associative encoding process. They further support the notion that the visual- and associative-semantic network activations are differentiable. The present study took the advantage of using the same stimuli (first animal words for priming) to elicit the encoding processes. Thus, the visual-associative encoding differences thereafter would not be due to the registration process associated with the visual stimuli but to the processes subsequent to the images being captured in the ionic memory. Our results support the conventional view that semantic information can be processed in two main streams: associative/functional stimuli and visual/perceptual-based stimuli. The sensory-functional hypothesis (Warrington & McCarthy, 1987; Warrington & Shallice, 1984) further stipulates that visual encoding will process the subordinate sensory, visual properties of the stimulus, while associative encoding will process the superordinate abstractive meaning of the stimulus. These encoding processes have been framed to follow a

hierarchical order, in that visual semantic information requires more specificity and details,

the processing of which will be slower and shallow. In contrast, associative semantic

information involves conceptual representation and a high degree of generality and class

inclusion, the processing of which will be faster and have higher recall accuracy (Biederman,

1987; Tversky & Hemenway, 1984).

Age effects on normalized congruent-incongruent conditions

The present study utilized stimuli of the same form (animals only) and well-trained

conditions (training and qualification) to minimize the task-related factors which could

confound the age-group comparisons across the different congruency and encoding process

conditions. Neely (1991) and Ober (2000) proposed computing the differences in reaction

times between incongruent and congruent trials (i.e., unrelated RT – related RT) to reflect the

priming facilitation effect. To further tackle the general decrease in processing time among

the older subjects, this study used the proportional differences in RT when conducting the

comparisons between the older and younger groups (i.e., (Incongruent RT – Congruent RT) /

Congruent RT yielded the visual and associative facilitation scores). The normalization

process further eliminated the effects brought by the systematic slowness among the older

subjects.

The results indicated that the associative facilitation score was significantly larger

than the visual facilitation score among the older subjects. These differences were not observed among the younger subjects. The associative facilitation score for the older subjects was significantly higher than that for the younger subjects. The visual facilitation scores were not significantly different between the two age groups. These findings suggested that older subjects would gain less facilitation from the priming when encoding visual semantic information. In contrast, the facilitation when encoding associative semantic information seems to be relatively better preserved. Our results also indicated that the older subjects had more difficulty with encoding visual related characteristics, which were specific and detailed in nature (Craik, 2006). Ramponi et al. (2004) further explained that the decline in visual semantic encoding is likely to be due to the decrease in ability among older people to merge characteristics of an encoded event or stimulus into a cohesive representation; this decreased ability is associated with poor binding and working memory functions (Naveh-Benjamin, 2000; Naveh-Benjamin et al., 2003, 2004, 2007). Conversely, the associative semantic network of general knowledge is regarded as being relatively more cohesively organized and as having links that have been established over a lifespan, and thus it is less susceptible to the binding problem associated with ageing (Backman, Small, & Wahlin, 2001; Naveh-Benjamin et al., 2003).

Variation of Semantic Encoding Process in Chinese and English

In this study, the subjects are Chinese and the stimuli were Chinese words. However, most of the previous studies we have discussed regarding semantic process and category specific effect, sensory/functional hypothesis were based on English. These raise questions of whether the linguistic difference between English and Chinese will modulate the visual and associative semantic process under the semantic verification paradigm design. Chinese characters have many distinct features that alphabetical words lack (Hung and Tzeng, 1981; Wang, 1973). The logographic nature of Chinese characters may engender a contention that there exists a closer relationship between shape and meaning, which in turn leads to a conjecture that reading Chinese characters would preferentially engage the ventral processing stream. (Chen and Juola, 1982; Leck et al., 1995). However, other studies revealed that the semantic processing of Chinese characters, English words activates a common semantic system within which there are modality-specific differences. Chee, Weekes, Lee, Soon, Schreiber, Hoon, & Chee (2000) found that a similar pattern of activation and contrasts was observed when English words and pictures were compared in another set of bilingual participants. When character and word semantic processing were compared directly, the loci of activation peaks were similar in both languages. Moreover, Chen & Ng (1989) utilized lexical decision to investigate the semantic facilitate effect in across Chinese and English bilinguals. They found that between language and within language stimuli produced

comparable effects of semantic facilitation. This further support that the lexical access to meaning across Chinese and English shared the same structure of conceptual system. In the present study, a same set of single word animal was used across both visual semantic and associative semantic conditions. Therefore, the logographic effect should be reduced and balanced out. We can assume that the semantic encoding processing of Chinese characters closely resembles English words under the current experimental paradigm design.

CHAPTER VI

CONCLUSION

The present study used category verification tasks to investigate the effects of ageing on the human memory's processes of encoding visual and associative semantic information. We utilized Chinese characters for animal words and descriptors of animal features (visual semantic information) and characteristics (associative semantic information) and manipulated SOA length, congruency, and the types of encoding between the younger and older groups. The results indicate that both the younger and the older subjects had significantly longer reaction times in the visual trials than in the associative trials, suggesting that associative semantic encoding was facilitated more in the experimental tasks. Our findings concur with those of other studies (e.g., Guo et al., 2004; Walla et al., 2001) which suggest a more extensive activation from the associative semantic network relative to the visual semantic one. In our study, such superior effects appeared to be maintained among the older subjects. In the results generated from the raw and normalized data, the older subjects consistently showed a decline in terms of their visual semantic encoding process. The general observation is that the older subjects had relatively longer reaction times when undergoing visual rather than associative semantic encoding processes. The decline in visual encoding processing was also shown in the smaller differences between the congruent and incongruent

trials. It seems that the age-related decline was due to less efficient access to the visual network. The lower efficiency could have been due to the decrease in the attentional and regulatory function, which meant that irrelevant information could not be eliminated from the processing. It also could have been due to the decrease in working memory impeding the binding of the relational information within the neural network. It is noteworthy that the age-related visual-associative differentiation was observed in the discrepancies in the reaction times but not in the accuracy rate in the category verification tasks.

Limitations

The relatively small sample size and the specific demographic characteristics of the subjects recruited in this study limit the power of the statistical analysis and generalization of the findings. Caution should be taken when interpreting the results and applying the findings to individuals or groups different to those in the study. The differences in the educational level of the younger (higher level) and older (lower level) subjects confounds the results. Previous studies have reported that older subjects with a higher education level may have less deterioration in their processing speed and attention function (Nebes et al., 2006) and memory functions (Angel et al., 2010; Nyberg et al., 1996). The differences revealed between the younger and older groups could possibly have been aggravated by the difference in educational level. However, as Desgranges, Eustache, and Rioux (1994) reported that

education level is not a significant factor influencing older subjects' performance in implicit word-stem completion tasks, the extent to which the lower education level of the older subjects in this study affecting their performance could be less than anticipated. The training received by the older subjects prior to the experiment on learning the animal word and associated features/characteristics may have further alleviated such differences.

Finally, our present study utilized a behavioural investigation approach, which also limits the inferential power to unveil the temporal difference in a particular stage of the encoding process. This is a general limitation of behavioural studies in cognitive psychology when studying a cognitive neural process.

Implications for Future Research

From the present study, we have identified the factors that modulate the effectiveness of encoding in the visual and associative semantic networks. Apparently, there are extraneous neural activities present in particular encoding processes that create a facilitatory (or even inhibitory) effect on the response which is reflected in the speed of completing a word verification task. Therefore, a neurophysiological method should be employed in future studies to shed detailed light on mental processes related to encoding. An ERP technique is the valid method to use to uncover the encoding process in a temporal perspective. According to Friedman (2007), the ERP technique offers a means of examining

in detail a temporal resolution of a particular mental process in the millisecond (ms) range. It enables the precise quantification of the temporal characteristics of neural activity within the encoding process in the human memory.   As the present study demonstrated the role of perceptual and semantic encoding processes in the memory, its study design and method of investigation provides a foundation for further neurophysiological or neuroimaging investigations on these encoding processes.   The behavioural data obtained can further substantiate the notion that visual and associative semantic-based encoding strategies involve different mental processes.

Second, it is important to investigate further the potentially different cognitive mechanisms and neural encoding processes of healthy older adults and people with pathological cognitive change.   As we learnt that visual and associative semantic encoding processes go through associative changes with ageing, in terms of a larger semantic network and diffused semantic activation (Miyamoto, Katayama, & Koyama, 1998), and in older adults with Alzheimer's disease, there seems to be a partial network deterioration apart from the decline in retrieval (Rogers & Friedman, 2008).   Froger et al. (2009) yielded results that indicated that older adults with mild cognitive impairment (MCI) benefit less from associative semantic encoding than younger healthy adults and their healthy counterparts. These findings seem to indicate that as one ages or contracts Alzheimer's disease or MCI, the problem may lie with the network, and if this is the case, intervening in the retrieval process

cannot address the issue. This implies that rehabilitation efforts should be directed towards designing interventions that enhance the associative semantic categorical structure of the knowledge representational network of older adults and place emphasis on minimizing interferences with visual semantic encoding while they build up this network. Therefore, the current findings can assist the design of theory-based and effective memory retraining programmes for people with stroke and brain injuries.

Finally, further research is necessary to enable us to understand the relationships between an individual's age, encoding style, cognitive ability, and memory performance. More importantly, the results of such research will help to explain the shortfalls of the current retrieval-based memory training in rehabilitation received by older adults and patients with age-related diseases. They fill the knowledge gap on designing interventions to enhance encoding functions and hence improve retrieval, which is the ultimate goal of memory for patients with brain pathologies.

CHAPTER VII

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CHAPTER VIII
APPENDICES

Appendix I – Consent Form (English Version)
The Hong Kong Polytechnic University
Department of Rehabilitation Sciences
Research Project Informed Consent Form

Project title: Encoding in healthy young adults and older adults: Semantic and perceptual processes

Investigator: Kin Chung Tang, Davynn Gim Hoon Tan

Supervisor: Prof. Chetwyn C H Chan

Project information:

        This study aims to explore the relationships between inhibition and the facilitative effect of semantic and perceptual encoding; and the differences in inhibition across age.

        There are two parts to this study, conducted on separate days. The duration for each part will be approximately 45 minutes to 1.25 hours. The tasks involve looking at pairs of words in traditional Chinese, learning them and responding to the presentation on a computer screen by pressing relevant keys on a keyboard. Details of the procedure are provided during the session. These tasks are designed to capture the cognitive process in encoding that is of interest in this study.

        The results of this study will enable us to understand more about the encoding of information which is crucial in subsequent recalling, and also the ageing effect on this cognitive process which has important implications for designing clinical interventions to enhance encoding for older adults and those with cognitive decline.

        You may approach the investigator for any clarification. Your participation in this study is entirely on a voluntary basis.

Consent:

I, _____, have been explained the details of this study. I voluntarily consent to participate in this study. I understand that I can withdraw from this study at any time without giving reasons, and my withdrawal will not lead to any punishment or prejudice against me. I am aware of any potential risk in joining this study. I also understand that my personal information will not be disclosed to people who are not related to this study and my name or photograph will not appear on any publications resulted from this study.

I can contact the investigators, Mr Tang KC (9679   ) or Ms Davynn Tan, at 34003960 (office) or davynn.gimhoon@   (email) for any questions about this study. If I have complaints related to the investigator, I can contact Ms Michelle Leung, secretary of the Departmental Research Committee, at 27665397. I am aware that I will be given a signed copy of this consent form.

Signature (subject): _____   Date: _____
Signature (witness): _____   Date: _____

Appendix II – Consent Form (Chinese Version)

香港理工大学康复治疗科学系科研同意书

研究題目

認知抑制如何影響健康年輕人和老年人的記憶編碼之促進作用：語義和知覺編碼過程

研究员

科研人員：鄧健聰先生, 陳錦芬小姐

導師：陳智軒教授

研究目的

這項研究主要探討認知抑制以及語義和知覺編碼之促進作用之間的关系, 并且認知抑制在不同年齡層的分別。

此項研究有兩部分，分兩天進行。每個部分為時大約 40 分鐘至 1 個小時。研究内容主要包括看電腦顯示屏上一對對的文字（中文繁體），把它們記下，並且按照指示在鍵盤上按鍵作出選擇。詳情可參閱[科研內容說明書]。研究內容的設計是為了引發記憶編碼過程和認知抑制。

這項研究的結果將有助於了解認知抑制在編碼過程的效應, 這是之後記憶的重要關鍵; 並且了解老化對認知抑制的影響，這對於為長者和患有認知退化的人設計臨床治療有深遠的意義。

若有疑问，您可詢问研究人员。您的参与是完全自愿性的。

同意书

本人＿＿＿＿＿＿＿＿＿＿＿已了解此项研究的具体情况。本人自愿参与这项研究，本人有权在任何时候、毫无理由地退出这项研究，而此举不需要我承担任何后果。本人明白参加此项研究的潜在危险性以及本人的资料将不会泄露给与此研究无关的人员，名字或相片不会出现在任何出版物上。

本人可以致电此次研究课题的研究人员:鄧健聰 9679　　或陈锦芬 34003960。若本人对研究人员有任何投诉，可以联系梁女士（部门科研委员会秘书），电话：2766 5397。本人亦明白，参与此研究课题需要本人签署一份同意书。

参与者的名字：

签名（参与者的家长/监护人）：＿＿＿＿＿＿＿＿＿　　　日期:＿＿＿＿＿＿＿＿

签名（证人）　　　:＿＿＿＿＿＿＿＿＿＿＿＿＿　　　日期:＿＿＿＿＿＿＿＿

Appendix III – Reading Passage for Screening

Qualification: Mistakes less than 10 words, repeated mistakes counted as one

有一天，小井蛙對來井邊喝水的畫眉鳥說："上一次，我不實事求是，而且總把今天該做的事推到明天做，結果一事無成。這一回，我再次立下雄心壯志：在八年內成為一位知識淵博的學者，還要學會爬樹，唱歌。

畫眉鳥聽了，說："井蛙弟弟，就別再說大話了，你整天只知道玩，能懂得1、2、3、就了不起了。"她說完就飛走了。

畫眉鳥走後，小井蛙心想：你不相信我，哼，你等著看！他拿出一本借來的《天空的奧秘》看了起來。他越吃越有滋味，他從早讀到晚，連飯都顧不上吃，他覺得書本的魅力實在太大了，把他深深地吸引住了。

這樣日復一日，年復一年，六年過去了，小井蛙已經是一位知識淵博的學者。他又開始想練習唱歌。清早，他從床上爬起來，他怕吵醒鄰居們，來到大海邊練習唱歌，他唱呀唱，一直唱到夕陽西下。一年365日天天如此。

一年後，小井蛙歌喉已經十分甜美，他又想練習爬樹。每天早上，他早早地來到森林裡一棵大白樺上練爬樹。一開始，他總是爬了一丁點就掉了下來，他不灰心，反反復複練習，終於成功了。

不知不覺，八年到了，畫眉鳥在此來到小井蛙住的井邊飲水。她對小井蛙說："井蛙弟弟，對不起，我不該看不起你。你知識淵博，歌喉甜美，爬樹勝過猴子，你真是森林裡的全能冠軍！"

Appendix IV – Stimulus Used in the Experiment

V1	Match						Not Match				
鴿	尖嘴	羽毛	兩腳	細小	翅膀		觸鬚	光滑	四腳	肥胖	鰓部
鯊	利齒	光滑	背鰭	巨大	鰓部		大鼻	毛髮	利爪	細小	甲殼
貓	觸鬚	毛髮	四腳	瘦小	長尾		尖嘴	皺紋	背鰭	巨大	翅膀
豬	大鼻	细毛	足蹄	肥胖	短尾		利齒	羽毛	兩腳	瘦小	鰓部
熊	利齒	毛髮	利爪	巨大	短尾		尖嘴	羽毛	足蹄	細小	長尾
龜	小眼	皺紋	四腳	細小	甲殼		觸鬚	细毛	利爪	肥胖	翅膀

A1	Match						Not Match				
鴿	飛行	家畜	溫馴	和平	生蛋		笨重	野生	懶惰	危險	吃肉
鯊	游水	野生	兇猛	危險	吃肉		緩慢	寵物	可愛	和平	爬行
貓	蹦跳	寵物	可愛	高貴	乾淨		飛行	野生	兇猛	污糟	生蛋
豬	緩慢	家畜	懶惰	污糟	胎生		爬行	寵物	游水	高貴	乾淨
熊	笨重	野生	兇猛	危險	吃肉		游水	家畜	溫馴	長命	生蛋
龜	爬行	寵物	溫馴	長命	生蛋		飛行	家畜	兇猛	危險	蹦跳

V2	Match						Not match				
鷹	尖嘴	羽毛	兩腳	巨大	翅膀		長舌	鱗片	四腳	扁長	背鰭
鯉	觸鬚	鱗片	鰓部	細小	背鰭		头角	皺紋	利爪	肥胖	翅膀
狗	長舌	毛髮	四腳	瘦小	長尾		尖嘴	羽毛	足蹄	扁長	背鰭
牛	头角	细毛	足蹄	肥胖	長尾		利齒	羽毛	兩腳	細小	翅膀
虎	利齒	毛髮	利爪	巨大	班紋		長舌	鱗片	鰓部	細小	硬皮
鱷	利齒	皺紋	四腳	扁長	硬皮		觸鬚	毛髮	足蹄	肥胖	班紋

A2	Match						Not match				
鷹	家畜	野生	敏锐	威风	生蛋		缓慢	家畜	勤劳	忠心	缓慢
鲤	游水	寵物	优闲	富贵	生蛋		奔跑	飛行	兇猛	危險	看守
狗	奔跑	寵物	可愛	忠心	看守		游水	野生	兇猛	威风	生蛋
牛	缓慢	家畜	溫馴	勤劳	吃素		爬行	生蛋	敏锐	富贵	吃肉
虎	奔跑	野生	兇猛	危險	吃肉		飛行	家畜	优闲	勤劳	吃素
鱷	爬行	家畜	兇猛	危險	吃肉		奔跑	寵物	可愛	忠心	吃素

Appendix V – Digit Span (Forward)

Discontinue after failure on BOTH TRIALS of any item.   Administer one trial per item.   If subject fails the first trial, go to the second trial.
Score 1 for the success in first or second trial per item.

Part I   DIGITS FORWARD

我會講一啲數目字，你留心聽住，當我講完之後，你將佢講番出嚟。
（錄音）

Digits Forward		Pass-Fail	Score (1 or 0)
3.	5-8-2		
	6-9-4		
4.	6-4-3-9		
	7-2-8-6		
5.	4-2-7-3-1		
	7-5-8-3-6		
6.	6-1-9-4-7-3		
	3-9-2-4-8-7		
7.	5-9-1-7-4-2-8		
	4-1-7-9-3-8-6		
8.	5-8-1-9-2-6-4-7		
	3-8-2-9-5-1-7-4		
9.	2-7-5-8-6-2-5-8-4		
	7-1-3-9-4-2-5-6-8		
10.	5-2-7-4-9-1-3-7-4-6		
	4-7-2-5-9-1-6-2-5-3		
11.	4-1-6-3-8-2-4-6-3-5-9		
	3-6-1-4-9-7-5-1-4-2-7		
12.	7-4-9-6-1-3-5-9-6-8-2-5		
	6-9-4-7-1-9-7-4-2-5-9-2		
13.	8-1-6-4-9-7-3-4-9-1-6-7-2		
	9-2-5-7-3-1-4-7-6-1-3-9-4		
14.	1-5-9-3-1-6-2-7-6-8-1-3-6-1		
	7-3-6-4-8-3-5-1-4-2-9-3-5-1		
15.	4-1-9-8-1-4-3-8-5-7-2-9-6-3-5		
	5-9-2-6-1-8-2-7-5-1-3-7-2-4-9		
		Total Forward	Max = 15

Appendix VI – Digit Span (Backward)

Part 2   DIGITS BACKWARD

我而家會講一啲數目字，但呢次當我講完之後，你要將佢掉轉頭講番出嚟，譬如我話 1-7，你會點講呢?啱喇。(錄音)

Mistake

唔係，你應該話 7-1。我頭先講 1-7，你要掉轉頭講 7-1 至啱。而家試下呢個，記住，你要將佢掉轉頭講番出嚟:3-9。

Digits Backward		Pass-Fail	Score (1 or 0)
2.	2-4		
	5-8		
3.	6-2-9		
	4-1-5		
4.	3-2-7-9		
	4-9-6-8		
5.	1-5-2-8-6		
	6-1-8-4-3		
6.	5-3-9-4-1-8		
	7-2-4-8-5-6		
7.	8-1-2-9-3-6-5		
	4-7-3-9-1-2-8		
8.	9-4-3-7-6-2-5-8		
	7-2-8-1-9-6-5-3		
9.	6-3-1-9-4-3-6-5-8		
	9-4-1-5-3-8-5-7-2		
10.	6-4-5-2-6-7-9-3-8-6		
	5-1-6-2-7-4-3-8-5-9		
11.	2-6-9-1-7-3-8-6-4-2-7		
	5-7-3-4-1-8-4-2-8-7-3		
12.	8-4-7-3-8-2-5-1-7-9-2-6		
	6-1-4-8-6-2-9-1-5-7-4-6		
13.	3-1-6-3-8-2-9-7-1-4-6-1-7		
	2-7-1-5-4-8-9-4-3-7-4-2-5		
		Total Backward	Max = 13
		+	
		=	