Learning ability in people with aphasia: How is it different from healthy speakers and what is the role of cognitive functions?

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Abstract

Background – The ability to learn new information may have a crucial impact on rehabilitation with people with aphasia (PWA). However, there has been little research on learning in PWA. Although recent studies have shed light on learning and how it might be affected by cognitive functions, the tasks involved are mostly dependent on language and their findings show much inconsistency. This gap in the existing literature inspired this thesis to examine systematically learning and cognitive functions in PWA.

Aim – This thesis investigates the ability of PWA to learn new information with particular attention to whether the learning deficit(s), if any, is language-specific or general in all aspects of learning, including non-linguistic material. Also, the potential occurrence of implicit learning is examined to have a comprehensive understanding of learning among PWA. The learning outcomes are further explored in terms of how cognitive functions account for the patterns observed in the various learning tasks involved in the current study.

Methods – A series of psycholinguistic experiments, with PWA and two groups (young and older) of healthy participants as controls, are included in the thesis. The experiments conducted investigated the following perspectives of learning: 1) pair-associative learning of materials of various linguistic load; 2) implicit learning in the visual modality; and 3) the effect of massed versus spaced practice on learning. In addition, cognitive profiles of PWA were built through cognitive assessments covering language, memory, attention, and executive functions. The relation between the performances on the cognitive assessments and the learning outcomes were further explored.

Results and discussion – The results of the experiments have provided insight into learning in PWA in various learning tasks and how the patterns of learning differ from or resemble those in the control groups. The outcomes of learning demonstrate that, compared to the controls, PWA have reduced learning ability regardless of the type of to-be-learnt material(s). Also, the findings broadly support the evidence that learning can be enhanced through feedback and repeated practice. Further, correlations are restricted among learning tasks, indicating that learning ability in people with aphasia is independent from other cognitive functions.

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Chapter 1 Learning in people with aphasia: Do people with aphasia learn and what aspects of cognition might influence performance?

1.1. Introduction

This chapter aims to specify why the investigation of learning in people with aphasia (PWA) should be taken further from its current stage. Firstly, the existing literature on learning in PWA is reviewed and taken as the foundation for the current thesis. Secondly, some methods that have been consistently reported to facilitate learning in PWA and non-brain-damaged populations are discussed; attention is drawn to the application(s) of these methodologies and how to employ these in the experiments in the current study to minimise the effect(s) of confounding factors on learning. Thirdly, cognitive functions other than language in PWA have received attention in the recent three decades; four domains of cognitive ability will be reviewed and discussed in terms of how the exploration of relationships between cognitive functions and learning can be taken forward. The main argument in this chapter centres around the idea that although the phenomena of learning in PWA have been studied, further and more systematic evidence is required before determining whether learning ability is intact in PWA. If it is not intact, then further consideration needs to be given to what might be the potential variables that influence successful learning. The chapter concludes by presenting the primary research questions and what inspired exploration of the issues in the subsequent chapters.

1.2. What is aphasia

After more than a century of debate, the definition and classification of aphasia have still not come to an agreement (McNeil & Pratt, 2001). Among various definitions for aphasia, the most widely accepted one is that it is a language impairment resulting from acquired brain injury to language regions of the brain, mostly located in left-hemisphere. Stroke is a common cause of aphasia and it affects 1/5 of chronic and 1/3 of acute patients in the UK (Cummings, 2008); this population is the groups of PWA investigated in the current study. Symptoms of aphasia can vary among individuals; comprehension, production, reading, and writing can be all or selectively impaired; classification, on the other hand, has based on not only characteristic of language impairment(s) but also neuro-anatomic localizations of lesions. Although spontaneous recovery is observed in majority people with aphasia, the speed and extend of recovery largely depend on stroke-related factors, such as lesion site, size of lesion, and initial severity (Plowman et al., 2011; Sinanovic et al., 2011).

Primary aphasia is considered as a pure language disorder whilst secondary aphasia is a consequence of disordered memory, attention, or perception (Mildner, 2006). To achieve successful communication requires complex cognitive processes that are domain-general rather than specific to language function. Nonetheless, people with aphasia have constantly been reported to demonstrate reduced memory (Basso et al., 1982; Burgio & Basso, 1997; Christensen & Wright, 2010; El Hachioui et al., 2014), attention (Hunting-Pompon et al., 2011; Murry, 2000), and executive function (Brownsett et al., 2014; El Hachioui et al., 2014; Fridriksson et al., 2006; Purdy, 2002). These non-linguistic cognitive factors not only affect spontaneous recovery (Brownsett et al., 2014) but also responses of PWA to speech and language treatments (Fillingham et al., 2005a, 2005b). Details about potential impacts of cognitive factors might on various tasks are discussed in the later sessions (1.5 & 2.2).

1.3. Previous works looking at learning in PWA

Learning deficits have been widely reported among people with aphasia and some early studies looked at this issue from the perspective of behaviourism. Brookshire (1969) claims that although learning curves generated by people with aphasia are not as smooth as an average curve produced by normal subjects, behaviour shaping techniques can be effective with people with aphasia.

In Brookshire's study, learning in people with aphasia was investigated with a two-choice probability learning experiment. In the experiment, participants were to turn on a set of lights by pressing one of two buttons (A or B) and to change their response patterns according to the reinforcement ratios of each button. Brookshire reported that, compared to the control participants, PWA needed more learning trials before realising the probability had changed and their responses were to change accordingly. In this study, the severity of aphasia, which may result in individual differences among the participants, was not reported; instead, some PWA demonstrated a tendency to make perseverative errors, which was the major factor that caused reduced learning for the task. Moreover, it is unknown whether the lack of obvious changes of behaviour throughout the first three sessions was, in some way, related to their language deficit or whether they were slower in generating strategies for the tasks.

Nonverbal learning in people with aphasia has also been studied by Tikofsky and Reynolds (1962, 1963) with card sorting tasks. In their experiments, participants had to sort their cue cards in accordance with the target sorting categories, including colour, form, and number. Their findings also indicated that improvement was not evident until a later stage of the learning trials, in comparison with the control group. Yet, the card sorting tasks in Tikofsky and Reynolds's work involved three categories that could easily be verbalised by people without language deficits; therefore, there is a question about the extent to which inefficiency of linguistic knowledge influences learning of both linguistic and non-linguistic information.

More recent studies involving learning of associations of new word forms and meanings, by Kelly and Armstrong (2009) as well as Tuomiranta et al. (2011), have shown that PWA are capable of learning new words, and also demonstrate that the learning outcome can be long-lasting, though reduced. However, in the case of new word learning, distinctive individual differences among PWA have been reported. Even when three learning approaches that could enhance learning were made available to the participants during the learning task and the majority of the participants did employ the same learning approach(es) provided, individual difference was still evident (Kelly & Armstrong, 2009). They found a correlation between the learning outcome and the time the PWA allocated to learn an item; that is, the longer the participant spent consolidating the new words, the better the learning outcomes were. Moreover, arguing from the perspectives of cognitive abilities, Kelly and Armstrong pointed out that the insensitivity of PWA towards the approaches was a result of impaired executive function.

The studies above have shown that regardless of material used (linguistic or non-linguistic), PWA have demonstrated the capacity to learn, albeit at a reduced level. Nonetheless, learning of new linguistic and of non-linguistic information have not been directly compared. In addition, the 'reinforcements' participants received in the behaviourism studies were simply 'correct' or 'wrong'; this may not always be the case in therapy sessions, where different cues or repeated presentations of a target may boost their learning or form a different learning curve. These issues can be taken into consideration in the current study. Despite the limitations of previous studies, they have provided evidence that PWA are capable of forming new learning, which we must presume is a crucial ability for speech and language rehabilitation.

1.4. Methods that boost learning

1.4.1. *Retrieval effect*

Retrieval practice – The retrieval effect, also known as the testing effect, refers to the benefit of conscious retrieval of the newly learnt information in learning. Retrieval provides opportunities for encoding, which is an important process for the formation of new memory and achieving learning and retention. Karpicke and Roediger (2007a) gave their participants, university students, a list of words to learn under three conditions, including repeated study, two study phase each followed by retrieval opportunities, and one study phase followed by repeated retrieval opportunities. Karpicke and Roediger reported that both conditions providing the participants opportunities to retrieve the to-be-learnt words immediately after study outperformed the pure study condition. Despite the fact that the retrieval effect has mostly been reported by studies that present participants with the 'to-be-remembered' items to 'study' prior to retrieval/test(s) (Karpicke & Blunt, 2011; Karpicke & Roediger, 2008; Kole & Healy, 2013; Wheeler et al., 2003), the benefit of 'pure' retrieval is found in performance of PWA on naming tasks. Even when a task does not contain 'study', repeated attempts to name an object result in better naming outcome or improvement (Howard et al., 1985b; Nickels, 2002), even when feedback is absent (Fillingham et al., 2005a; 2005b). Furthermore, the retrieval effect is not restricted to free recall; it has been widely observed in cued-recall with a pair-association paradigm (Pashler et al. 2003; Sumowski et al, 2010). The majority of accounts of the effect emphasise that retrieval enhances retention as a result of elaborated memory trace being built upon existing memory during processing, creating a 'retrieval route' to stored information (Bjork, 1994; Bjork, 1999); this should reinforce the information in both implicit and explicit memory (Roediger, 1990; Roediger et al., 2002).

In combination with spacing – Based on the assumption that the effect of retrieval practice benefits learning of new linguistic knowledge, studies have focused more on how retrieval practice and other learning approach(es) might operate together with retrieval to produce maximum benefit in various learning tasks. One approach that has been consistently reported to facilitate learning among people without brain damage is spacing (Cull, 2000; Carpenter & DeLosh, 2005; Karpicke & Roediger, 2007a). That is, when retrieval opportunities are spaced out, retrieval success increases, compared to repeated consecutive retrieval of the same piece of information. This phenomenon is known as *spacing effect*. A few studies involving undergraduate participants learning verbal/linguistic material have provided evidence for the long-term effect of spaced practice (Carpenter & DeLosh, 2005; Karpicke & Roediger, 2007a). Carpenter and DeLosh (2005) tested potential spacing effects in face-name association learning. They pointed out that the spacing effect appeared not only under the condition when participants were given opportunities for retrieval practices, but also under the circumstances when participants were only allowed to restudy the to-be-learnt items. That is, spacing out the opportunities for restudy of the same to-be-learnt material leads to better retention than consecutive restudy. This finding suggests that, even though retrieval practice has been considered as an important process to facilitate learning, the spacing effect can occur without retrieval opportunities. In line with Cull's (2000) study involving cue-recall tasks, spaced schedule for study/test and retrieval practice maximises recall outcomes; nonetheless, the spacing effect and the retrieval/testing effect each have independent effects (Carpenter & DeLosh, 2005). In addition, the benefit of spaced practice is not restricted to learning linguistic material, such as word-pairs, word lists, and text passage(s). Spacing seems to improve outcomes across various types of learning, including non-linguistic conceptual material (Kornell et al., 2010; Kornell & Bjork, 2008).

1.4.2. *Target-oriented cuing*

It is suggested that the language presentations and procedures in the aphasia are not lost but inaccessible; therefore, stimulation is the preferred approach to speech and language therapy (Abel et al., 2005; Howard & Hatfield, 1987). To aid the patients in accessing their knowledge, model-based cueing methods have been practiced with people with aphasia, with the aim of improving their performance in naming tasks. However, the evidence reported has been inconsistent in terms of what type of cue (semantic, phonological, or personalised) could be beneficial across PWA with language impairments of different domain(s) of language.

Based on the theory of depth-of-processing (Craik & Tulving, 1975), phonological retention of inputs depends on the qualitative nature of the encoding processes. That is, to prompt the retrieval of a target word may only require a surface level of encoding, while the cues that yield more semantic knowledge, namely more in-depth encoding, should be more effective and durable facilitators. Hence, Marshall et al. (1994, 2001) trained people with aphasia to learn abstract symbols and subordinate category names with two different cueing methods, phonological and personalised cueing.

Marshall et al. (2001) claimed that personalised cues were significantly more effective in prompting the correct name than phonological cues. [Prompting refers to helping the subject name a picture at the time of difficulty (Howard et al., 1985)]. Marshall et al. presented stable results, showing personalised cueing as a more helpful prompt. It seems that cues that are created by the participants themselves yield a better quality of processing than cues provided by the experimenter(s).

In contrast, the study by Drew and Thompson (1999) suggested that different cueing types result in different patterns of improvement among patients. Drew and Thompson found that two out of four of their subjects with severe picture-naming problems, resulting partially from semantic impairments, did not benefit from pure semantic treatments where only the visual stimuli and the descriptions of them were presented. These two patients showed improvements only when extra phonological and orthographic information was provided; for the others who demonstrated semantic effects, naming accuracy was further increased when the extra information was given. This finding can be interpreted as difficulties in accessing representations; therefore, extra phonological cues help to further distinguish the target word from its associations and increase the chances for successful retrieval. Also, it leads us to consider the effects caused by breakdowns in different domains of language among PWA. Nickels (2002) concluded from previous literature that most individuals with impaired retrieval of phonological forms benefited from tasks that combine semantic and phonological activation. Individuals with semantic impairments, on the other hand, are more likely to find semantic tasks, in which feedback and discussion on the semantic features of the targets are available, beneficial.

Although in the current study the intention is to keep the learning tasks as non-verbal (in this case, requiring no language production) as possible in order to minimise negative effects of language impairments, the need for linguistic knowledge cannot be ruled out and PWA who are able to create these kind of cues on their own may be able to produce greater learning success. What is more, among the limited literature on non-verbal learning task(s) with participants with aphasia, no evidence has suggested whether non-linguistic learning is achieved in the same way as linguistic tasks. If learning of linguistic and non-linguistic material both benefit from having linguistic cues, learning outcomes for non-linguistic material might be relatively lower, compared to learning of linguistic material, due to the fact that it is more difficult to form a cue on a deeper level of processing for non-linguistic material.

1.4.3. *Errorless versus errorful learning*

Errorless (EL) learning is a learning approach that has been increasingly adopted in cognitive rehabilitation. In a typical EL paradigm, participants are presented with the target information for study or immediate re-production in order to prevent any error from being made during learning and leaving a misleading memory trace. Although it is an approach that has been reported to effectively improve recollection among memory impaired populations (Evans et al., 2000; Kessels and de Hann, 2003; Tailby & Haslam, 2003), it is actually contradictory to the argument that retention of information benefits more from conscious retrieval from long-term memory (discussed in 1.3.1).

Moreover, an increasing body of studies on word-finding treatments for aphasia (Conroy et al., 2009; 2012; Fillingham et al, 2003, 2005a, 2005b, 2006; Middleton & Schwartz, 2012) have employed an EL paradigm; yet, the effect of EL was inconsistent. In most cases, EL results in learning outcomes that are similar to Errorful learning (EF), in which participants are given at least one opportunity to retrieve target information before feedback or target-oriented cues are provided (Fillingham et al., 2005a). It is possible that learning is reinforced via feedback and PWA are not sensitive to these approaches. Hence, in the current study, the more consistent benefit from retrieval is adapted and integrated into all learning tasks.

1.5. Cognitive functions and potential impact(s)

This section reviews previous evidence on how four perspectives of cognitive function, namely, language, memory, attention, and executive function, potentially influence performance of PWA in various tasks.

1.5.1. *Language*

Diagnosis of language deficits and therapy/treatments for aphasia are largely based on the existing psycholinguistic models (Dell et al., 1997; Patterson & Shewell, 1987; Roelofs, 1997). In this section, the review focuses on models of single word processing, due to the fact that the main interest of the current study is to explore the general ability to learn linguistic as well as non-linguistic material; therefore, the linguistic material used does not require comprehension and/or processing beyond single word level. Furthermore, understanding the mechanism underlying word processing provides insight into the potential difficulties that PWA might encounter while learning because of their language impairments. On the other hand, the models serve as the basis of accounting for reduced performance, if any, across the language assessments (see Chapter 2).

One model that is commonly employed to account for single word production is Dell's interactive lexical network (Dell et al., 1997), which demonstrates the lexical retrieval mechanism specific to naming. The idea of the model is that lexical knowledge is embedded in a three-layer network, including semantic (concept of an object), lemma (a word), and phoneme (phonological sound of a word) layers. All layers are interactively activated and connected in both top-down and bottom-up directions during lexical retrieval. The potential faults that may occur in each level of processing and among the interactions between layers are the basis for speech errors. This model, as well as other models of word retrieval [i.e. Logogen model (Morton, 1969; Patterson & Shewell, 1987) and WEAVER model (Roelofs, 1997)], demonstrates that a fully-functioned system of single word processing requires multiple storages of linguistic representations and inter-connected routes between the centres of storage. It is argued that linguistic representations are not lost but inaccessible in people with aphasia (Abel et al., 2005). That is, language deficits are not due to the loss of linguistic knowledge but the inability to coherently access the information required during processing.

Based on the models of language production for single words (Dell et al., 1997; Levelt, 1983; Roelofs, 1997), two major steps are involved in lexical access, a semantic and a phonological step. A representation of a word is mapped to a meaning during semantic processing; phonological processing involves mapping a lexical representation onto its phonology. Hence, impairment(s) in either one or both steps leads to language deficits with distinct characteristics. Nonetheless, the lexical models proposed by Dell et al. (1997) as well as Levelt (1983) and Roelofs (1997) are single-route, in terms of how phonological input is conveyed to output level. Therefore, they are restricted to accounting for the production of real words due to the absence of a non-lexical route, which facilitates production or repetition of non- /unfamiliar words.

According to dual-route theories of word production, repetition of familiar and unfamiliar words requires both lexical and non-lexical components. Dual-route models of word production, such as the Logogen model (Morton, 1969; Patterson & Shewell, 1987), include an additional non-lexical route, linking phonological input directly to phonological output buffer. That is, a phonological input can be transferred directly from phonological input analysis to phonological assembly for articulation without going through semantic or phonological step when deeper level(s) of processing is not required. What is more, Hanley et al. (2002) suggest that repetition of known words involves lexical as well as non-lexical routes. At the time a phonological input of a known word is received, the lexical route automatically conveys it to the semantic level, and meaning is activated, whilst linking the input to a lexical representation and then converting to phonological output buffer to form an output. Meanwhile, the non-lexical route transfers the input of a known word to phonological output in the same way that a new or non-word is transferred. Therefore, deficits can occur due to not only impaired semantic and/or phonological system(s) but also breakdown(s) of the routes linking the two. Whether the non-lexical route facilitates repetition of a known word or not has been controversial (Baron et al., 2008; Hanley et al., 2004); the role of the non-lexical route is emphasized by Hanley et al. in word learning. If this is the case and rehearsal is the key to retaining new information (Baddeley, 2003), failure to achieve learning could be the result of 1) reduced linguistic knowledge to support processing via linguistic route and/or 2) impairment in one or both route(s) so that rehearsal is unsuccessful.

1.5.2. *Memory*

Memory has been reported to be closely related to performance on linguistic tasks. As mentioned, there is a considerable amount of evidence in support of the theory of depth-of-processing (Craik & Tulving, 1975), suggesting that information that is processed at a deeper level, semantically encoded, is retained better compared to information that is processed at surface level, phonologically encoded. If this is the case, it could be assumed that memory and language could jointly affect learning outcomes. Indeed, the relationship between memory and language is still to be untangled. Two types of memory have been constantly linked to learning: 1) short-term memory (STM), which has limited capacity and where information retained decays over a short period of time, and 2) working memory (WM), which comprises a central executive and its three slave systems, including phonological short-term storage (Baddeley, 2003).

Existing studies have pointed out reduced STM and/or WM capacity occurring variably along with language impairments among PWA (Burgio & Basso, 1997; Christensen & Wright, 2010; Wright & Shisler, 2005). Yet, there is evidence suggesting that activation of STM is partially supported by representations in long-term memory (Hulme & Maughan, 1991; Majerus et al., 2012), so reduced performance on STM task(s) could result from inaccessibility of linguistic representation in long-term storage. On the other hand, despite the fact that scores on memory tasks are claimed to predict performance on language tasks (Caspari et al., 1998; Friedmann & Gvion, 2003; Martin et al., 2012), the correlations are mostly found between memory and language tasks that required or were supported by the same aspect(s) of language functions, at least to a certain extent. Whether STM and/or WM performance predicts learning in general among PWA is still not known.

Based on the STM deficits reported (verbal STM in particular) and the relation with language performance, research has been carried out investigating whether treating verbal STM by improving activation of linguistic representation can lead to better performance on language tasks. Although, at this stage, there is inconsistency among evidence from various studies, some positive results of improvement at single word level and beyond, at sentence level, have been presented (Kalinyak-Fliszar et al., 2011; Majerus et al., 2012; Salis, 2012). With prevalent findings demonstrating positive correlation(s) between verbal memory and language, better learning outcomes, at least of linguistic material, are anticipated in PWA with higher verbal STM/WM scores.

1.5.3. *Attention and Executive function*

In addition to memory and language, two cognitive functions, attention and executive function, that have been extensively investigated in relation to the performance of PWA on language tasks and learning are taken into account in the current study (see chapter 2 for details).

Summarising Murray (2012), most models of attention consist of four perspectives: 1) sustained attention, which maintain the ability to respond over time, 2) selective attention, which selectively processes stimuli that are relevant to the present task, 3) attention switching, which allows one to shift focus between tasks or stimuli within one task, and 4) divided attention, which is required to respond to two or more concurrent stimuli or increased task demands. Furthermore, based on the existing literature, Murray has pointed out that 1) impaired attention as well as other cognitive functions occur in most but not all PWA; 2) as with their language impairment, the degree of severity and the symptoms presented vary among individuals; 3) most importantly, potential associations among attention and other cognitive functions should be taken into account when interpreting the data generated by PWA.

1.6. Rationale, research questions, and thesis structure

1.6.1. *Rationale of the current thesis*

This chapter has reviewed evidence on learning among PWA and a few methods that have been considered to facilitate learning of various groups of participants, with and without brain damage. Most of the methods have been applied to learning of linguistic material or treating certain aspect(s) of language impairment. Reduced performance, in comparison with people without brain damage, has been prevalently reported. Despite employing approaches that benefit learning, most of the tasks used by the studies discussed relied heavily on language function; consequently, reduced performance can be foreseen. The current evidence alone is not sufficient enough to make the assertion that PWA suffer from a deficit in learning. Hence, the current thesis aims to investigate beyond learning of linguistic material and determine if PWA have an intact ability to learn.

Furthermore, cognitive functions other than language have also been reported to affect learning outcomes among PWA. To investigate how learning in PWA is influenced by cognitive functions, four aspects of cognition are assessed and performances on cognitive assessments are examined to determine whether any of the cognitive functions affect learning in general or correlate specifically to certain aspect(s) of learning.

1.6.2. *Research questions and thesis structure*

The two principal questions asked in this thesis are:

1) Are PWA able to demonstrate learning (and how does this relate to performance of age matched controls)?
2) What is the relationship, if any, between cognitive functions and learning in PWA?

Moreover, the current study extends the exploration of learning to non-linguistic material and further investigates if the assumptions between learning and memory hold. Extending from the two main research questions above, the thesis considers potential accounts from the following perspectives: 1) Whether the reduced patterns of performance previously observed in PWA are due to their language impairment or a more general deficit in ability to learn new information, 2) Whether PWA demonstrate a different pattern of learning from people without brain damage, and if so, how it differs, and 3) To what extent performance on learning tasks is affected by cognitive functions.

The questions are explored with a series of experiments with various paradigms of learning (presented in chapter three, four, & five). Employing different approaches to directing learning along with material of various 'linguistic loads' and modalities will provide a well-rounded view on learning and, hopefully, identify one or more learning method(s) that benefit PWA across learning tasks. The same group of PWA were invited to participate in all the experiments involved in this study to in order to observe their patterns of learning across experiments. Moreover, for each of the participants with aphasia, a cognitive profile containing four perspectives of cognition is given (see chapter two) for the purpose of further understanding the questions about cognitive functions and learning (analysis and discussion are included in chapter six) before any conclusion (see chapter seven) in relation to the two principal questions is drawn.

Chapter 2 Cognitive assessments and background profiles of the individuals with aphasia

2.1. Introduction

The ability to learn plays a crucial role in speech and language rehabilitation. The ability to learn new information is constructed based on one's language and other cognitive functions, including memory, attention, and executive function. That is, impairment(s) of any aspect of cognitive function will result in reduced performance on learning tasks. PWA show great variability in the integrity of their cognitive functions and there has been an inconsistency among the existing literature on the relation between aphasia and cognitive functions other than language. Therefore, having a complete cognitive profile that includes language and other cognitive functions may provide insight into potential deficits in learning as well as individual differences in performance among PWA, and how these differences could be accounted for by reduced cognitive functions.

In the current study, aphasia is considered as impairment of one of the cognitive functions. We investigated whether other cognitive deficits co-occur with aphasia, with particular attention to how they interact with language function to affect the performance of PWA in learning. Each of the factors that were explored falls into one of the four perspectives: 1) language, 2) memory, 3) attention, or 4) executive function. The choice of assessments focused only on factors that potentially affect the outcome of pair-association learning tasks. The aim and procedure of each assessment will be described in detail. As reported in previous studies (Caspari et al., 1998; Lambon Ralph et al., 2010), the factors that affect learning may also serve as predictors for performance on tasks that yield the same underlying mechanism(s) while processing. Consequently, the performances of the 18 participants with aphasia on cognitive assessments are reported as individual cases at the end of the chapter; further, the relations between the cognitive functions and learning are discussed in detail in chapter six.

The current study is approved by the Speech and Language Sciences Research Ethics Committee at Newcastle University. Samples of the information sheet and the consent form used for the study are attached in Appendix A.

2.2. Factors that may affect learning outcomes

2.2.1. *Language processing*

An increasing body of literature supports the theory that individuals who share signs and symptoms of aphasia do not necessarily have common underlying mechanisms for their deficits. That is, even if two PWA appear to have shared linguistic deficits and are classified as having the same type of aphasia, it is possible that the deficits result from breakdowns in different levels of processing (Hanley et al., 2002; Patterson & Shewell, 1987; Roelofs, 1997; Whitworth et al., 2005). Consequently, detailed assessments should be included in order to determine the source(s) of impairment and how it may influence learning ability of PWA. Based on psycholinguistic models of single word processing, such as the interactive lexical network model (Dell et al., 1997) and models of word retrieval (Patterson & Shewell, 1987; Roelofs, 1997), researchers have been able to determine the possible level(s) of breakdowns and account for patterns of impairments.

The majority of psycholinguistic models of language processing (Dell et al., 1997; Levelt, 1983; Roelofs, 1997; Patterson& Shewell, 1987) argue for a multi-layered interactive processing network. The layers are broadly categorised into semantic and phonological levels of processing, which involves mapping a word onto its semantics/phonology. Multiple storages of linguistic representations exist within each level and are linked by inter-connected routes. In order to successfully produce single words, conveying information from one level to another is essential; that is, semantic and phonological levels are connected by bi-directional routes. In addition, it has been suggested that repetition of non-words can be achieved without going via a ‘non-lexical’ route (Hanley et al., 2004; Nozari et al., 2010; Patterson & Shewell, 1987), which links the phonological input buffer directly to the phonological output buffer rather than going through linguistic processing. Consequently, potential faults that occur in any level or route can result in speech errors or, in the case of PWA, language deficit(s).

One of the ways of investigating underlying impairment is employing tasks that share some of their processing components and contrasting participants’ performance on the tasks (Whitworth et al., 2005). Evidence from picture naming and auditory word repetition tasks has shown how two different tasks are supported by phonological processing of the underlying mechanism that are partially overlapped. Picture naming involves both semantic and phonological steps of production; word repetition, on the other hand, could benefit from direct mapping between input and output phonology with no involvement of either the semantic or phonological step. Hence, impaired ability in picture naming could be due to either failure to retrieve semantic and/or phonological information or disrupted connection between the two systems. As for impaired repetition ability, it could be an indicator of a deficit in the phonological system and/or impaired phonological input-to-output conversion/ non-lexical route. Nozari et al. (2010) reported frequency effect in picture naming as well as word repetition tasks, suggesting that both tasks involve lexical retrieval. Their study further supports that the non-lexical route contributes to repetition of known words. As they predicted, PWA who had better non-word repetition scores made less errors in word repetition. Reduced performance on repetition of non-words and words indicates possible impairment of auditory phonological analysis. In terms of what symptom(s) presents as a result of the breakdown of various levels and/or routes, Whitworth et al. provides a detailed model-based diagnostic.

2.2.2. *Short-term memory*

The discussion of short-term memory (STM) in the current study focuses on how it has been reported to affect the performance of PWA on linguistic tasks and, further, how it might impact learning outcomes. Studies (Gupta & Tisdale, 2009; Locke et al., 1978; Martin et al., 2006; Martin & Saffran, 1997) have shown a close relationship between language and STM, although whether the effect is bi-directional and to what extent they are affected by each other are still under intensive research. Short-term memory impairment has been constantly reported among populations with aphasia of different types; earlier literature (Locke & Deck, 1978; Martin & Saffran, 1997) investigated STM impairment in PWA based on the hypothesis that STM capacity is a dependent of language processing. Therefore, the degree of STM impairment is considered to reflect the severity of lexical-semantic and phonological processing impairment. While working memory (WM) has also been reported to significantly correlate with language function in populations with aphasia (Christensen & Wright, 2010; Potagas et al. 2011), the memory deficit found in PWA is primarily related to retention of information, STM, rather than manipulation of information, WM (Potagas et al., 2011).

Based on the hypothesis that STM capacity is sensitive to language processing (Locke and Deck, 1978), Martin and Saffran (1997) argued that, if the hypothesis is true, repetition span should vary according to the degree of severity of lexical-semantic and/or phonological impairment. What is more, impairment of lexical-semantic or phonological processes influences serial recall differently. The occurrence of a primacy effect is likely to be disturbed by semantic-lexical impairment since semantic processing is linked with information received at the beginning of an input string. Phonological impairment, on the other hand, leads to difficulty recalling information that is presented in the end of an input string; therefore, recency effect is reduced.

In addition, impairment of STM reported in PWA is not restricted to verbal memory tasks. A case study by Basso et al. (1982) reports the performance of a person with mild aphasia (PV) on various short-term memory tasks in both visual and auditory domains. The STM tasks that were involved in the study included 1) repetition of numbers, letters, and word, 2) free recall of lists of concrete, familiar, disyllabic words, 3) recognition of digit strings by pointing, 4) recognition of letter strings by pointing, 5) recall, by pointing, of meaningful and meaningless sequences of increasing length of visual patterns, and 6) recall of meaningless strings of consonants of increasing length from one to three with four delayed recall conditions (immediate, 3, 9, or 15 seconds later). PV had higher scores when the stimuli were visually presented, compared to auditory stimuli; however, overall performance was reduced. What is more, in accordance with literature on STM deficits, a recency effect was not found by Basso et al., suggesting the possibility that the order of recall was adopted and, consequently, the last items were not retrieved due to an impaired short-term store.

A study by Burgio and Basso (1997) provides an insight into how performance on verbal STM tasks is likely to be affected by the presence of aphasia. A large group of people with acute and chronic vascular left-hemisphere damage were included; the inclusion criteria was restricted to people with no or very mild aphasia. Five memory tasks (digit span, paired associates, story recall, Corsi’s spatial span, and Corsi’s spatial learning test) were used to assess short-term verbal and spatial memory. Though the performance was poor across tasks among Burgio and Basso's participants, the presence of aphasia was not found to be a source of the reduced memory capacity. Out of the five memory assessments, only the pair association task was reported to be influenced by aphasia. Despite the fact that Burgio and Basso argued that memory impairment among their participants did not vary according to site(s) of lesion(s), pair association along with story recall and short-term spatial memory were pointed out to link with left-hemisphere damage. The findings were in support of the argument that, other than site of lesion(s), language function is not the sole source that results in the STM deficit observed in PWA.

The literature reviewed above has provided evidence from various scopes in support of a strong relation between language and the STM system. The ability to learn new, at least verbal, information can be affected by STM. In fact, STM has been widely reported to affect word learning among participants without brain damage (Gathercole, 2006; Gupta, 2003) as well as PWA (Gupta & Tisdale, 2009; Martin & Saffran, 1999). Martin and Saffran have claimed that 'the capacity to learn verbal information depends on the integrity of word processing and verbal STM'. What is more, being aware of the role of STM in language processing, treatments of aphasia have developed in two ways: 1) treating language processing through improving activation and maintenance of representations in STM (Kalinyak-Fliszar et al, 2011; Martin et al, 2006) and 2) treating STM capacity to improve performance on language tasks (Koenig-Bruhin & Studer-Eichenberger, 2007).

2.2.3. *Attention and Executive functions*

Cognitive functions other than language and memory, including executive function, attention, and visuo-spatial skill, have also been found to relate to performance of PWA on language tasks and therapy outcomes. A high degree of variability in cognitive performances among PWA is found not only in language ability but also other aspects of cognitive functions. Although the relation between other cognitive perspectives and language ability of PWA is not fully understood, there is a growing amount of literature (Helm-Estabrooks, 2002; Lambon Ralph et al., 2010; Seniow et al., 2009) suggesting that all cognitive domains are important in terms of therapy outcome. While other cognitive functions cannot be predicted based on severity of aphasia, it is necessary to carefully examine and interpret any relation observed between the factors.

One of the cognitive functions discussed in this section is executive function, which is required when an individual is involved in a complex and/or new activity. The importance of this has been brought to light by studies with pre-treatment measurements of the executive function of PWA (Fillingham et al., 2005a, 2005b; Fridriksson et al., 2006; Purdy, 2002). Fillingham et al. have suggested that executive function alongside self-monitoring skills (not discussed in the current study), predict participants' response to therapy. Moreover, Ramsburger suggests that "executive functions may serve an important mediating role in the complicated task of human communication especially when routine processing schemas are no longer viable due to primary speech and language processing disorders". Also, it was emphasised by Conner et al. (2000) that the cognitive difficulties observed in PWA, such as working memory, attention, and problem solving, all fell into the category of executive function.

The other cognitive function considered in the current study is attention, which has not only been documented in PWA but also been suggested to account for the poor performance in language comprehension and production observed in the group. The attention system is a capacity limited system; to make the attention system fully functional, one needs to be able to flexibly and simultaneously deploy and allocate the available resources to one or more activities (Murray, 1999). Evidence on the effect of attention deficits on the performance of language tasks has been reported (Connor et al., 2000; Hunting-Pompon et al., 2011; Murray, 2000; Ramsberger, 2005; Tseng et al., 1993; Yu et al., 2013). For instance, Tseng et al. (1993) gave PWA a dual task involving components of phoneme monitoring and semantic judgement, in which participants were asked to detect auditorily-presented semantic and phonetic targets under two experimental conditions: explicit (where the participants were told about the probability structure and given the attention allocation strategy for the task) and implicit (where the participants were to detect the change of probability in order to effectively allocate attention).

Deficits of attention are also revealed in PWA while performing automatic and controlled processing tasks. Tasks requiring minimum or no attention are regarded as automatic processing whilst those requiring conscious attention are referred to as controlled processing. Hunting-Pompon et al. (2011) have provided evidence that PWA performed at the same level as the control participants during automatic processing. Nevertheless, once interfering stimuli were added in the task, PWA had difficulties attending only to the target stimuli and, consequently, performance decreased. Similar findings were reported by Murray (2000) in the performance of PWA on word retrieval tasks. As attentional demands increased, the performance of PWA on word retrieval worsened. The result was accounted for by Murray (2000) as inadequate source of attention to complete extended search during retrieval and/or inefficient ability to allocate attention. In addition, attention deficits can lead to reduced auditory comprehension. Connor et al. (2000) proposed three potential ways to account for the effect: 1) fluctuation of attention in PWA leads to incomplete access to language representations and, therefore, even the performance on an individual item can be inconsistent in every retest; 2) when PWA encounter an auditory distractor, performance is likely to be reduced, no matter whether the task is a linguistic one or not; 3) when extra linguistic inputs (slowing down the rate of inputs or providing an alternative signal/stress) are given, auditory comprehension can be improved.

As Connor et al. (2000) pointed out, the effect of attention is not restricted to the performance of linguistic tasks. When demands on attention increase, PWA show increasing difficulties in targeting non-linguistic visual (Cohen et a., 1981) and auditory stimuli (Erickson et al., 1996). Hence, based on the current literature, attention plays an important role in processing and should be taken into consideration as a factor that affects learning.

2.3. Background assessments

Building a profile that comprises more than the language functions offers further insight into the potential factors that might affect performances on different learning tasks. Furthermore, different levels of breakdown among each PWA could potentially account for any distinct learning patterns observed, providing a chance to not only look at PWA as a group but also individual cases.

Based on the existing literature about language processing and cognitive abilities that affect the performance of PWA, the background assessments chosen for the current study can be categorised into three domains: language, memory, and attention and executive function.

2.3.1. *Language*

As suggested by existing literature, language is closely related to other cognitive functions and language impairments might affect or be under the effect of other cognitive functions. Therefore, a few tasks that tap into various aspects (repetition, naming, and narrative speech) of language deficit were chosen to build a basic language profile. Furthermore, the scores for the following tasks were combined later to form a score for language production, which reveals the severity of the participant's language deficit.

Repetition of words and non-words

Three subtests of the Comprehensive Aphasia Test (CAT) (Swinburn et al., 2004) were administered to investigate the participants' ability to repeat words, complex words, and non-words. The lists of words were recorded by a native speaker of English. During the test, the participants were asked to repeat each word after they had heard the recording. The target words could be repeated on request.

The CAT provides a list of words varying in imageability (high and low), frequency (high and low), and number of syllables (one to three) so that the effects of the three variables can be investigated. The complex words have prefixes and suffixes (e.g. unthinkable, defrosted). Many PWA are able to repeat real words but not non-words; therefore, the performance in non-word repetition was compared with the performance in repetition of real words to detect this deficit. The stimuli consisted of five non-words that varied in length and phonological complexity.

Each item gave a score of 2 for a correct and prompt response. If any repetition of a target was requested or correct response was given after a delay of 5 seconds, a score of 1 was given. Distorted responses due to dysarthria were scored as correct; however, verbal, phonemic, neologistic, or dyspraxic mistakes were considered as incorrect responses, giving a score of 0. The maximum scores for repetition of words, complex words, and non-words were 32, 6, and 10 respectively.

Naming objects

Naming difficulties are a common deficit observed in PWA. The ability to name pictures was tested using the subtest in CAT. The test comprises 25 black-and-white pictures of objects, including one practice item. The objects vary in imageability (high versus low), frequency (high versus low), animacy (animate versus inanimate), and length (one versus three syllables), offering a chance to examine the factors that may have an impact on naming.

During the test, the presentation of the pictures followed the instruction in the CAT manual. As mentioned in the manual, a phonemic or semantic cue was provided, depending on the error type, when first attempt to name failed. The test was terminated when a participant had failed to name eight pictures consecutively. Successful naming after receiving a cue was not marked as correct but was noted on the scoring sheet.

Each item carries 2 points; a prompt and accurate response was given two points. One point was given to a delayed or self-corrected response. Verbal, phonemic, neologistic, and dyspraxic errors were marked as incorrect, scoring 0. However, dysarthric distortion was acceptable if each phoneme is correctly chosen. Any response including the target name (e.g. ‘knife’ named as ‘carving knife’) or a variant of the target name (e.g. ‘brush’ named as ‘hairbrush’) was considered as a correct response. The maximum score on the test was 48 and the sub-score for each variable that may affect naming was also recorded.

Picture description

The subtest of picture description was selected from CAT. The test provides a systematic rating for a recorded sample of connected speech of PWA obtained from describing a complex black-and-white picture. The scores provide a measure of severity of production of narrative speech.

For the task, the participants were presented with the picture and asked to describe it using as many sentences as possible, in as much detail as possible. If any area in the picture was missed out by the participants, the examiner encouraged the participants to describe it in more detail by asking the question “What about this?”

Each sample of connected speech was scored according to 1) the number of appropriate information carrying words (ICWs) as well as 2) inappropriate ICWs in the speech, 3) syntactic variety, 4) grammatical well-formedness, and 5) the speed of speech. Words/word-units, not necessarily content words, can be counted as ICWs as long as they convey information. An appropriate ICW is one with correct meaning in the right context; an inappropriate ICW, on the other hand, is one that incorrectly selected with possible phonemic errors, verbal paraphasias, or neologisms. Each appropriate/inappropriate ICW scored 1 and there was no maximum score for these two subcategories. Syntactic variety and grammatical well-formedness were scored on a 0-6 scale, where 0 is the lowest and 6 is the highest. As for the speed of speech, a scale of 0-3 was used with midpoints (0.5 available); Score 0 was given when the speech was significantly and consistently delayed, while score 3 signifies normal speed.

The overall score was calculated by adding up the score of appropriate ICWs minus inappropriate ICWs and the other three scores (syntactic, grammatical, and speed).

Digit repetition and digit pointing

Short-term memory span was assessed with two digit string repetition tasks, one involving verbal repetition, and the other requiring responses by pointing. Two sets of thirteen-level (Level 1 to Level 13) stimuli were constructed for the verbal and the pointing version respectively; each level consisted of 5 trials (Trial I to Trial V); the trials in the first level were two-digit strings, and the length of trials increased 1 digit from one level to the next. Ten cards of size 6 by 6cm were created for the digit point task, each card showing a number between 0 and 9.

For the verbal repetition, the participants were asked to repeat the digit string immediately after the examiner in the exact same order. Digit pointing span was taken by having the participants point to the digits in the exact same order as they had been read by the examiner. Prior to the task, the examiner presented the cards with digits to the participants one by one, from zero to nine. The cards then remained on the table in front of the participants in no particular order, to avoid the possibility that the participant remembered the relative position of the numbers rather than recognising them. Instead of verbal responses, the participants were instructed to point at the cards with the target numbers printed on.

Both tasks were directed with a staircase method, starting with a list of 2 digits. One more digit was added to the next list if the repetition of the existing list was accurate; otherwise, the next list was shortened by one digit. Each participant was given 12 lists with lengths adjusted according to the responses. The final repetition span and pointing span were calculated by averaging the fifth to the twelfth list; the first 4 lists were removed from analysis because they could reveal the arbitrary length of the first list.

2.3.2. ***Memory***

Episodic memory

Episodic memory for newly learnt information was assessed with a story recognition task. The story recall and recognition task in the Birmingham Cognitive Screen [BCoS (Humphreys et al., 2011)] was chosen since it provides insight into the perspectives of encoding, retrieval and forgetting/consolidation. However, due to the population involved in the study (PWA), verbal recall was excluded since language deficits were not the factors of interest here.

The story was read by a native speaker of English and recorded for this task. Participants were asked to listen to the recording carefully, and were also notified that they would be asked detailed questions about the story afterwards. An immediate recognition task with 15 multiple choice questions followed the story telling. Each multiple choice question was printed on a sheet of A4 size paper. The examiner presented the multiple choice questions, one at a time, whilst reading the question and the corresponding choices to the participants, before they made the choice.

For the immediate recognition, participants were given feedback and the answers to the question(s) for which they failed to choose the right answer. The time frame between immediate recognition and delayed recognition was controlled by conducting a few intervening tasks lasting approximately 15 minutes. The same 15 questions were presented to the participants for the delayed recognition; no feedback was given. Two scores were obtained: 1) score for immediate recognition revealing whether the participants had problems encoding the information; 2) score for delayed recognition showing whether new episodic memory was formed.

Semantic memory

The three-picture version of The Pyramids and Palm Trees Test (Howard & Patterson, 1992) was used to assess semantic memory. The test consists of 52 sets of three black-and-white pictures. During the test, each set of pictures, one picture above the other two, was presented, one after another, to the participants. The participants were told to match the pictures by choosing one of the two pictures at the bottom that was more associative to the picture above. A score that is lower than 49 indicates difficulty retrieving semantic information.

Recognition memory

The Camden Memory Test for faces (Warrington, 1996) was used as a short test of recognition memory. The difficulty is manipulated by the similarity of the distractor items. The test includes 50 non-distinctive faces, 25 targets and 25 distractors. Each target was shown to the participants for 3 seconds and the participants were told to judge if each face they saw was ‘pleasant’ or ‘not pleasant’. Recognition memory was assessed immediately after presenting all the targets. The participants were given a force-choice test, in which each target was paired with a distractor and the participants were asked to identify which one of the faces they had seen in the first half of the test.

The test provides data for three age groups: 18-49, 50-69, and 70-85. The participants were, therefore, scored according to the age group they were in.

Visual-spatial memory

Non-verbal short-term memory span was assessed with a task involving square-tapping forwards, also known as Corsi Blocks. We modified the visual memory span test from the Wechsler Memory Scale – Revised (Wechsler, 1987). Two cards (size 6” by 4”) were created with black-and-white squares in a random pattern. One card (Figure 2.1), with 10 identical black squares distributed randomly, was presented to the participants during the test. The other (Figure 2.2) was designed to have a small number underneath each square so that the examiner could direct the task based on a list of digit strings and keep track of the participants' responses. Also, the number of squares on the card was increased from 0 to 9, two squares more than the original version, to make the level of difficulty higher. In addition, the trials and levels were expanded from two trials on each of 7 levels to 13 levels, going from lists of two squares to fourteen squares, with 6 trials at each.

The examiner had to memorise the number that each square was assigned before directing the task, to ensure the test went smoothly and accurately. The participants were instructed to observe the examiner tapping the squares on the card presented in front of them and repeat the pattern of tapping immediately after the examiner had finished. Their response was only considered as accurate if they tapped the squares in the exact same order as it was done by the examiner.

The task was directed with a staircase method, starting with a list of two squares. If the participants successfully repeated the pattern of tapping, one more square was added in for the next trial; if not, the next trial used one square fewer. If a participant failed to get the first list, which was of two squares, correct, he/she was given another list of the same length to try it again. Each participant completed 12 trials before the task finished.

The first four lists were excluded from scoring as they could reveal the arbitrary length of the starting list. The average length of the fifth to the twelfth lists was taken as the non-verbal memory span.

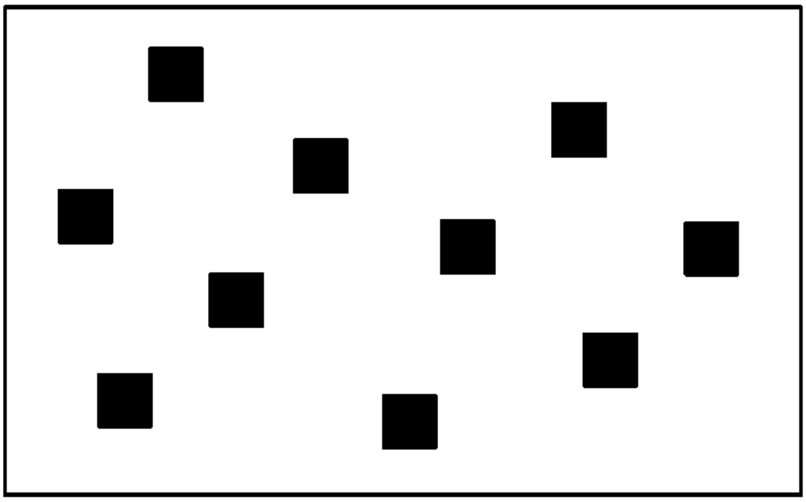

Figure 2.1. Corsi's blocks – participants' version.

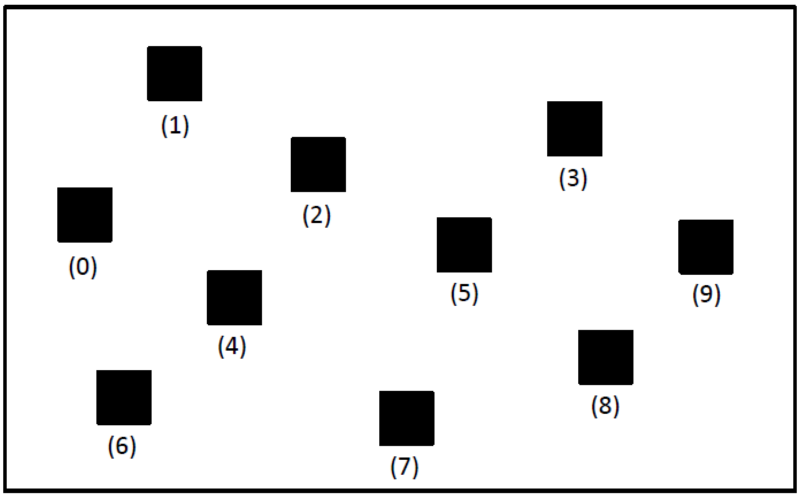

Figure 2.2. Corsi's blocks – examiner's version.

2.3.3. *Attention and executive function*

Auditory attention

The auditory attention task in BCoS (Humphreys et al., 2011) provides measures of selective attention, sustained attention, and working memory. The pre-recorded material consisted of 6 high frequency words, including three target words (‘no’, ‘hello’, ‘please’) and three highly related distractors (‘yes’, ‘goodbye’, ‘thanks’). Each word was repeated an equal number of times throughout the test in random order.

Participants were given a pen and instructed to tap the table with the pen when they heard the target words and not to respond to any other word. Before starting the practice trial(s), in which each word was played once, participants were presented with a sheet of paper with target words and distractors randomly listed on and asked to recall/point out which three words they needed to respond to. If the participant failed to recall the words, the examiner repeated the words; otherwise, the task proceeded with the practice trial. Participants were asked to recall/point out the target words once finishing the practice trial and the examiner would repeat the target words if any mistake was made. A maximum of three practice trials were allowed, the test only continued when participants were able to recall/point out the targets or responded correctly to at least one of the targets. The test trial consisted of three blocks of 18 words. At the end of the test trial, participants were asked to recall/point out the targets again. However, the test stopped if participants had made more than eight errors in the any of the blocks.

Selective attention was measured by calculating the overall accurate responses; scores for false positive and omission were also recorded. A score for sustained attention was obtained by number of correct responses in block 1 minus number of correct responses in block 3. Finally, the number of target words recalled/pointed out at the end of the test revealed how well memory is sustained in working memory.

Visual attention

The map search task in the Test of Everyday Attention (TEA) (Robertson et al., 1994) was administered to assess selective attention in the visual modality. The task is timed and involves searching for a symbol (of restaurant, petrol station, or garage) on a coloured map for 2 minutes and circling as many instances of the target symbol as possible.

The test is age sensitive and not suitable for people with severe visual problems. Therefore, the test did not proceed without a target being successfully pointed out by the participants. The TEA includes a cue book containing three different symbols: 1) a fork and a knife for restaurants, 2) a screwdriver with a wrench for garages, and 3) a gas pump for petrol stations, as well as two maps of the Philadelphia area, each containing two types of symbol.

The examiner started the test by telling the participants that they were on an imaginary road trip and they needed to find restaurants/gas stations/garages in the area, whilst showing one of the target symbols in the cue book to the participants and saying ‘this is the symbol for restaurants/gas stations/garages’. To make sure that each participant was able to do the test, he/she was asked to find a symbol that was the same as the one in the cue book before proceeding to the full test. The test terminated if the participants failed to point out the target symbol after 3 attempts.

The participants were informed that they would be timed for one minute and they needed to circle as many symbols as possible, then the examiner would stop them to swap pens to a different colour before giving them another minute to continue the test. During the test, the cue book with the target symbol was always presented above the map to constantly remind the participants of the target.

Each participant was scored according to the number of symbols found within one minute and overall symbols found in two minutes. These raw scores were then converted to scaled-scores and the final percentile based on the age group he/she belonged to. Scaled-score is suggested, by the assessment manual, to be a more accurate index of performance. The scores reveal the ability to filter out irrelevant visual information. Also, the percentile shows that a participant performed better than a certain percentage of people in his/her age group.

Switch of attention

The visual elevator task in the TEA provides a measure of attention switching, which can be an index of cognitive flexibility. However, the task involves counting, within the range of one to ten, upwards and backwards verbally; therefore, the task is not suitable for participants with output deficits or those who have difficulty with numbers.

It was explained by the examiner that the participants were to imagine that they were going up and down in a lift. The indicator in the lift was broken and, therefore, they would need to count so that they knew which floor they were on. As Figure 2.3 shows, the participants were presented with a series of pictures of the doors of a lift. The direction of counting wass shown by the small arrows. Every once a while, a large vertical arrow pointing either up or down appeared, indicating that the lift was going up or down. The participants were instructed to continue to count upwards when they saw a large arrow pointing up and to reverse the count when they encountered a large arrow pointing down. Also, the participants were directed to say ‘up’ or ‘down’, instead of counting, when they came to a large arrow. With every trial, the participants started the count with ‘one’ and counted upwards until a downward arrow came up.

The examiner demonstrated a sample trial before starting the practice trials. Two practice trials were available prior to the test trials and the participants had to perform both practices accurately to precede to the test trials. Since the task could be quite complex for PWA, the procedure was explained repeatedly, if necessary, with different practice examples. The task was terminated in the situation that the participant failed to perform the task after several attempts; this usually occurred, in the current study, when the participants stated they understood the task but could not do it due to the speech output requirements.

The participants were informed that the task was self-paced but the examiner would record the time taken to complete individual trials. Moreover, for each trial, they had two chances before reporting the floor number to the examiner; that is, if the participants had lost the count, they were allowed to start over only once. In total, 10 test trials were given and the degree of difficulty of each trial varied by the number of attention switches (large arrows) involved.

Two scores were generated from the test, accuracy score and timing score. The accuracy score was the number, out of 10, of final floor numbers reported correctly by the participants, excluding the practice trials. Only the trials with correct responses were taken into the calculation of timing score, which was obtained by dividing the total time by the number of switches in the correct items. The cut-off scores for abnormal performance, which vary among different age groups, were then used to measure the participants' performances.

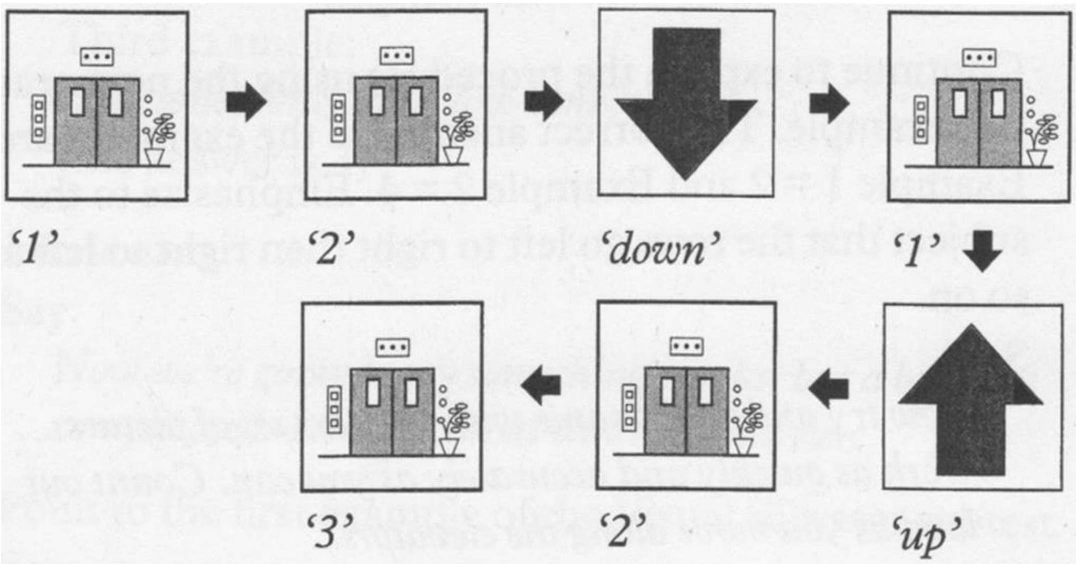

Figure 2.3. Example of visual stimuli and expected responses for the visual elevator sub-test in TEA. (Figure copied from the manual of The Test of Everyday Attention, p16)

Executive function

The Modified Wisconsin Card Sorting Test (Schretlen, 2010) was used to investigate executive function in PWA. The test involves working memory, planning, attentional flexibility, and response inhibition to problem solving (Schretlen, 2010). The test material comprises four key cards which vary in colour (blue, red, yellow, or green), form (cross, circle, triangle, or star), and number (one, two, three, or four) along with 48 response cards.

During the test, the four key cards were placed in a row in front of the participants. The participants were given the pile of 48 response cards and told to sort the cards under the key cards according to certain rules, which they must figure out by trying different rules and adjusting based on the examiner's feedback ('right' or 'wrong'). Whichever rule the participant chose first became the correct first category and the subsequent responses were marked accordingly; moreover, the participants must use the same rule for six consecutive responses to be considered as finding a rule successfully. Once the participants had six correct responses, the examiner directed them to come up with a new rule by saying 'The rule has now changed. I want you to find another rule'. Then, whichever new rule was supplied by the participants was considered as the second category. The participants again needed to make six consistent responses before the examiner asked them to find the third/final rule.

After having found the three rules, the examiner asked the participants to switch the rule again. The last three categories had to be in the same order as the first three rules found by the participants; that is, the participants were to repeat the first three categories they found. The task was completed when the participants figured out all six categories successfully or had used up the response cards. Feedback was given after each response; an incorrect response was marked as a perseverative error if a participant persisted on the same sorting category immediately after receiving negative feedback.

Each participant was given a score for executive function composite and four sub-scores, including numbers of correct categories, perseverative errors, total errors and the percentage of perseverative errors. The scores were derived based on individuals' gender, age, and years of education. Ten qualitative labels were provided by the test, from extremely superior to extremely abnormal.

2.4. Individual case report

In this section, we describe the performance of PWA involved in the study on the cognitive assessments. The description of each case focuses on general information about participants and any performance that stood out from the group. Details of background information of the PWA, including age, gender, years of education, when the stroke occurred, and handedness, is listed in Table 2.1. Outcomes of language and memory assessments are shown in Table 2.2 and Table 2.3 respectively with the raw scores for each task. In terms of executive function and attention, some of the scores provided in Table 2.4 are scaled according to the manual of assessments in order to demonstrate their level of performance in comparison to the norms. However, in some cases where the participants dropped out of the study or were unable to do the tasks after a few attempts, the results are marked as ‘N/A’, indicating the data is missing. Also, results of the tasks that are not directly related to the current study are shown in Table 2.5. The scores that are outside the range of norm, provided by the assessment tools, were highlighted. These tasks (test of visual neglect, visual extinction, and textile extinction) were used as filler tasks for the purpose of keeping appropriate duration of time between the immediate and delayed test of episodic memory, story recognition.

BR, a right-handed male participant with 12 years of education was 69 year-old and at five years after the onset of the stroke at the time he participated the study. BR performed well on language tasks, with only a few failures at naming and non-word repetition. His performance on memory assessments showed intact semantic and recognition memory; further, BR was able to form new episodic memory. In digit repetition tasks, both verbally and by pointing, BR did well in comparison with other participants with aphasia. In contrast, his visuo-spatial STM span was poorer than verbal STM span. It could be argued that the language impairments of BR were mild enough to have no obvious effect on his performance on verbal tasks. BR’s abilities in executive function as well as visual attention were found to be intact. Nevertheless, the ability to sustain auditory attention fell outside the range of norm. Overall, BR had a strong cognitive profile that is close to people without brain damage, at least in the aspects investigated.

CE is a right-handed male with 16 years of schooling, age 53 at the time of the study, who was at seven years post stroke onset. CE had hardly any speech output and scored zero in almost all language tasks except for naming; even his naming ability was very limited. In terms of memory, semantic and recognition memory was intact. The visuo-spatial STM span was found to be similar to people without brain damage. However, once verbal output (i.e. digit repetition) or rehearsal (i.e. digit reception by pointing) was involved, CE’s STM span reduced significantly. What is more, in the story recognition task, CE performed poorly when asked to recognise details about the story immediately after the story was presented but the performance improved in the delayed recognition. This pattern points to a potential deficit of encoding newly learnt information; yet, the CE was still capable of forming new episodic memory with the help of feedback/repeated presentation of the information.

CE had impaired visual selective attention. Also, he was unable to do the task that assesses attention switching in visual modality. However, there is not sufficient evidence to conclude whether it is the case that his visual attention switching ability was impaired because the assessment also required language output, which was found to be severely impaired for CE. As for attention in the auditory modality, he had poor selective auditory attention. This might add an alternative account for the reduced performance in the digit repetition task. Regardless of the output modality required for digit repetition, the digit strings were presented auditorily; therefore, impaired auditory attention accounts, at least to a certain extent, for the reduced performance on the task. In addition, the participant’s executive function was intact; with other systems impaired, CE could have been relying more heavily on this ability to learn new information.

DB is a male right-handed participant with 16 years of education, 74 years old at the time of participation, who had a stroke ten years ago and was left with aphasia. His performances on the language tasks showed reduced production ability at single word level as well as in connected speech. The difficulty in word repetition lay mainly in repetition of low imageability words with multiple syllables. The difficulty in repetition increased along with the degree of complexity of the words. The same pattern was also observed in the naming task; most errors DB made were with items of relatively low frequency and with more than one syllable. As for the picture description task, DB produced mostly single words and simple sentences with poor or no grammatical structure(s).

Verbal and visuo-spatial memory STM span were at the same level; moreover, DB did not perform better on repetition of digit strings by pointing, which is supposed to lower the demand for verbal output from PWA. It is unclear whether DB's performances on STM tasks show an overall reduced STM capacity or were under the influence of the language impairment. Semantic and recognition memory, on the other hand, remained intact. Also, despite showing a deficit in encoding information, new episodic memory could be formed through correction and feedback. In addition, DB showed intact attention in the visual modality; yet, the abilities of selective and sustained auditory attention were impaired. It is likely that when new information was presented auditorily, this had a negative effect on performance. Executive function ability was reduced.

EC, a right-handed female with 17 years schooling, was 59 years of age at the time of participation. She was at eight years post onset of the stroke that left her with mild aphasia. EC was able to perform all language tasks, except for non-word repetition, at high level and successfully retrieved the targets in the first attempt. Only a few mistakes were made in her speech production as assessed by the picture description task. Moreover, although EC's verbal STM span improved significantly when verbal repetition was not required, both of her digit repetition scores, verbally and by pointing, fell into the category of people without brain damage. Semantic, recognition, and episodic memory were intact. Also, no deficit was found in the perspective of attention and memory.

EG is a right-handed male with 18 years of education. He had a stroke five years ago and was 84 at the time he took part in the study. In terms of repetition, EG performed poorly on word repetition and complex word repetition but was able to repeat all the non-words, indicating the possibility that the non-lexical route might have been intact so that stimuli requiring no lexical processing were conveyed from input to output lexicon successfully. All three linguistic factors affected EG's performance on repetition; that is, more errors were made when a target was of low imageability, of low frequency, or multi-syllabic. Whilst attempting to repeat complex words, EG made errors that were phonologically similar to the targets. Naming ability was reduced and so was the ability to produce connected speech. However, it is notable that the connected speech produced by EG had fairly good syntactic variety and most sentences were grammatically correct. The main difficulty for EG was finding appropriate words to convey the information.

EG demonstrated reduced verbal STM span but relatively intact visuo-spatial STM; he performed poorly, compared to visuo-spatial tasks, on both verbal digit repetition and digit repetition by pointing. Although he scored higher with pointing, the difference between the two modalities (verbal versus pointing) was not significant. Semantic, recognition, and episodic memory were intact. In terms of visual and auditory attention, EG performed well on the tasks that tapped into visual selective attention and auditory attention as well as executive function. However, he had difficulties with the task involving visual attention switching, which was relatively complex.

JS was 71 years old when she took part in the study. JS is a right-handed female who has 13 years of education. She had a left-hemisphere CVA eleven years ago and was left with aphasia. Despite delayed speech rate, JS performed fairly well on the language tasks. In repetition tasks, JS was able to reach more than fifty per cent accuracy except in the non-word condition, although she usually required the examiner to repeat the stimuli before she could successfully repeat the complex words. Most mistakes JS made involved words of low frequency and multiple syllables suggesting that her performance was affected by those two linguistic factors. Naming and narrative speech were relatively intact. JS accurately named most of the items in the first attempt; if naming failed at first, JS responded well to the phonological cues provided by the examiner and was able to retrieve the names in the second attempt.

In terms of memory, JS showed no deficit in semantic memory and/or recognition memory; also, JS was capable of forming new episodic memory. However, when it came to digit repetition, verbally and pointing, JS was found to have reduced performance. Although JS benefited slightly from the digit string task that required no verbal output, the performance of the task with both output modalities demonstrated reduced verbal STM span. Looking at the result for non-linguistic STM span (Corsi's block test), JS performed at a higher level compared to her performance on digit repetition. The difference between verbal and non-verbal STM tasks might point to the possibility that her reduced STM was, at least partially, a consequence of impaired language processing.

JS had intact executive function but reduced abilities in some aspects of attention. One was visual attention, which was scored in two parts, in one-minute and two-minute time limit. The performance of JS was better after the first half of the task, suggesting that it is possible that visual attention was not impaired but that it took JS relatively longer to attribute the visual attention needed for the task.

JH is a 67 years old right-handed male who was at seven years post the stroke onset at the time of the study and has 15 years of education. Overall, his repetition ability was reduced, although he was able to repeat some non-words and complex words. The majority of mistakes JH made in word repetition involved low frequency and/or multi-syllabic words. With complex words, he failed to repeat the words after the examiner repeatedly presented the stimuli. However, JH was capable of repeating non-words. Naming ability was impaired, although JH successfully named half of the stimuli. The difficulty he had in naming also appeared in his connected speech, in which he produced almost equal numbers of appropriate and inappropriate information carrying words.

JH performed worse in digit repetition by pointing than verbal repetition, indicating potential difficulties in visual processing. Therefore, the initial intention of having participants respond by pointing in order to lower the demand for verbal output did not benefit JH but caused more difficulty instead. Nevertheless, the visuo-spatial span was not worse than other PWA or age-matched control participants. Semantic memory and recognition memory were intact. Despite encoding difficulty, JH was able to form new episodic memory for newly received information.

Again, when attention was assessed, JH showed difficulties performing visual tasks. His scores for the visual selective attention task were too poor to find an equivalent on the scale provided by the assessment tool. Moreover, although he was able to do visual attention switching, it took him much longer than it should have to complete the task. Auditory attention was also severely impaired in all the aspects we assessed, including selective attention, sustained attention, and auditory working memory. Additionally, impaired executive function was found.

JG is a right-handed female with 15 years of education, 68 years old at the time of participation. Her had the stroke that left her with serve aphasia seven years ago. JG showed difficulties in all the language aspects we assessed, including word repetition, naming, and production of connected speech, and had no speech output at all. However, she was able to do the verbal STM task, which requires verbal repetition of digit strings, though the span was reduced. It is likely that, to certain extent, she was able to maintain linguistic input for repetition but, because of her impaired linguistic knowledge, subvocal rehearsal failed, causing reduced verbal STM span as well as failure in word repetition. Furthermore, JG did not benefit from digit pointing, which supposedly decreases the demand of having to produce verbal output, indicating potential disruption in visual processing. In addition, her semantic, recognition, and episodic memories were impaired.

From the perspectives of attention and executive function, JG was unable to do any of the assessments used. Yet, based on observations made whilst conducting the assessments, the problems she had could have been a combination result of reduced comprehension, which is required to understand the direction of the tasks, and impaired attention and/or executive function. For instance, JG understood the instructions for the map searching task, which was a task requiring visual selective attention with simple instruction, and was able to spot one of the targets on the map during practice; however, once the task started, she failed to ignore the visual noise and focus on the targets. In contrast, the instructions for the visual attention switching task, the visual elevator sub-test from TEA, are more difficult for most PWA to comprehend; JG was unable to do the task after the examiner had repeated the instruction and given an example by demonstrating a practice trial. In addition, similar difficulties were found with the auditory attention task and task that assessed executive function.

JB, who had a stroke six years, is a 74 year-old right-handed male participant with 12 years of education. JB showed reduced performance on verbal repetition and picture naming. It is particularly notable that JB’s performance on naming was affected greatly by the length of words, where multi-syllabic names were more difficult for him to retrieve; yet, the same effect was not found in word repetition. He produced grammatically correct connected speech with relatively good syntactic variety and fluency; nonetheless, the speech contained many inappropriate information carrying words. As for his performance on the memory tasks, JB showed close to control verbal and visuo-spatial STM spans, although the score was lower when responding by pointing. Semantic, recognition, and episodic memories were intact. No severe impairment of attention was found in either visual or auditory modality. In addition, JB performed well on executive function.

JHH, who had a stroke three years ago, is a right-handed male with 18 years of education. He was 88 years old at the time he took part in the study. In terms of language profile, JHH was capable of repeating some words, up to three syllables, but not complex words or non-words. His naming ability was limited and production of connected speech was severely impaired. JHH was capable of performing verbal and visuo-spatial STM tasks, and his verbal STM span did not seem to be biased by his language impairment. In addition, JHH had impaired semantic memory and recognition memory. Verbal STM span by pointing and episodic memory were not assessed because JHH dropped out of the study due to illness.

JHH had within-normal executive function ability. Yet, he performed poorly on visual selective attention task and was unable to do the visual attention switching task, which was a more complex task. His auditory attention was not assessed.

JR is a left-handed male with 15 years of schooling; he was 66 years old and at seven years after the stroke onset at the time of taking part. JR was able to repeat only limited words and complex words and was unable to repeat any non-word. By contrast, JR had relatively intact naming ability and speech production, performing well on the story description task. In spite of reduced rate of speech, the sentences were grammatically well-formed with some syntactic variation.

Verbal STM span was assessed with two output modalities, verbal and by pointing. JR showed slight benefit from pointing and had a higher pointing span than verbal repetition span. His semantic memory was intact as well as recognition memory. The result of assessment of episodic memory indicated that JR had a minor degree of encoding difficulty but was capable of forming new episodic memory through feedback and repeated presentation of new information.

JR had intact visual attention but selective as well as sustained auditory attentions were impaired. Therefore, his performance(s) on tasks involving auditorily presented stimuli might have been affected as a result of reduced auditory attention. Executive function, on the other hand, remained intact.

JT, a right-handed male, participated in the study at age 62. He has 10 years of education and the stroke occurred five years ago. JT showed intact ability to repeat words but relatively lower accuracy of non-word repetition. Naming ability was good and so was production of connected speech. Despite slightly delayed speech rate, JT had no difficulties producing grammatically correct speech with a good variety of syntactic structures. Overall, JT performed similar to norms in the memory tasks. The only outstanding result was reduced verbal STM span, in pointing modality in particular. This pattern was not expected because no obvious deficit was shown across the language tasks. However, this phenomenon could also indicate a reduced verbal memory span that is independent from language impairment. Results from assessments of attention further demonstrate that, despite taking more time to complete tasks requiring visual and/or auditory attention, JT could successfully reach the goals without feedback. Finally, JT was found to have intact executive function.

JW is a left-handed male with 12 years of education. JW was 56 years old and had a stroke five years prior to taking part of the study. Overall, JW had impaired word repetition ability; more errors were made when the targets were multi-syllabic words or complex words. Naming was also impaired; however, the majority of errors were phonologically similar to the targets. JW performed poorly on production of connected speech; very limited syntactic structures were used, along with grammatical errors. JW produced mostly single words instead of sentences. Delayed word retrieval was observed in both naming and connected speech.

From the perspective of STM, JW was reported to have reduced verbal STM span as well as visuo-spatial STM span. Semantic memory and recognition memory were intact; also, the ability to form new episodic memory was preserved, in spite of encoding deficit at the initial stage. As for attention, reduced selective visual attention and sustained auditory attention were observed. JW was unable to do the visual attention switching task, which was more complex in nature and required counting verbally. JW's executive function remained intact.

PF is a right-handed male who has 20 years of education. He was 82 at the time he took part in the study, and he had a stroke which left him with aphasia eight year ago. PF showed difficulty in repetition of words and non-words. With most of the word repetition tasks, PF needed the examiner to repeat the stimuli before he could successfully repeat them. The errors PF made were mostly phonological. Also, PF was found to have reduced naming ability; for those pictures that he attempted to name several times, the first few words retrieved were usually semantically related to the target and only a few phonological mistakes were recorded. PF was able to produce connected speech at close to normal speech rate. Moreover, the sentences were mostly grammatically well-formed with good syntactic variation. The language deficit PF had was mainly in retrieving appropriate words for the context.

In terms of STM, PF had limited verbal as well as visuo-spatial memory span. Semantic and recognition memories were intact and the ability to form new episodic memory was preserved. In addition, PF performed close to the norm in the visual selective attention task and auditory attention task, although he failed to do the more complex visual attention switching task. His executive function was within normal range.

RH is a right-handed male with 16 years of education, who was at five years post the stroke onset and took part in the study aged 67. RH was able to do word repetition, even with complex words, and non-word repetition; no deficit in naming was found. His production of connected speech was close to norm with high grammatical accuracy and relatively good syntactic variety, although the rate of speech was reduced.

Compared to more severely impaired participants in this study, RH had a larger verbal STM span and his performance benefitted from repetition by pointing, suggesting that RH not only had no difficulty processing visually presented stimuli but also that his mild language impairment can be attributed to slightly worsened verbal STM. Semantic, recognition, and episodic memories were preserved. RH had intact visual and auditory attention and executive function.

RJ, a male with 12 years of education, 50 years old at the time of participation, and was at 11 years after the stroke onset. He had reduced repetition ability across words, complex words, and non-words. In word repetition, the majority of the mistakes made were with low-frequency words and the errors could be considered as phonologically related to the targets. Naming was impaired but no obvious linguistic characteristic was found among the targets that he failed to retrieve. He had poor production of connected speech, with not only reduced rate of speech but also almost no syntactic variety and grammatical structure.

RJ was capable of performing verbal STM tasks, verbally and by pointing, though the results indicated reduced span. Semantic, recognition, and episodic memories were intact. Furthermore, RJ was capable of utilising selective attention in both visual and auditory modalities to focus attention to the targets. However, deficits were reported in visual attention switching and sustained auditory attention, which could account for the reduced capacity in verbal STM and why RJ did not benefit from repetition by pointing. His executive function was intact.

SH was 55 years old at the time he participated the study and he had a stroke eight years ago. SH is a right-handed male with 14 years of schooling. SH performed well on repetition of words and non-words as well as naming. Moreover, SH was able to produce connected speech that was grammatically well-formed and had good syntactic variety and speech rate. SH performed at the same levels as the age-matched controls. His semantic, recognition, and episodic memories were intact. In terms of attention, SH performed well on visual and auditory attention tasks. His executive function, on the other hand, was on the lower end of the scale.

TB, who had a stroke 11 years ago and participated aged 81, is a right-handed male with 10 years of schooling. TB had difficulties in word repetition but was able to repeat complex words on the first attempt. Although TB failed to repeat some words, he generated (non-)words that were phonologically similar to the targets. Also, he repeated some non-words successfully. Naming ability was reduced. The errors in naming were mostly semantic, with only a few phonological errors. TB was unable to produce connected speech. During the task, he produced mostly words instead of sentences. Overall, the syntactic structure he used was simple but still contained grammatical errors.

Compared to other participants with aphasia, TB performed relatively well on verbal STM tasks, both verbally and by pointing. Moreover, TB benefitted from repetition by pointing, suggesting possible influence of his language impairments on verbal STM span. TB had intact semantic, recognition, and episodic memories. Additionally, TB showed no deficit in visual selective attention. He was unable to complete the visual attention switching task due to his problem with counting. Also, no attention deficit was found in auditory modality. TB had preserved executive function ability.

Table 2.1. Background information about the participants with aphasia.

Participant	Age	Gender	years post stroke	Education (years)	Handiness
BR	69	M	5	12	R
CE	53	M	7	16	R
DB	74	M	10	16	R
EC	59	F	8	17	R
EG	84	M	5	18	R
JS	72	F	11	13	R
JH	67	M	7	15	R
JG	68	F	3	15	R
JB	74	M	6	12	R
JHH	88	M	3	18	R
JR	66	M	7	15	L
JT	62	M	5	10	R
JW	56	M	5	12	L
PF	82	M	8	20	R
RH	67	M	5	16	R
RJ	50	M	12	12	R
SH	55	M	8	14	R
TB	81	M	12	10	R

Table 2.2. Raw scores of language tasks

participant	word repetition (maximum=32)	complex word repetition (maximum=6)	non-word repetition (maximum=10)	naming (maximum=48)	Picture description (CAT) connected speech					
					overall	*appropriate ICWS*	*inappropriate ICWS*	*Syntactic variety*	*Grammatical well-form*	*speed*
BR	32	6	6	44	77.5	71	2	3	4	1.5
CE	0	0	0	8	0	8	8	0	0	0
DB	24	2	1	36	16	21	8	1	1	1
EC	32	6	4	48	101	88	2	6	6	3
EG	12	1	10	29	34.5	43	17	3	4	1.5
JS	18	4	2	35	60	61	10	4	4	1
JH	25	1	4	24	5	17	18	2	3	1
JG	N/A	N/A	N/A	N/A	0	0	0	0	0	0
JB	21	1	4	33	27	55	39	4	5	2
JHH	13	0	2	11	0	0	0	0	0	0
JR	10	2	0	44	33	29	5	3	4	2
JT	32	6	4	46	53	44	2	4	5	2
JW	26	0	6	41	15.5	23	8	0	0	0.5
PF	13	6	2	36	14	42	40	5	4	3
RH	31	6	9	48	50.5	42	3	4	5	2.5
RJ	23	2	6	38	16.5	19	6	1	1	1.6
SH	32	6	8	48	59	48	2	4	6	3
TB	24	6	4	23	-11.5	6	21	1	1	1.5

Table 2.3. Raw scores of memory assessments

Participant	Digit repetition - verbal	Digit repetition – pointing	Viso-spatial memory	Semantic memory (maximum=52)	Recognition memory (maximum=25)	Episodic (maximum=15)	
						Immediate	*delayed*
BR	6.0	5.5	3.8	52	23	15	15
CE	2.7	2.5	5.0	50	24	9	12
DB	4.8	4.5	4.0	50	23	12	15
EC	6.5	9	4.0	52	25	15	15
EG	3.3	3.75	4.7	51	22	15	15
JS	2.7	3.5	4.1	52	24	15	15
JH	3.7	2.8	4.5	50	22	13	15
JG	3.7	2.8	3.4	45	11	6	7
JB	5.0	3.7	5.0	49	22	13	14
JHH	4.7	N/A	4.9	40	7	N/A	N/A
JR	3.0	3.5	4.9	52	25	11	14
JT	4.2	3.8	4.8	51	25	14	15
JW	2.5	3.5	3.5	52	24	13	15
PF	2.9	2.3	3.8	52	23	14	15
RH	6.5	8	4.2	52	21	14	15
RJ	3.3	3	4.8	49	25	13	14
SH	6.8	7.3	5.5	51	23	13	15
TB	4.8	5.5	4.2	50	21	14	14

Table 2.4. Scores of assessments of attention and executive function

participant	visual attention (scaled score)		attention switch – visual (scaled score)		auditory attention						M-WCST
	1 mins	*2 mins*	*time*	*accuracy*	*practice needed*	*accuracy*	*false positives*	*omissions*	*sustained attention*	*WM score*	
BR	7	9	6	11	1	53	0	1	-1	3	High average
CE	3	5	N/A	N/A	2	36	9	8	-2	3	Average
DB	11	11	5	9	1	48	4	2	3	1	Borderline
EC	8	17	8	10	1	54	0	0	0	3	Average
EG	7	8	N/A	N/A	2	53	0	1	1	3	High average
JS	5	6	6	11	2	54	0	0	0	3	Superior
JH	No equivalent	No equivalent	No equivalent	5	3	10	5	3	N/A	1	Borderline
JG	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
JB	8	8	6	15	2	53	0	1	-1	3	High average
JHH	No equivalent	No equivalent	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Average
JR	7	8	3	6	1	45	0	9	2	3	High average

participant	**visual attention** (scaled score)		**attention switch – visual** (scaled score)		**auditory attention**						**M-WCST**
	1 mins	*2 mins*	*time*	*accuracy*	*practice needed*	*accuracy*	*false positives*	*omissions*	*sustained attention*	*WM score*	
JT	9	9	3	6	2	54	0	0	0	3	Average
JW	6	5	N/A	N/A	1	51	2	1	2	3	Average
PF	8	7	N/A	N/A	1	47	0	7	0	3	Average
RH	6	7	4	15	1	53	0	1	1	3	Average
RJ	9	9	7	3	2	40	4	9	4	3	Average
SH	9	11	9	9	1	52	0	2	-2	3	Low average
TB	7	7	N/A	N/A	2	34	14	4	2	2	Average

Table 2.5. Results of other cognitive assessments used as filler tasks in the study

participant	visual neglect (apple cancellation)			visual extinction		tactile extinction	
	correct response (maximum=50)	*asymmetry (full)*	*asymmetry (incomplete)*	*Left*	*Right*	*Left*	*Right*
BR	50	0	0	4	4	4	4
CE	50	0	0	4	3	4	3
DB	50	0	0	4	4	4	4
EC	50	0	0	4	4	4	4
EG	49	-1	-1	4	4	4	4
JS	50	0	0	4	4	4	2
JH	25	-2	0	4	1	4	1
JG	45	-5	0	4	1	4	2
JB	48	0	0	4	4	4	4
JHH	N/A	N/A	N/A	N/A	N/A	N/A	N/A
JR	50	0	0	4	4	4	3
JT	49	-1	0	4	4	4	4
JW	50	0	0	4	4	4	4
PF	44	0	0	4	4	4	4
RH	50	0	0	4	4	4	4
RJ	50	0	0	4	4	4	4
SH	41	2	0	4	4	N/A	N/A
TB	50	0	0	4	4	4	4

Chapter 3 The effect of ‘linguistic load’ on pair-associative learning: non-incremental versus incremental learning approach.

3.1. Introduction

This chapter sets out investigate the ability for learning new information in PWA. As reviewed in Chapter 1, the performance of PWA on various tasks can be improved through providing feedback (yes/no) and/or providing target-oriented cues (e.g. cues that are semantically or phonologically related to the target) and these improvements can be observed in language tasks as well as non-linguistic tasks. Therefore, it is arguable that, at least to a certain extent, the ability to learn is intact in PWA. However, to further understand the possible limitations of learning in PWA and potential methods to enhance this, further studies are required, therefore the current project has the goal of bridging this gap in the existing literature.

The fundamental questions asked here are two-fold. Firstly, whether, compared to people without brain damage, PWA show learning across stimuli with various ‘linguistic loads’. *Linguistic load* of a stimulus, as defined by Christensen and Wright (2010), is determined by the degree to which it can rapidly elicit a name within a confrontation naming task. In other words, the basis for categorising the linguistic load is the ease with which a stimulus can be named and/or assigned a semantic or phonological code. Although the term (linguistic load) and the terms of its three sub-categories (linguistic-heavy, semi-linguistic, & non-linguistic) were used by Christensen and Wright for categorising the to-be-learnt objects, the terms were applied to the three sets of auditory material. The purpose of investigating the performance on learning new information containing various linguistic loads is to examine whether the learning deficit, if present, is specific to verbal material. Secondly, whether the two approaches chosen to direct the learning task (i.e. non-incremental and incremental) facilitate or hinder learning.

In this chapter, the above questions were investigated using a pair-associative learning task involving pairs of visual and auditory stimuli. The linguistic load of auditory stimuli was manipulated to investigate the effect of linguistic load on learning. In the two experiments, three sets of auditory stimuli were included: real words (linguistic-heavy), non-words (semi-linguistic), and animal sounds (non-linguistic). In addition, by employing two methods of directing learning (non-incremental vs. incremental) within the same pair-associative materials the learning outcomes were able to be directly compared.

It also provided an opportunity to see whether a learning method, incremental learning, which was previously reported to benefit learning among participants without brain damage (see below), may also enhance the performance of PWA.

3.2. Background

As reviewed in the previous chapter, learning deficits have been reported among PWA in various tasks. In comparison to people without brain damage, PWA generate learning patterns that fluctuate rather than improve steadily (Brookshire, 1967, 1969). Despite reduced learning ability, it has been reported that PWA are capable of learning new linguistic (Freed et al., 1998; Kelly & Armstrong, 2009) and non-linguistic (Brookshire, 1969; Tikofsky & Reynolds, 1962, 1963) information. Nonetheless, among the existing literature, studies have involved either sole learning of words (Freed et al., 1998; Kelly & Armstrong, 2009), non-words (Basso et al., 2001), or non-linguistic material (Brookshire, 1969; Tikofsky & Reynolds, 1962, 1963). A study that provides a direct comparison between linguistic and non-linguistic learning is still necessary in order to draw in order to draw firm conclusions on the learning ability of PWA.

In addition, a large amount of literature has found reduced memory capacity in PWA (Burgio and Basso,1997; Caspari et al., 1998; Christensen & Wright, 2010) and since memory is closely related to learning (Gupta & Tisdale, 2009; Locke & Deck, 1978; Martin et al., 2006; Martin & Saffran, 1997), it is important to take into account the potential impact of memory deficits on learning. However, no study has specified an exact number of items that can be learnt by PWA within a single learning session without overloading their memory capabilities. Therefore, in spite of controlling the number of to-be-learnt items, having a method of learning that minimises memory load could further increase the possibility that learning is affected by the reduced memory capacity. One of the memory factors that has been suggested to confound learning outcomes is the occurrence of proactive interference (PI) in short-term memory. Proactive interference refers to the loss of information in memory due to interference from the material that is presented prior to the to-be-remembered item(s). Previous studies (Flowers, 1975; Hamilton & Martin, 2007) have reported the negative effect of PI on the performance of verbal tasks among PWA and also populations without brain damage. It is expected that PI, if present, can be minimised through employing an incremental learning method. *Non-incremental learning* refers to when all of the to-be-learnt items are given to learners at once. In contrast, *incremental learning* introduces the to-be-learnt items one by one; that is, learners are given opportunities to familiarise/practice the items before the next item(s) is added to the learning process.

3.3. Current experiments – hypothesis and predictions

The goal of the current experiments was to answer the fundamental questions asked about learning in section 3.1. Based on the literature reviewed above, it was hypothesised that the learning deficits observed in PWA resulted from their language deficits. If the hypothesis was accurate, learning of linguistic stimuli would be affected the most and, therefore, the performance should be most distinct from people without brain damage compared to the learning of other types of stimuli. Reduced learning of the semi-linguistic stimuli (non-words) should also be observed among people with aphasia because linguistic knowledge serves as a facilitator in non-word learning. As for non-linguistic stimuli (animal sounds in this case), the chance of using linguistic knowledge to facilitate learning was assumed to be minimal and, therefore, people without brain damage and PWA should share similar grounds for learning for this set of stimuli. Consequently, although PWA may still generate relatively reduced learning outcomes in learning of non-linguistic items, the difference between PWA and the controls was expected to be smaller, compared to learning of real words and non-words. As for people without brain damage, with intact linguistic knowledge, real words should be the easiest to learn among the three sets of stimuli. The level of difficulty should increase for learners without brain damage as the amount of linguistic information the stimuli carried decreases. Therefore, the performance on learning of non-words and animal sounds were expected to decline in accordance.

In terms of the method of directing learning, incremental learning was hypothesised to result in better learning outcomes due to its advantage for minimising proactive interference. That is, with the same learning materials, incremental learning should lead to better performance in comparison with non-incremental learning. The effect of incremental over non-incremental learning was expected to be observed in learning outcomes among all three groups of participants.

3.4. Experiment 1a

3.4.1. *Participants*

This experiment involved PWA in addition to people without brain damage who served as control groups. Eighteen PWA were recruited through North East Trust for Aphasia (NETA) in Newcastle. All PWA met inclusion criteria, including: 1) individuals with impaired language due to single left hemisphere cerebrovascular accident (CVA); 2) at least six months post-onset of stroke; 3) had no language deficits before the CVA; and 4) no significant hearing and visual problems according to self-report.

To match the number of PWA who took part in the study, 18 young participants (age 18-30) and 18 participants (age 50-80) whose age matched the PWA, were also recruited to take part. The group of young participants consisted mostly of university students. Young participants were thought to provide information on whether the task was learnable and what the pattern(s) of learning would be like without the confounding factors of language impairments and age. Older participants without brain damage were recruited as age-matched controls for the PWA. All the older participants met the following requirements: 1) no significant visual and/or hearing deficits; and 2) no history or sign of dementia or other cognitive deficit(s) based on self-report. Table 3.1 provides information on the average age of the three groups.

Table 3.1 Average age (in years) of the three groups of participants

	Mean	Std. Dev.	Age range
young control	21.56	2.03	18-30
older control	61.65	8.91	50-80
PWA	67.33	11.60	50-80

3.4.2. *Materials*

The paired-association task of non-incremental learning involved three sets of 10 visual-sound pairs for participants to learn on three separate occasions. Each experimental session lasted approximately 40 minutes. The visual stimuli were items that were completely new to the participants. The purpose was to ensure that the learning experience was new to all the participants and it was less likely for them to create a semantic cue for the stimuli as reference for later recollection. Three types of visual stimuli were included, including: 1) (traditional) Chinese characters, 2) non-objects (developed by Kroll & Potter, 1984), and 3) black-and-white nonsense line-drawings. The Chinese characters selected were easily distinguishable from one another. The non-objects, novel tools, were taken from a set that originally created by Kroll and Potter (1984) to investigate concept representation. Ten black-and-white nonsense line-drawings were designed to be as difficult to verbalise as possible; that is, no obvious shape and/or salient feature were in the line-drawings. The three sets of visual material are presented in Appendix B.

Each visual stimulus was randomly paired with a corresponding auditory associate. The three types of auditory stimuli were: 1) real words, 2) non-words, and 3) animal sounds. All words and non-words contained two syllables and followed the spelling convention of CVCVC (i.e. consonant, vowel, consonant, vowel, consonant). A native speaker of British English was hired to record the auditory stimuli containing linguistic information, real words and non-words. Non-words were names of space aliens created by Gupta et al. (2004) based on English rules of pronunciation; the stimuli were downloaded from www.psychonomic.org/archive/ and then re-recorded by the native British English speaker. Animal soundtracks were downloaded from FindSounds (http://www.findsounds.com/types.html); all downloaded soundtracks were edited to be the same length (4 seconds) in order to meet the design of the experiment. Appendix B includes lists of the words and the non-words involved.

The experiment was run on either a PC in a computer lab at Newcastle University or a laptop of equal screen size for participants who were unable to travel to the University. In each session, the participants received a different set of visuo-auditory pairs presented by psychological experiment software, DMDX (Forster & Forster, 2003). The visuo-auditory pairs were built by pairing a set of visual stimuli and a set of auditory stimuli in a pseudo-randomised manner. The rationale was that the current experiment focused on how linguistic load of the stimuli might affect learning outcomes; therefore, the different sets of visual stimuli were paired with three sets of auditory stimuli by rotation in order to avoid the visual stimuli becoming a confounding factor in the learning task. To achieve the pseudo-randomisation, nine versions of DMDX scripts of different visuo-auditory pairing were built in order to allow counter-balancing. That is, in script versions one to three, Chinese characters were paired with real words, non-words, and animal sounds respectively; in script versions four to six, non-objects were paired with real words, non-words, or animal sounds; and in scripts seven to nine, the three sets of auditory stimuli were paired with nonsense line-drawings. Following from the scripts above, a further nine scripts were created to allow the pseudo-randomisation within pairings of the ten visuo-auditory pairs. In other words, a visual stimulus and an auditory stimulus were paired differently to how they were within the first nine scripts. For instance, '*colleague*' was the auditory associate of '夜' (a Chinese character) in the original within-pairing system; in the alternative system of within-pairing, '*colleague*' was assigned to another visual stimulus in the set. The sets of visuo-auditory pairs were counter-balanced across the participants. During the learning task, the order of presentations of the pairs was randomised by DMDX. Furthermore, the positions of which items occupied on the screen were also randomised by DMDX. By doing so, the chance of using the relative position of an item as learning reference was minimised.

3.4.3. *Procedure*

The learning task, summarised in Figure 3.1, consisted of two parts. In Part 1, the ten visuo-auditory pairs were presented to the participants one after another. The participants were asked to focus on remembering the pairs for the immediate assessment trial(s). Part 2 was a computer-assisted training and assessment trial, in which participants were assessed on how many pairs they had learnt immediately after the pairs had been presented and feedback was available to reinforce the learning. Depending on the performance of the participants on the assessment trial (Part 2), each trial repeated a maximum of six times, if necessary, giving the participants a maximum of 60 learning opportunities. For the first presentation, each visual stimulus was shown on screen for 8 seconds with its audio associate repeated through the interval. A cross sign (like this, +) was used between the presentation of every pair to notify the participants that an item was about to appear. In the training and assessment session (Part 2), the participants were assessed and were also learning at the same time. For the ten test trials, they first saw 4 items distributed at each corner of the screen and then heard an auditory stimulus; the task was to match the auditory stimulus with the correct item. Participants made their selections by making a mouse-click on the item of choice. After having made a decision, auditory feedback was given by the computer, informing the participants '*Correct/Wrong*'. Then, regardless of whether the choice was correct or not, the to-be-learnt pair would be shown again with its auditory associate repeated. Part 2 was repeated until the participants had reached 100% accuracy or they had completed 6 repeated trials. This was controlled by the DMDX software.

The outcome measure was the percentage of the mean accuracy across all six trials. Once the participants had reached a hundred percent of accuracy in a trial, the learning task terminated and the percentages(s) of the following trial(s) was assumed as 100%. For example, if a participant learnt 80% in the first trial, 90% in the second, and 100% in the third; the percentages of accuracy of the rest trials (trial 4-6) were considered as 100%; in this case, the participant's overall learning outcome would be 95%.

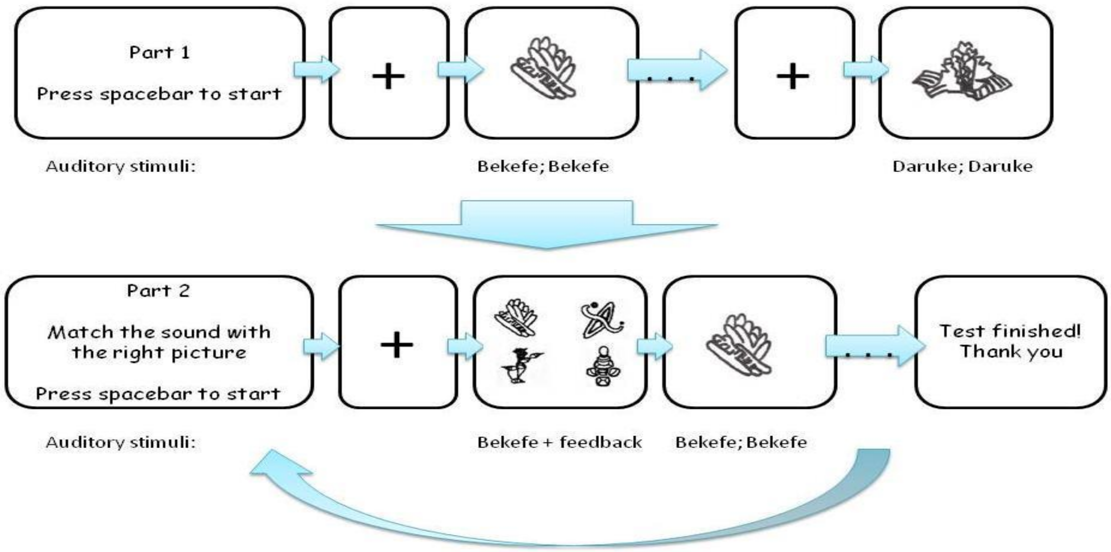

Figure 3.1. Procedure of non-incremental learning task.

3.4.4. *Results and discussion*

In this section, the data analysis focuses on answering: 1) whether PWA demonstrated patterns of learning that were different from the participants without brain damage; and 2) whether the learning outcomes were affected by the amount of linguistic information that the stimuli carried. Though the visual stimuli were not of primary interest and were counterbalanced among participants to minimise their influence, data was categorised into visual and auditory sets to explore the potential effect of visual stimuli on learning. SPSS, statistic software, was used for the data analyses.

A mixed repeated measure analysis of variance (ANOVA) was employed to explore the effect of auditory and visual stimuli independently. This was done on preference to considering visual condition (Chinese characters, non-objects, & nonsense line-drawings) and auditory condition (real words, non-words, & animal sounds) as two within participant factors and having group (young, older, & PWA) as a between participant factor. The rationale for this was that the focus of the current experiment was to investigate the effect that the various linguistic load that the auditory stimuli contained whereas visual stimuli were designed to minimise potential confounds. Therefore, the initial assumption was that the three sets of visual stimuli did not affect learning. In addition to statistic significance, the strength of the effect of different variables, known as effect size, was examined in the analyses. The effect size index used was the value of partial Eta squared (η_p^2), which is provided by SPSS in ANOVA. The value varies between 0 and 1; the guideline cut-off points are 0 - 0.1 is a weak effect, 0.1 – 0.3 is a moderate effect, and above 0.5 is a large effect.

Table 3.2 summarises the average percentage of the learning outcomes, generated by the three groups of participants; visual and auditory stimuli are reported separately. The maximum accuracy was 100% and the standard deviations, also expressed as percentages, are shown in the brackets. Compared to young participants, PWA and their age-matched control participants showed a wider range of standard deviations, indicating that the individual differences among the two groups were more varied than for the group of young participants.

Table 3.2 Average percentage of accuracy under each experimental condition – non-incremental learning.

Stimuli Type	Young	Older	PWA
Visual			
Chinese characters	97.13 (4.59)	80.18 (19.63)	51.02 (14.31)
non-objects	98.23 (3.98)	87.96 (15.27)	59.06 (27.12)
line-drawings	97.86 (3.95)	85.28 (22.35)	54.97 (15.05)
Auditory			
real words	98.61 (3.57)	89.81 (16.11)	59.56 (18.10)
non-words	96.94 (4.75)	84.45 (20.59)	48.71 (22.56)
animal sounds	97.68 (3.47)	79.17 (20.18)	56.78 (17.17)

Firstly, a mixed repeated measure ANOVA was applied to the data for auditory stimuli, with auditory type as a within participant factor and group as a between participant factor. The dataset was explored with a boxplot, Figure 3.2, demonstrating the performance of the three groups of participants under the three levels of auditory conditions; the error bars present the standard deviations of the experimental conditions. Figure 3.2 also reveals the outliers of each group. Yet, the outliers were not eliminated from the analyses because that, to certain extend, they represented the individual difference of learning ability.

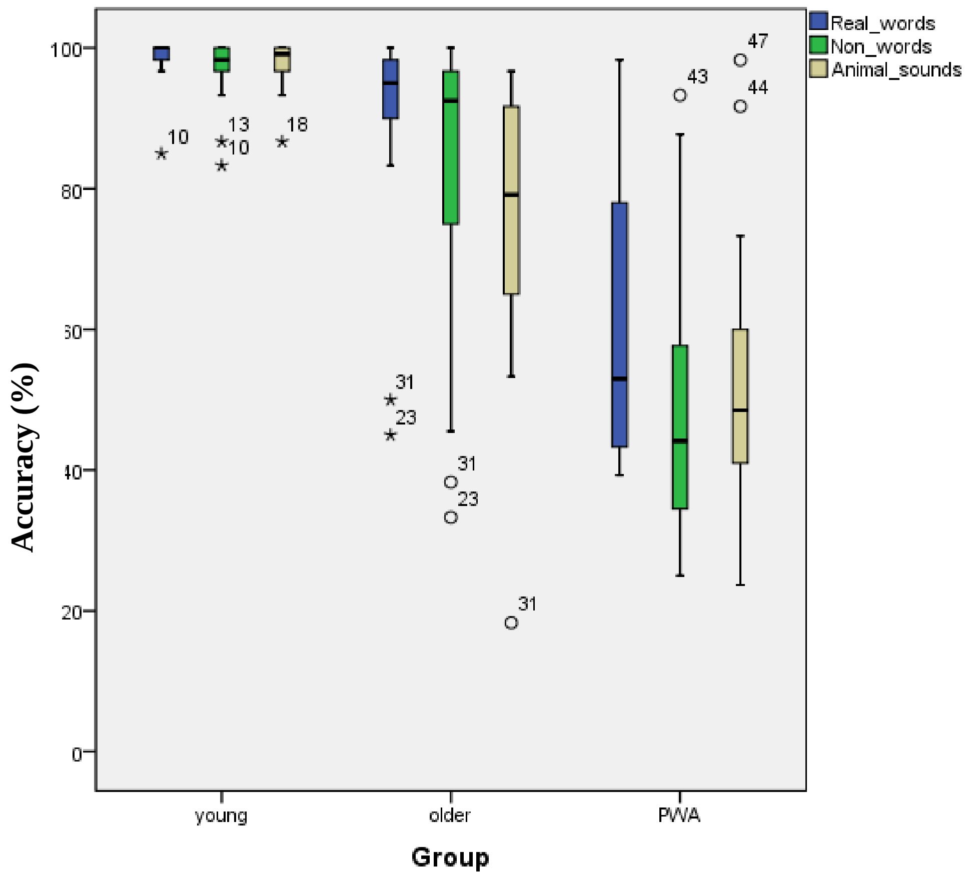

Figure 3.2. Boxplot for the descriptive statistics of auditory dataset.

The result of Mauchly's test of sphericity was significant (*p*=0.023), suggesting that the assumption of the univariate tests did not hold; therefore, Greenhouse-Geisser corrections were used. A main effect of auditory type was found ($F_{(2,102)}$=6.976, *p*=0.002; η_p^2=0.120), indicating that the linguistic load carried by the auditory stimuli had a weak impact on learning outcomes. The pairwise comparisons revealed that the level of significance lay between real words and the other two conditions, non-words (*p*=0.003) and animal sounds (*p*=0.002) with the outcomes of learning on non-words and animal sounds being similar (*p*=1.000). The trial-by-trial learning curves of the three auditory conditions are presented in Figure 3.3. As Figure 3.3 demonstrates, the participants learnt significantly more visuo-auditory pairs when the auditory stimuli were real words, in comparison to when the auditory stimuli were non-words or animal sounds. In addition, a main effect of group condition was found ($F_{(2,51)}$=47.921, *p*=0.001; η_p^2=0.972), showing that the three groups of participants performed significantly different on the task. The Bonferroni post-hoc test demonstrated that young participants were better at learning than older participants (*p*=0.004) as well as PWA (*p*<0.001). Compared to the age-matched controls (older participants), PWA also performed relatively poorer ($p<0.001$). The overall performances of each group are summarised in Figure 3.4. PWA showed significantly reduced performance regardless of auditory stimulus type; also, the wider range of standard deviation, shown by the error bars, indicates more evident individual difference among the group. No interaction was found between the two independent factors ($F_{(4,102)}=2.382$, $p=0.065$; $\eta_p^2=0.085$). Therefore, it is arguable that the manipulation of auditory type affected the performance of the three groups in the same manner, although the levels of performance were different among the groups.

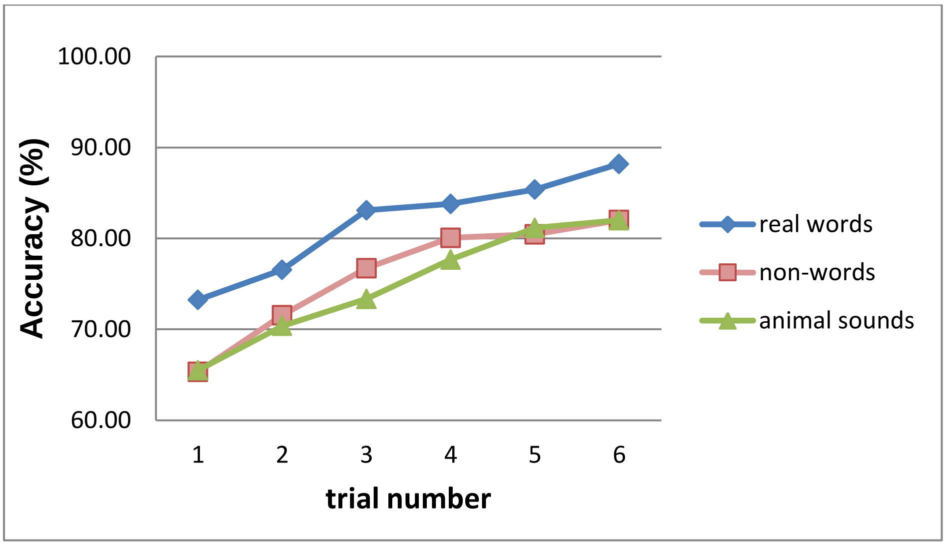

Figure 3.3. The impact of auditory type on learning outcomes (average) – non-incremental learning.

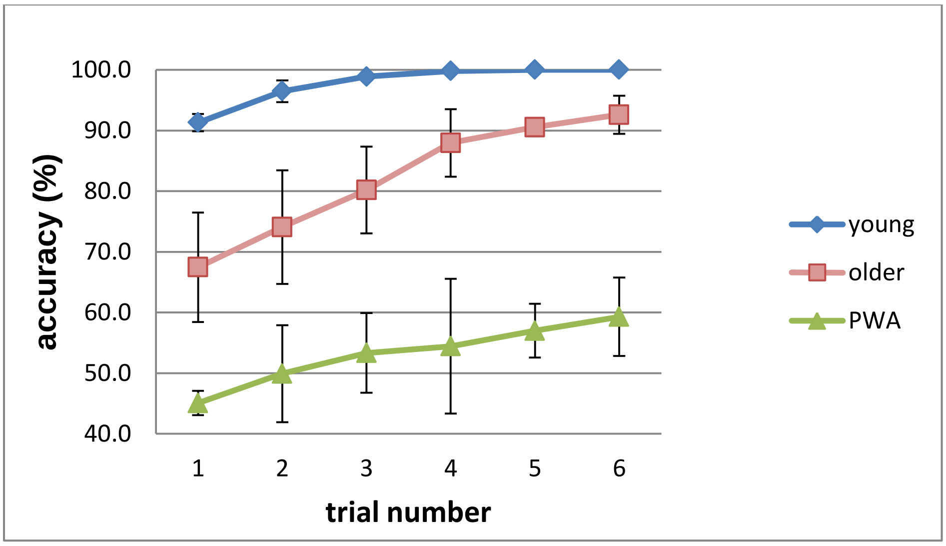

Figure 3.4. Auditory stimuli – the average accuracy achieved by the three groups after each trial – non-incremental learning.

Data from visual stimuli were analysed using a mixed repeated measure ANOVA to investigate the effect of visual type. Two independent factors, visual type and group, were used in the analysis. The descriptive data is reported in Table 3.2. A boxplot, Figure 3.5, was used to demonstrate the overall performance of the three groups under the experimental conditions with outliers reported. The same as the analysis for auditory date set, the outliers were included. The results showed that visual type ($F_{(2,102)}$=6.585, p=0.002; η_p^2=0.114) had a weak but significant main effect on learning outcomes. Therefore, although the three different types of visual stimuli were created to minimise confounds among the pairs involving different auditory stimuli, it failed to serve this purpose. For some reason, according to the results of pairwise comparisons, Chinese characters were learnt significantly less well than non-objects (p=0.019) and nonsense line-drawings (p=0.006) despite all three sets of stimuli being completely novel to the participants. As presented in Figure 3.6, which shows the effect of the manipulation of visual stimuli types, Chinese characters yield lower accuracy in almost all trials. However, this result needs to be interpreted with care. As all visual stimuli were novel to the participants, conclusions cannot be drawn without further evidence to suggest that one set of stimuli was somehow more salient than the others.

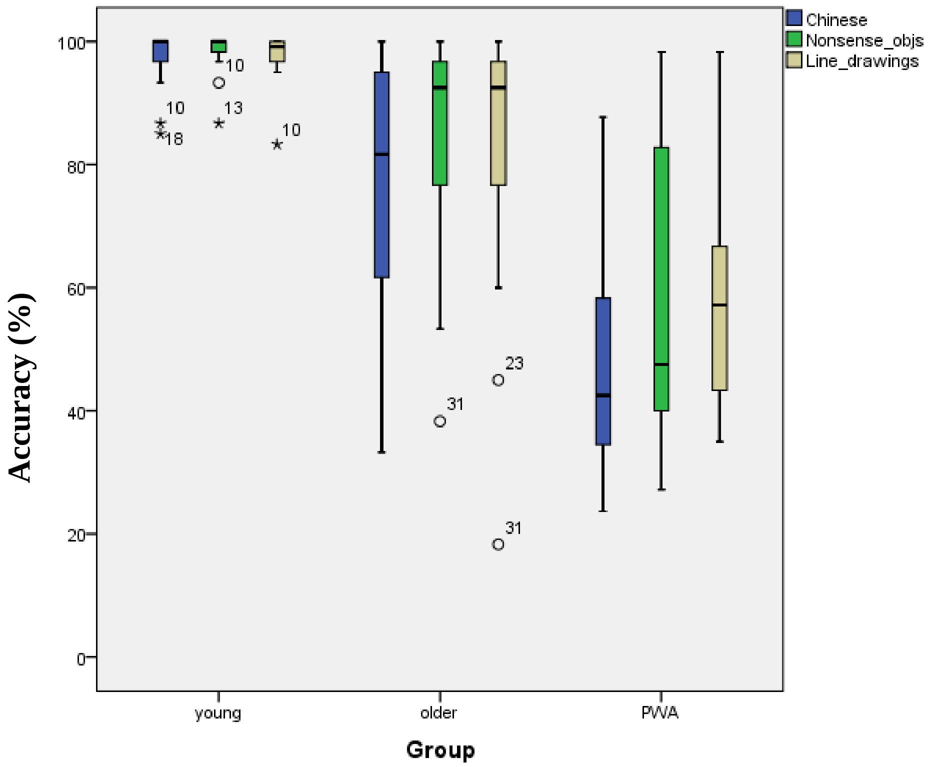

Figure 3.5. Boxplot for the descriptive statistics of visual dataset.

The between participant factor, group, was also found to significantly affect learning outcomes ($F_{(2,51)}$=47.483, p<0.001; η_p^2=0.651). The three groups of participants performed differently on the pair-associative learning task. As groups, the patterns of learning of visual stimuli were the same as the ones demonstrated in Figure 3.4. The Bonferroni post-hoc test showed that the young participants significantly outperformed the older control group (p=0.004) and PWA (p<0.001). Even compared to only their age-matched control group, PWA showed significantly reduced learning (p<0.001). In addition, no interaction was reported between stimuli type and group condition, indicating that the effect of visual type did not change in accordance with group condition. That is, the main effect of visual type could be generalised across groups and, despite the overall accuracy being lower in the older control and PWA groups, the trends for learning were similar.

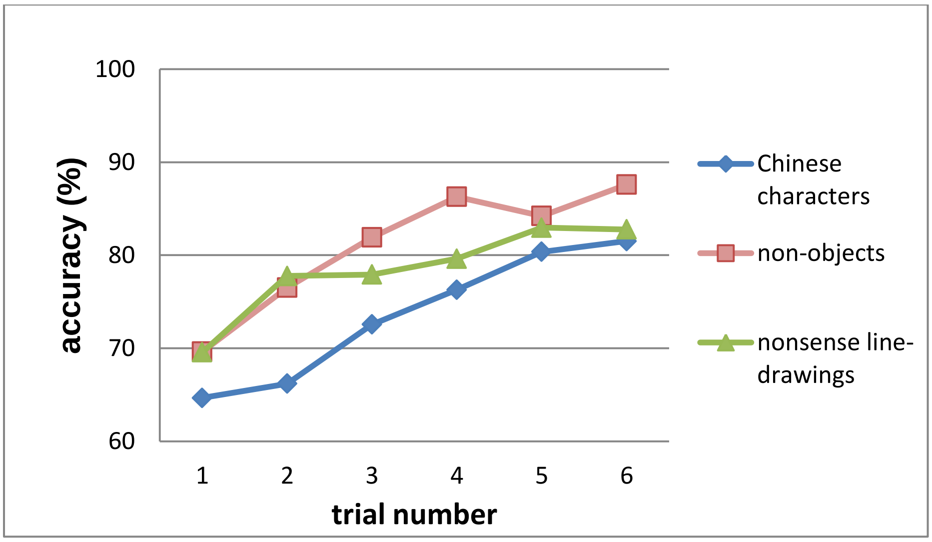

Figure 3.6. The impact of visual type on learning outcomes (average) – non-incremental learning.

3.5. Experiment 1b

3.5.1. *Participants*

In order to directly compare the learning outcomes of the two methods of directing the pair-associative learning (incremental vs. non-incremental), the 18 PWA who participated in Experiment 1a were invited to take part in Experiment 1b. Twelve out of the original 18 PWA were invited to participate in the current experiment so that the outcomes of learning with the two learning approaches could be compared. Also, two groups of eighteen control participants, young (age 18-30) and older (age 50-80) were recruited. Generally, the participants in the control groups were new participants who did not take part in Experiment 1a, although there was overlap in the older control group with 5 participants taking part in both experiments. The age information of the participants who took part in Experiment 1b is provided in Table 3.3.

Table 3.3. Age information (in years) for the three groups of participants of Experiment 1b.

	Mean	Std. Dev.	Age range
young control	21.94	2.41	18-30
older control	67.44	8.96	50-80
PWA	66.58	10.41	50-80

3.5.2. *Materials*

The materials involved in the incremental learning task were the same as those used in the non-incremental learning task. The stimuli were presented by DMDX on a PC or a laptop of the same screen size. The three sets of visual stimuli (Chinese characters, non-objects, and nonsense line-drawings) were again paired with the three sets of auditory stimuli (read words, non-words, and animal sounds) with the pseudo-randomised design described in 3.3.2. Accordingly, the versions of DMDX scripts were rotated across the participants. The three sets of visuo-auditory pairs were to be learnt in three separate forty-minute sessions.

For the participants with aphasia, they were given identical versions of scripts for incremental and non-incremental learning task so that the learning outcomes were comparable. The time between administrations of experiment 1a and 1b was over a year apart. Moreover, the majority of PWA did not learn more than half of the pairs of each visuo-auditory condition. Therefore, having any memory trace on the to-be-learnt items involved in the incremental learning task was considered to be unlikely.

3.5.3. *Procedure*

In accordance with non-incremental learning, a visual stimulus was presented on the screen for eight seconds with its auditory associate repeated throughout the interval; a cross sign (+) was placed in between pairs to notify the participants when the next pair was about to appear. In comparison to experiment 1a (i.e. non-incremental learning) the learning task in experiment 1b was directed in an incremental manner. All participants started the learning task with two visuo-auditory pairs in the first part (Part 1), followed by an immediate training and assessment session (Part 2) comprised of the two pairs. Part 2 required the participants to match a sound to its visual associate, which was one of four items presented simultaneously on the screen. In other words, the incremental learning started with showing the participants two visuo-auditory pairs; in the immediate training and assessment, the participants were given the two pairs, one after the other, to match the sounds with the items. Auditory feedback, '*Correct/Wrong*', followed immediately after the choice-making. Regardless of whether their choice was correct or not, the to-be-learnt pair was presented again. Therefore, in the incremental learning condition, each trial consisted of a learning phase (Part 1) and a training and assessment phase (Part 2).

That is, a task started with a learning phase (Part 1) presenting two to-be-learnt pairs one after another, followed by the training and assessment phase (Part 2) containing the two pairs just presented. A new visuo-auditory pair was introduced in the learning phase of the next trial only when the participants had successfully matched the existing pairs. That is, a third pair was added in the second trial, once a participant had learnt the two pairs in the first trial. In the first two trials, the numbers of items presented on the screen for choices were two and three respectively. As learning progressed to more than four visuo-auditory pairs, only four items were presented for choice. If, however, the participants failed to match the visuo-auditory pairs correctly, they were to re-learn the same pairs instead of having a new pair added in the next trial. In each phase, only the newly introduced pair was presented but all the pairs that a participant had learnt up to the point were tested in the following training and assessment trial. For instance, a participant had successfully matched four visuo-auditory pairs, in the next trial, the fifth to-be-learnt pair was presented along with its auditory associate repeated before the participant was tested for all five pairs of stimuli. On the contrary, if the learning broke down at the stage of four pairs, by making one or more mistakes, the participant was to repeat the training and assessment trial of the four pairs in the next trial.

The participants were directed to complete nine trials in total. Beginning with two visuo-auditory pairs, if the participants successfully matched all the pairs at the first attempt, ten pairs were to be learnt by the end of the nine trials. The task terminated once the participants had completed nine trials regardless of the number of items learnt so that the number of learning opportunities were equal between non-incremental and incremental learning. The final score was calculated by either taking the percentage of accuracy of the last trial a participant had achieved or averaging the percentage of accuracy of the trial that a participant had been working on but where they had not learnt all the pairs within the trial. In the case that a participant managed to learn all the pairs in the trials prior to the end of Part 2, the final score was a hundred per cent accuracy. If not, for instance, if a participant had received eight pairs to learn and he/she learnt them successfully, then Part 2 terminated; his/her final score was considered to be 80%. Another example: where considering repeated attempt to learn the pairs but where this was failed, the percentages of the same repeated trial were averaged. That is, if a participant had been given seven pairs to learn in a trial but he/she only matched six pairs with success at the first attempt (60%), five pairs in the second attempt (50%), and all the pairs in the third attempt then the test ended (70%); the final score was 60%.

3.5.4. ***Results and discussion***

The analyses in this section explored the following issues: 1) Whether incremental learning was more effective than non-incremental learning, at least for the current task; if so, 2) whether the benefit could be observed in all groups of participants; and 3) whether stimuli of different linguistic loads affected performance in the case of incremental learning, and if so, whether it affected performance in the same manner as it was reported in Experiment 1a. Given the findings of visual effect in Experiment 1a, potential effects of visual stimuli type were also investigated here. As with the statistical methods used in Experiment 1a, mixed repeated measure ANOVAs were applied to auditory and visual data sets separately. Auditory type or visual type was taken as a within participant factor and group as a between participant factor. The average percentages of the number of pairs learnt under the experimental conditions are presented in Table 3.4. Boxplots were used to demonstrate the performance of the three groups of participants as well as the outliers found in each experimental condition. The same as the methods of analyses employed in

Experiment 1a, auditory and visual data sets, Figure 3.7 and Figure 3.8, were analysed separately and any outlier reported was not excluded from the analyses.

Table 3.4. Average percentage of accuracy under each experimental condition – incremental learning.

Stimuli Type	Young	Older	PWA
Visual			
Chinese characters	98.22 (3.83)	78.66 (18.89)	42.29 (25.56)
non-objects	98.33 (3.83)	92.83 (10.78)	48.58 (26.63)
line-drawings	98.89 (3.23)	90.72 (18.28)	51.83 (27.63)
Auditory			
real words	98.89 (3.23)	94.21 (11.31)	57.46 (27.77)
non-words	96.33 (3.83)	86.94 (15.64)	45.00 (27.29)
animal sounds	97.22 (5.75)	81.06 (21.59)	42.25 (22.82)

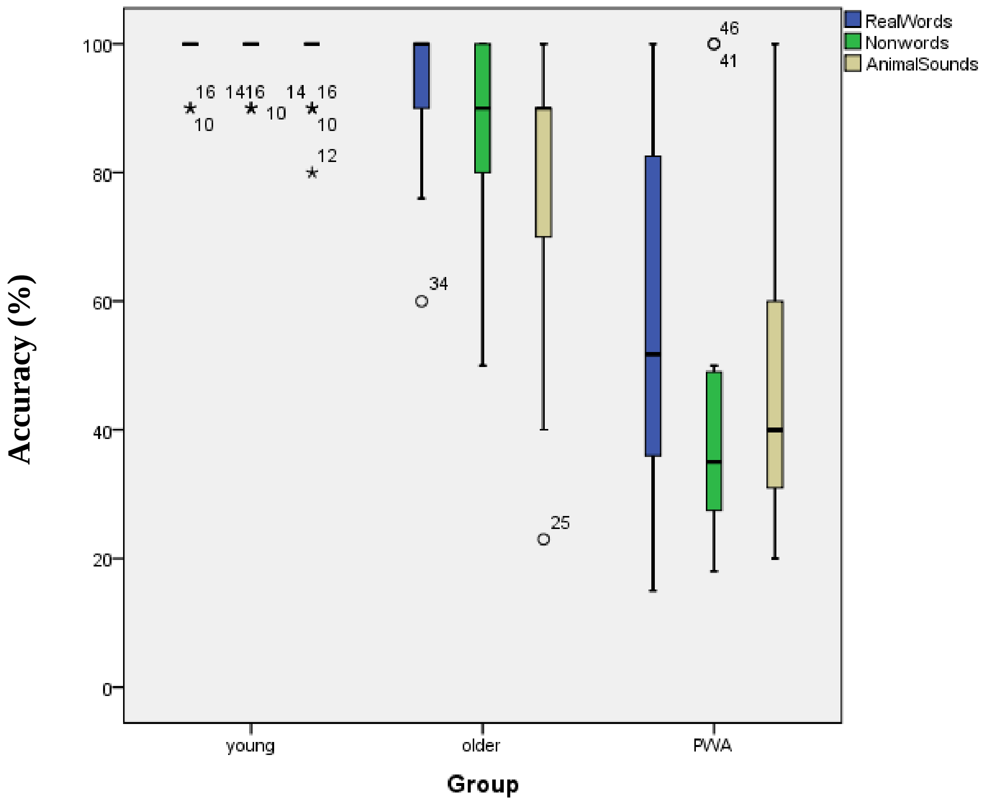

Figure 3.7. Boxplot for the descriptive statistics of auditory dataset.

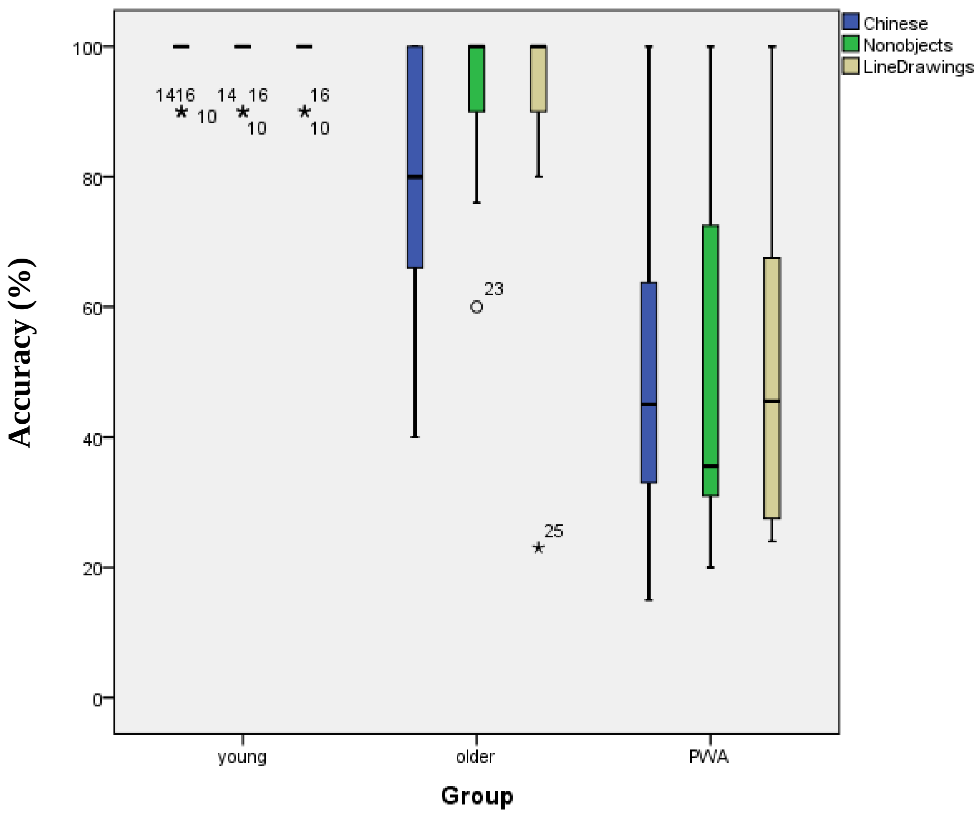

Figure 3.8. Boxplot for the descriptive statistics of visual dataset.

The mixed repeated measure ANOVA dealing with auditory stimuli reported that auditory type ($F_{(2,90)}=5.268$, $p=0.007$; $\eta_p^2=0.105$) significantly affected learning outcomes, although the effect size was relatively small. The pairwise comparisons demonstrated that, as with non-incremental learning, pairs with real words as auditory counterparts were learnt better than pairs with non-words ($p=0.011$) or animal sounds ($p=0.004$). The learning outcomes of non-words and animal sounds as auditory counterparts were not significantly different ($p=0.585$). The average patterns of incremental learning of each auditory type generated by the participant are presented in Figure 3.9. Moreover, with the method of incremental learning, the three groups also performed differently from each other. A significant main effect of group condition ($F_{(2,45)}=53.699$, $p<0.001$; $\eta_p^2=0.705$) was found. As presented in Figure 3.10, the young participants outperformed the older participants ($p=0.015$) as well as the PWA ($p<0.001$). Also, the performance of the older participants was significantly better than PWA ($p<0.001$). As the error bars, range of standard deviations, in Figure 3.10 show, incremental approach did not minimise the individual difference observed among the group of PWA. No interaction was found between the two independent factors ($F_{(4,90)}=1.364$, $p=0.253$; $\eta_p^2=0.073$), indicating that the change of condition of a factor (i.e. auditory type) did not influence the effect of the other factor (i.e. group). In other words, the impact of auditory type was found in all three groups and the significant difference among the groups did not change in accordance with the manipulation of auditory stimuli.

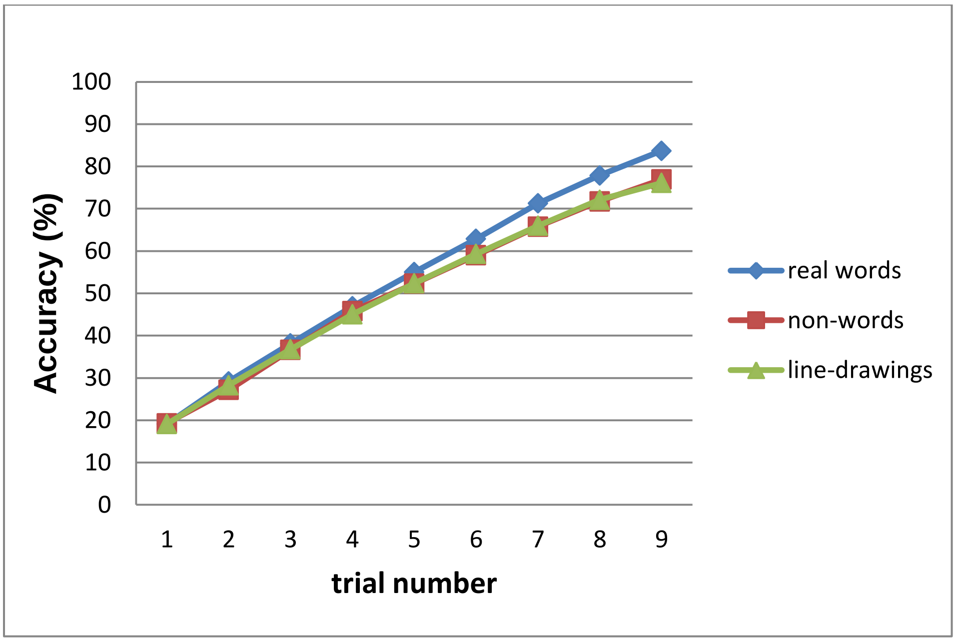

Figure 3.9. The impact of auditory type on learning outcomes (average) – incremental learning.

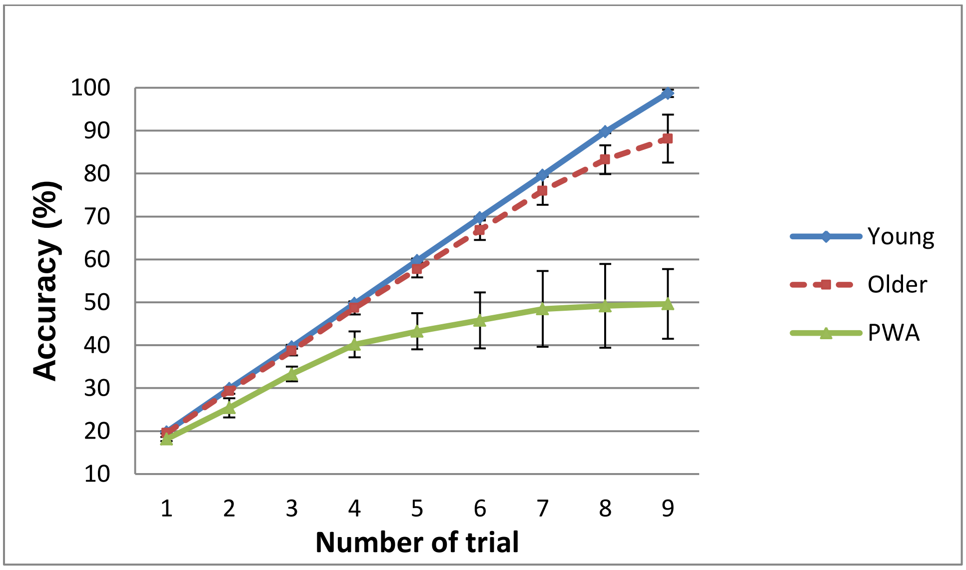

Figure 3.10. Auditory stimuli – the average accuracy achieved by the three groups after each trial – incremental learning.

On the other hand, the mixed repeated measure ANOVA with visual type as a within participant factor revealed that, in the current case of incremental learning, visual type did not have a significant effect on learning outcomes ($F_{(2,90)}$=2.026, p=0.138; η_p^2=0.043). This finding was in line with the original expectation, which considered that visual stimuli were not different in nature, as they were all novel items to the participants. Therefore, the factor that affected learning outcomes should not be the change of visual stimuli. Group was reported to have strong main effect on incremental learning ($F_{(2,45)}$=54.523, p<0.001; η_p^2=0.708). Again, Bonferroni post-hot test demonstrated that the young participants performed better than older participants (p=0.037) and PWA (p<0.001) and, compared with the older participants, PWA were still significantly worse (p<0.001) at incremental learning. Corresponding to what was reported in the auditory data analysis, there was no interaction between visual type and group. The lack of interaction between the two factors suggested the groups responded to the different sets of visual stimuli in similar ways.

3.6. General discussion

The results of the two experiments partially support the original predictions (detailed in section 3.3) in that: 1) the overall performance of PWA on pair-associative learning was reduced compared not only to the young participants but also their age-matched controls; and 2) the amount of linguistic load the stimuli carried did affect learning outcomes. The group effects reported in both experiments suggested that the outcome of learning varied due to aging. However, the limitation of accessing semantic and/or phonological information further accounted for the different performance between PWA and older control participants as well as the reduced patterns of learning observed among PWA.

The real words were learnt the best by the participants regardless of the approach used to direct learning. Although non-words were learnt better than animal sounds, the degree of superiority did not reach a significant level. The same effect of linguistic load was found in all groups, suggesting that PWA were similar to the control participants in terms of sensitivity toward the linguistic load of the stimuli. This finding suggests that despite presence of impaired language, PWA employed linguistic knowledge in learning novel materials. The current findings are in support of the study on the effect of linguistic load on working memory by Christensen and Wright (2010), which reported that linguistic heavy stimuli were better recalled than semi-linguistic stimuli and non-linguistic stimuli. The common ground between the current findings and those reported by Christensen and Wright indicates the possibility that language is an important facilitator for learning. Originally, the prediction was that PWA would perform relatively close to control participants on learning of non-linguistic stimuli due to the lower demand of linguistic knowledge; however, the results showed otherwise. The evidence adds to the claim that language plays an important role in learning; learning of non-linguistic information also requires verbal mediation (Silverberg & Buchanan, 2005). The importance of performing subvocal rehearsal during learning has been emphasised (Baddeley, 2003; Baddeley et al., 1984); to be able to do subvocal rehearsal in the phonological loop requires certain amount of linguistic information that is related to the to-be-learnt item(s). Therefore, instead of being relatively lower in terms of demand on linguistic knowledge, non-linguistic items were actually more difficult to rehearse because it may be difficult to assign certain linguistic code(s) to non-linguistic items. It appears (like controls) PWA still mostly relied on linguistic knowledge to perform pair-associative learning, therefore it is understandable why the performance in non-linguistic learning condition was the poorest among the three linguistic conditions.

In addition, for PWA, the incremental learning approach was not superior to the non-incremental one. The only group that responded differently to the two learning approaches was the older controls where the accuracy rate was higher in the incremental learning task than in the non-incremental learning task. Overall, this result was against the prediction that the incremental learning approach could reduce the potential for proactive interference and yield better learning outcomes. Nevertheless, based on the current results, the advantage of incremental learning approach cannot yet be rejected. The learning outcome of the groups did not differ to a great extent between the approaches. Regardless of the learning approach employed, both control groups learnt nearly all pairs by the end each experimental trial, PWA were the worst among the participants and, on average, only achieved 50% accuracy. One factor to consider is that the number of pairs given to the participants in one learning session was a relatively small set, compared to materials involved in the previous studies (e.g. Conrad, 1960; Hamilton & Martin, 2005, 2007) to elicit PI, even when directed with non-incremental approach. However, with the existing data, no further evidence can be provided to support this argument.

In Experiment 1a, the three sets of visual stimuli, although all novel to the participants, were found to differentially affect learning outcomes. The ability to map visual stimuli to semantic and/or phonological representations is crucial to allow the articulatory rehearsal to be performed (Baddeley, 2003). Although all visual stimuli chosen for the experiments were completely new to the participants, one set might still be easier to encode than the others. However, this effect of visual type was absent in Experiment 1b, suggesting that the effect reported in Experiment 1a was a consequence of certain outliers in the experiment. Alternatively, the incremental learning approach might have a positive effect on visual processing; hence, the PI of visual stimuli may have been reduced. At the current stage, no further evidence can be provided in support of this account. Nonetheless, Experiment 1a has drawn attention to the need for further consideration of visual stimuli in a pair-associative learning task and to further look into learning that occurs in the visual modality (if any). Since the focus of the two experiments here was on the manipulation of linguistic load carried by auditory stimuli, any effect on visual types was unexpected and requires further investigation before explanations can be offered.

The findings in this chapter form the basis for the further investigations in the following chapters. Despite the fact that PWA showed poor learning outcomes in general, implicit memory of visual stimuli might have formed because of their capability of using elimination to target an appropriate item. In the next chapter, implicit learning in the visual modality is explored to test this argument. Moreover, great individual difference was observed within the group of PWA and such individual differences will be explored further in chapter 6. The variability observed suggests that some PWA had no difficulty learning the pairs whilst others found the pairs almost unlearnable. Therefore, to a certain extent at least, the learning task was possible for PWA. The next step is to investigate whether other type of learning tasks and approaches are beneficial in directing learning for PWA.

Chapter 4 Investigating implicit learning with a picture recognition task with old-new paradigm

4.1. Introduction

This chapter is inspired by the questions left from the previous experiments regarding incremental versus non-incremental learning. The pair-association learning experiment provided an insight into the ability to learn in PWA. PWA not only performed worse than younger healthy participants but also showed different patterns of learning from age-matched control participants. Instead of mirroring the age-matched control participants who showed steady improvement after each learning opportunity, the patterns of learning shown by PWA fluctuated throughout the learning task. It remains unclear as to what extent the results of the previous experiments, involved non-incremental and incremental learning with pair-associative paradigm, reflected generalised reduced ability to learn in PWA, since the patterns observed might be task specific. Furthermore, an unexpected effect of the visual stimuli types on learning outcomes was observed in the older control group, indicating a possible influence of visual stimuli and, perhaps, the process of visual recognition on pair-associative learning. Although the same effect was not found in the group of PWA, according to the self-report, elimination was one of the learning techniques used while learning. This could be interpreted as evidence of the involvement of visual recognition and, potentially, the occurrence of implicit learning.

Using elimination suggested that the participants were capable of retaining the visual stimuli for a period of time and using them as references in order to rule out the stimuli that they were certain of not being the target or had been tested in the same learning trial. Also, in the pair-associative learning tasks, most of the participants, controls as well as PWA, were able to realise that they had made mistake(s) immediately after making a choice and before feedback was given. These phenomena shed light on the possibility that implicit memory plays a role in learning. However, more evidence is required to justify whether the participants demonstrate implicit learning of a set of new items, and if so, how long-lasting the implicit trace of memory can be.

Following from the previously reported experiments, which reported that learning outcomes were sensitive to visual stimuli type, this chapter focuses on exploring the possibility that implicit learning occurs in the visual modality. Also, restricting the investigation to learning behaviour in one modality may reduce the task demands and the participants can focus their attention on a single modality instead of having to coordinate visual and auditory information. The current chapter aims to investigate implicit learning in the following perspectives. The fundamental questions being asked are 1) whether implicit learning occurs in the visual modality; 2)If so, whether the patterns of implicit learning in PWA differ from people without aphasia; and 3) to what extent the implicit memory is affected by the lag duration between repeated presentations of a visual stimulus.

4.2. Background

Individuals without brain damage have been constantly reported to have impressive visual memory, particularly for pictorial stimuli. Standing (1973) demonstrated, in participants without brain damage, superior memory capacity for pictures than for words after the pictures/words were visually presented to the participants just once. With a large learning set, there was no upper bound identified to pictorial memory capacity. Although the percentage of pictures retained decreased gradually, the number of pictures retained always increased. Further, according to Standing, pictures that were categorised as ‘vivid’ (i.e. a dog holding a pipe) were better retained than the pictures in the ‘normal’ category (i.e. picture of a dog). In this case, vivid pictures were more salient and carried more semantic information. Verbalisation and creating semantic cues for newly received visual stimuli to mediate learning or retention have been widely reported (Craik, 2002; Howard et al., 1985; Marshall et al., 1994; Marshall et al., 2001; Tulving, 1985). What is more, rehearsal is considered as a process that facilitates memory of an item (Baddeley, 2003); linguistic knowledge/information is key to performing rehearsal. Silverberg and Buchanan (2005) directed participants to verbally describe novel figural designs and then identify the designs in a subsequent recognition test. Items that were relatively easy to verbalise yielded better recognition, compared to those items that were difficult to verbalise. Since the previous evidence suggests a positive correlation between verbalising and recognition in people without brain damage, the impaired language in PWA could be a factor in the poorer learning outcomes demonstrated in the incremental versus non-incremental learning tasks.

Recognition can occur explicitly or implicitly. There is a large body of literature (Brown & Bodner, 2011; Tulving, 1985; Yonelinas, 2002) on remembering (explicit recollection) and knowing (implicit recollection), suggesting that they involve two distinct memory processes. The implicit trace of memory can be enhanced through repeated presentation of a target item. It has been found in individuals without brain damage that total time of presentation of a picture affects the result(s) of later recognition task(s) and pictures that are presented repeatedly in a trial yield shorter reaction times (Martini & Maljkovic, 2009). Moreover, implicit learning has been reported in patient groups other than aphasia. For instance, individuals with progressive posterior cortical atrophy have been found to process visually-presented verbal information at the global level without being consciously aware of it (Filoteo et al., 2002).

To investigate whether people with aphasia show implicit learning and how long the implicitly learnt item can be retained, this study, using an old/new recognition paradigm, involved a large set of pictures with some of the pictures presented repeatedly. Both the number of repeated presentations and the interval of repetition (lag) were manipulated. The time(s) of repeated presentation was expected to positively correlate with the accuracy of recognition. Furthermore, with the occurrence of implicit learning, reaction time of the recognition of the repeated items should be shortened. Nevertheless, previous studies (Martini & Maljkovic, 2009; Standing, 1973) mostly involve shorter lag conditions and neurological intact participants; it is unknown whether the effect of repetition priming would reduce after a relatively longer lag duration, with more intervening items between repeated presentations, and how it might affect recognition in PWA. On the other hand, visual recognition memory deficits have been previously reported in neurological impaired populations (Filoteo et al., 2002, Hunting-Pompon et al., 2011, Viggiano et al., 2008; Wegesin & Nelson, 2000). For instance, Viggiano et al. (2008) indicated that the performance of individuals with Alzheimer’s disease on a picture identification task was affected by the manipulation of lag conditions, with performance worsening as the lag duration increased. Severity of the dementia also affected the results of the task and severity interacted with the effects of lag conditions.

At the moment, there is no existing evidence on how the manipulation of repetition and/or lag condition will affect recognition in PWA. In a previous study (Martini & Maljkovic, 2009) involving lag conditions between 1 to 3 intervals, the effect of relatively longer lag on recognition was unspecified. Therefore, the current study was designed to have short, medium, and long lag conditions. Also, the individual results from the experiments described in previous chapters suggested that some individuals with aphasia showed learning but the improvement was delayed compared to age-matched control participants. This may indicate that PWA require more presentations of the target items than the controls before learning can occur. To test the potential impact of number of repetitions on PWA, the same numbers of repeated presentations of the target items were involved and the slopes of improvement were investigated.

It was hypothesized that visual recognition would improve through repeated presentation of an item and manipulation of the lag duration between the first and the subsequent presentation(s) of an item would affect the accuracy of recognition. If implicit learning occurred, reaction time of recognition should decrease as the number(s) of repetition increased. However, with the inaccessibility of linguistic representations, the performance of PWA on visual recognition of pictures may be affected to a certain degree. Though the findings of the previous experiments did not offer compelling evidence on whether implicit learning occurred in the pair-associative learning task, PWA did show the ability to retain information. Hence, it was predicted that implicit learning could be observed among PWA and, as a result, reaction time would be shortened through repeated presentation of an item. Yet, the improvement on recognition in PWA was likely to take more repetitions to achieve than it was in people without brain damage. Also, both severity of aphasia, discussed in Chapter XI, and lag duration of repeated items were expected to influence the performance on recognition. It is possible that PWA's performance on background assessments will correlate with their performance on the task; longer lag would result in less accurate recognition than shorter lag and the effect would be more salient in people with more sever aphasia. See Chapter XI for the relation between the cognitive background and performance on the current recognition task.

4.3. Methodology

The picture recognition task employed old-new paradigm; the participants were to make judgement on whether they had previously seen a picture that was presented on the screen during the task. The pictures that the participants had seen before were considered as 'old' and those they had not seen before were ‘new’. The participants were instructed to respond to each picture appeared on the screen by clicking on the Yes/No button on a response device. The software, DMDX, used to present the pictures recorded accuracy as well as reaction time, which, in the current experiment, was the key to determine the occurrence of implicit learning.

4.3.1. *Participants*

Sixteen of the 18 participants with aphasia who participated in the incremental versus non-incremental pair-associative learning also took part in this picture recognition task. JG and JoH dropped out of the study due to health issues. Eighteen participants aged between 50 and 80 were also recruited to serve as the age-matched control group. Also, 18 younger participants, age between 18 and 30 were also recruited, in order to find out how young participants would perform on the task and to what extent age influences performance on the task. See Table 4.1 for detailed information about the ages of the three groups.

Table 4.1. Average age (in years) of the participants

Group	Mean	Std. Dev.	Age range
Young control	21.5	2.09	18-30
Older control	59.5	9.53	50-80
PWA	65.2	11.9	50-80

4.3.2. *Material*

The visual stimuli included 2 sets of coloured pictures of real-life scenes taken at various focal lengths. One set consisted of 80 target pictures used for the recognition task; the other set of 260 pictures were used as intervening items. None of the pictures had particularly salient information; therefore, the chance of imposing a verbal code on the pictures were minimised.

During the task, participants saw, 580 pictures overall, out of which, 80 were target pictures. The target pictures were sub-divided into four sets of 20 pictures according to the four lag conditions manipulated in the experiment: lag 3, 5, 10, and 20. Since lag conditions were designed to explore potential implicit learning in relatively shorter and longer lag conditions within the recognition trial, each target picture appeared four times with a fixed lag duration, depending on the lag condition of the picture. The duration of each lag condition was determined by the number of intervening pictures appearing between each of the four presentations of a particular picture. For instance, a picture of lag 3, the first presentation of the picture was followed by 3 intervening pictures before it was presented for the second time; then, another set of three intervening pictures prior to its subsequent presentations. Between each presentation of a target, there was a fixed number, depending on the lag condition a picture, intervening pictures. An intervening picture could be pictures of the other lag conditions or a filler picture.

That is, excluding the first presentation of the target pictures, 240 pictures were expected to be recognised as ‘old’ pictures. Another 260 pictures were shown once only, as fillers, along with the 80 target pictures when first presented were to be recognised as ‘new’. Extra seven pictures are used to form a practice trial with two of the pictures presented repeatedly with different lag conditions. In order to ensure that participants were familiar and confident with the task, the first 20 pictures in the test trial were used for training purpose and were not included in the later data analysis. Four of the 20 pictures were presented repeatedly with longer lag(s), compared to the practice trials, which were the same as what the participants would experience in the actual test. Figure 4.1 provides an example of how the learning trial proceeds and the condition of each visual stimulus.

All the pictures were sized to 10x8 inches (25.4x20.32 cm) and presented, one at a time, in the middle of a fifteen-inch computer screen with white background. The pictures were presented using DMDX (Forster & Forster, 2003), an experiment software that is widely used in psychological research. To minimise the effects of potential confounding factors (such as the saliency of a picture, the linguistic information a picture might carry, and the processing load required for a picture) on the results, the 80 target pictures were presented in a pseudo-randomised fashion. This pseudo-randomisation was two-folded: 1) Four versions of DMDX scripts were built, in each version, the four sets of pictures were assigned to a different lag condition; and 2) In a script, the pictures were distributed to five blocks of 112 items, containing four pictures of each lag condition; the order of presentation of the blocks was randomised by DMDX. The number of items, 112, in each block was determined to assure that one block contained appropriate numbers of pictures of each of the lag conditions.

item no.	target picture	lag condition	Presentation no.	response expected
1		3	1	no
2		20	1	no
3		filler	N/A	no
4		5	1	no
5		3	2	yes
6		filler	N/A	no
7		10	1	no
8		filler	N/A	no
9		3	3	yes
10		5	2	yes

Figure 4.1. Test trials, conditions, and expected response.

4.3.3. *Procedure*

Prior to the picture recognition task, participants were told that a series of 580 pictures would be presented to them successively and some of the pictures might appear more than once. The participants were instructed to identify, as quickly as possible, whether they had seen each picture before or not by clicking on the Yes/No button on a mouse. The mouse was used as a response box and fixed in front of the participants at the central position on the table. The mouse was marked with a 'Yes' label on the left and 'No' label on the right. Also, two labels were put on the left and right corner of the screen respectively as constant reminders of which was the correct button to press for the participants' intended responses. Before proceeding to the test trial, a practice trial was given to the participants to allow familiarisation with the task and to make sure that the task was fully understood.

The picture recognition task with old/new paradigm consisted of a single trial of serial visual presentation. Each picture was presented to the participants for two seconds; the picture was removed from the screen at the end of the two seconds. The time of each presentation was limited to 2 seconds to make sure that all target pictures received equal exposure time. Since the participants were instructed to make a yes/no decision as quickly as possible, responses were timed from as soon as the picture appeared on the screen. However, if no response was registered before a picture was removed from the screen, the participant was given a further five seconds maximum to respond while a blank screen was shown. If a response was received within the first two seconds, the picture remained on screen until the time had elapsed for the purpose of equalising length of exposure for all pictures. If participants responded within the five second time frame, having not responded within the first two seconds, the next picture was shown after a brief pause. The pause between the presentations of pictures was one second. Reaction time and the accuracy of response were recorded by DMDX. Overall, the experimental session was approximately 45 minutes including briefing and a practice trial.

4.4. Results and Discussion

The data analysis aimed to explore whether implicit learning occurred in the visual modality through investigating the change of the two dependent factors, reaction time and accuracy of recognition. Only the reaction times of correct responses were included in the analysis. Tests of mixed repeated analysis of variance (ANOVA), performed with SPSS, were employed with three independent factors, lag condition (lag 3, lag 5, lag 10, & lag 20), presentation number (P1, P2, P3, & P4), and group (young, older, PWA). Effect size(s), value(s) of partial Eta square, was also reported. The level of significance was accepted at level of 0.05 or lower. A partial Eta square value between 0 and 0.1 was considered as a small effect, a value between 0.1 and 0.3 was moderate effect, and a value of 0.5 or above was defined as a large effect. In addition, although outliers were observed in all groups whilst exploring the data, they were not replaced or excluded from the analyses.

Reaction time data was first investigated with lag condition and presentation number as within participant factors and group as a between participant factor. Table 4.2 summarises the average reaction time of the groups under all the experimental conditions with standard deviation shown in brackets. Mauchly's test showed that sphericity was met in lag condition ($p<0.062$) but violated in the condition of presentation number ($p<0.001$). Therefore, Greenhouse-Geisser corrections were used to interpret the results of the condition of presentation number.

Presentation number was observed to have a significant main effect on reaction time ($F_{(3,147)}=0.533$, $p<0.001$; $\eta_p^2=0.619$). As demonstrated in Figure 4.1, overall, reaction time decreased through repeated presentation of a picture. Furthermore, the pairwise comparisons showed that reaction times of the current presentations were significantly shorter than the previous presentation of the same picture. That is, the reaction times of the second presentation of pictures were significantly shorter than the first presentation of the pictures ($p=0.002$), the third presentation yielded significantly shorter reaction times than the second presentation ($p<0.001$), and the participants responded fastest toward the final presentations of the pictures comparing to all three prior presentations ($p<0.001$). Moreover, the between participant factor was found to significantly influence the outcome ($F_{(2,49)}=8.057$, $p<0.001$; $\eta_p^2=0.247$). Bonferroni post-hoc tests revealed that PWA took significantly longer ($p=0.001$) than the young participants to respond; however, the response times of PWA were not significantly different to the age-matched control group ($p=0.086$). The two control groups also had reaction times that were not significantly different (*p*=0.230). This pattern indicates that age does not act solely to influence performance; at least, in picture recognition, age, when considered independently, is not a strong enough factor to account for the relatively worse performance of PWA. Lag condition, on the other hand, did not affect the outcome significantly ($F_{(3,147)}$=0.716, *p*=0.544; η_p^2=0.014). In other words, reaction time decreased through repeated presentation of the pictures regardless of the lag duration between each presentation. It is also possible that the lag durations in the current experiment were still within a range that recognition was not inhibited by the lag between presentations.

Table 4.2. Mean reaction time (milliseconds) of the three groups under each experimental condition.

		young	older	PWA	overall
lag 3	*P1*	950 (177)	1136 (227)	1403 (540)	1154 (384)
	P2	909 (134)	1081 (159)	1223 (424)	1065 (290)
	P3	764 (95)	931 (121)	1150 (425)	941 (293)
	P4	752 (106)	865 (130)	1087 (409)	894 (279)
Lag 5	*P1*	991 (210)	1140 (179)	1363 (521)	1157 (358)
	P2	877 (124)	1046 (172)	1224 (422)	1042 (296)
	P3	778 (101)	939 (125)	1135 (433)	944 (291)
	P4	743 (84)	876 (124)	1073 (453)	891 (293)
lag 10	*P1*	990 (215)	1153 (209)	1373 (516.)	1164 (364)
	P2	872 (106)	1025 (160)	1252 (399)	1042 (288)
	P3	780 (111)	951 (160)	1138 (400)	949 (284)
	P4	757 (115)	887 (132)	1064 (430)	896 (283)
lag 20	*P1*	970 (246)	1156 (222)	1354 (505)	1153 (369)
	P2	918 (184)	1081 (174)	1258 (436)	1079 (310)
	P3	773 (93.03)	959 (157)	1164 (459.)	958 (314)
	P4	733 (112)	864 (121)	1085 (418)	887 (285)

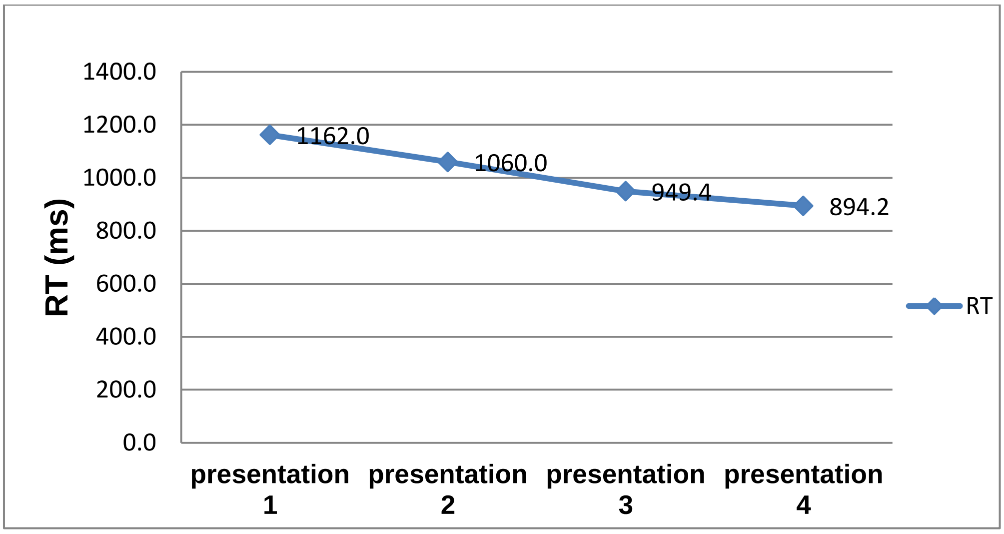

Figure 4.2. Pattern of improvement of reaction time (RT) through repeated presentations of pictures.

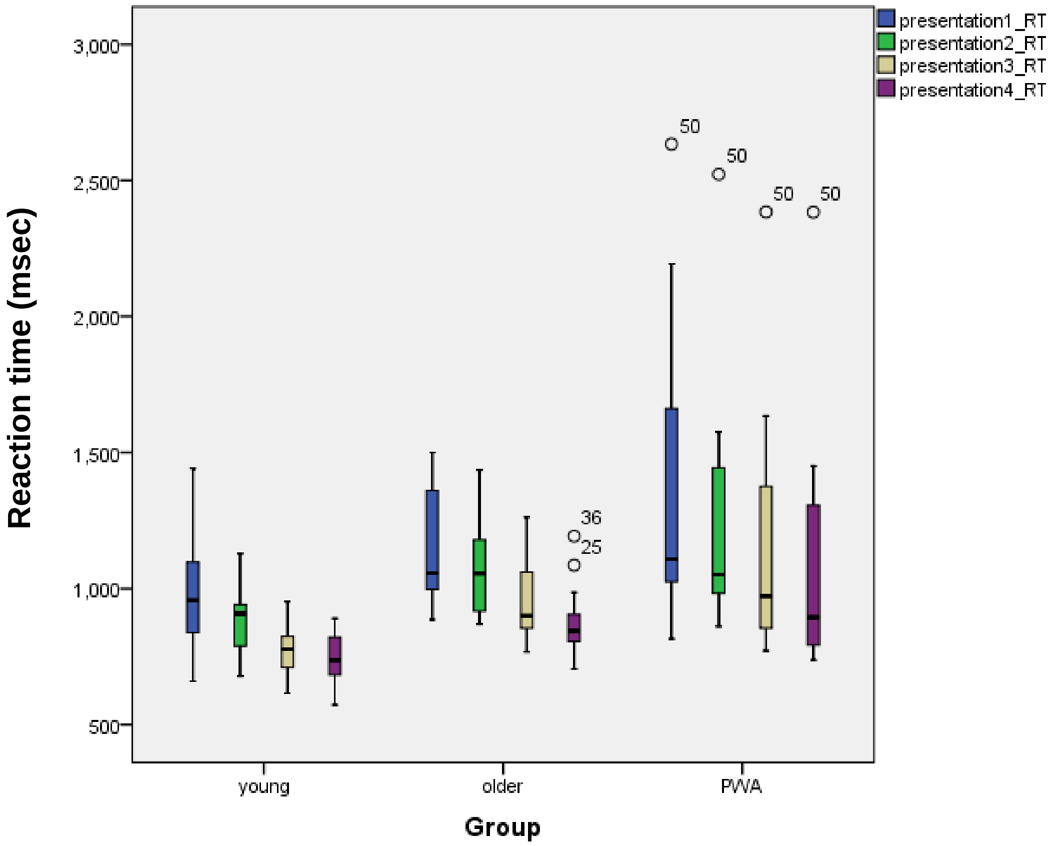

Figure 4.3. Improvement of reaction time (msec) of the three groups at each level of presentation condition.

No interaction was found among the independent factors. Neither of the within participant factors, lag ($F_{(6,147)}$=0.320, p=0.926; η_p^2=0.013) or presentation ($F_{(6,147)}$=0.533, p=0.631; η_p^2=0.021), interacted with the between participant factor, group. This finding, as shown in Figure 4.3, indicates that lag condition and the condition of presentation affected the performance of all three groups of participants in the same manner. The two within participant factors did not interact with each other ($F_{(9,441)}$=1.218, p=0.293; η_p^2=0.024), suggesting that RT improves as time of exposure increased regardless of the lag condition of the stimuli. In addition, no three-way interaction was observed ($F_{(18,441)}$=1.093, p=0.364; η_p^2=0.043).

Accuracy data served as complementary evidence of whether repeated presentation of the pictures improved recognition. A mixed repeated measure ANOVA was used for the analysis, with lag condition and condition of presentation number as within participant factors and group as a between participant factor. The data violated the assumption of sphericity; therefore, Greenhouse-Geisser corrections were adapted. The average accuracy generated by the three groups under each condition is listed in Table 4.3, along with the standard deviation in parentheses.

Presentation number had a significant main effect ($F_{(3,147)}$=0.533, p<0.001; η_p^2=0.461) on the accuracy of responses, indicating that picture recognition improved as a consequence of repeated presentations. The pattern of increasing accuracy through repeated presentations is demonstrated in Figure 4.4. Furthermore, the pairwise comparisons showed that each presentation significantly improved the rate of accuracy; although accuracy dips from presentation one to presentation two, accuracy improved significantly from the third presentation onwards. The between participant factor, group, also affected accuracy of recognition significantly ($F_{(2,49)}$=5.001, p=0.011; η_p^2=0.170). The post-hoc tests with Bonferroni procedures revealed that the level of significance lay between the two groups of control participants (p=0.009). It was unexpected that, in terms of accuracy, PWA performed at similar level to the controls; the differences between PWA and young participants (p=0.192) as well as older participants (p=0.775) were not significant. Figure 4.5 shows the performance of each group at each time of presentation. Young participants had higher overall performance than the other two groups and the accuracy rate generated by PWA was not much lower than the young participants and slightly higher than their age-matched controls. Performance was not affected by the lag condition ($F_{(3,147)}$=1.142, p=0.334; η_p^2=0.023), which, therefore, demonstrated the same pattern as was observed with the RT analysis.

No two-way interaction was observed among the independent factors. That is, neither lag condition ($F_{(6,147)}$=0.339, p=0.890; η_p^2=0.014) nor condition of presentation number ($F_{(6,147)}$=2.107, p=0.104; η_p^2=0.079) interacted with the group factor. The two within participant factors showed no interaction ($F_{(9,441)}$=0.846, p=0.530; η_p^2=0.017). Also, the three-way interaction among the factors did not reach significance ($F_{(18,441)}$=0.545, p=0.936; η_p^2=0.022). The lack of interaction demonstrated that the performance was not affected by all the factors concurrently; instead each factor had its independent effect on the dependent variables.

Table 4.3. Mean accuracy of responses (maximum=1) under each experimental condition.

		young	older	PWA	overall
lag 3	*P1*	0.96 (0.04)	0.89 (0.13)	0.92 (0.09)	0.92 (0.10)
	P2	0.89 (0.09)	0.84 (0.11)	0.87 (0.10)	0.87 (0.10)
	P3	0.98 (0.03)	0.98 (0.03)	0.98 (0.06)	0.98 (0.04)
	P4	0.98 (0.03)	0.99 (0.03)	0.99 (0.02)	0.99 (0.03)
Lag 5	*P1*	0.99 (0.02)	0.87 (0.12)	0.92 (0.10)	0.93 (0.10)
	P2	0.88 (0.08)	0.83 (0.13)	0.88 (0.09)	0.86 (0.10)
	P3	0.98 (0.03)	0.95 (0.07)	0.96 (0.10)	0.96 (0.07)
	P4	0.98 (0.04)	0.99 (0.03)	0.97 (0.05)	0.98 (0.04)
lag 10	*P1*	0.99 (0.02)	0.89 (0.14)	0.90 (0.09)	0.93 (0.11)
	P2	0.87 (0.12)	0.81 (0.16)	0.84 (0.20)	0.84 (0.16)
	P3	0.98 (0.03)	0.95 (0.08)	0.97 (0.04)	0.97 (0.06)
	P4	0.10 (0.01)	0.98 (0.03)	0.98 (0.05)	0.98 (0.04)
lag 20	*P1*	0.98 (0.06)	0.87 (0.13)	0.92 (0.09)	0.92 (0.11)
	P2	0.88 (0.13)	0.84 (0.12)	0.85 (0.11)	0.85 (0.12)
	P3	0.98 (0.04)	0.96 (0.06)	0.96 (0.04)	0.96 (0.05)
	P4	0.99 (0.02)	0.98 (0.04)	0.97 (0.05)	0.98 (0.04)

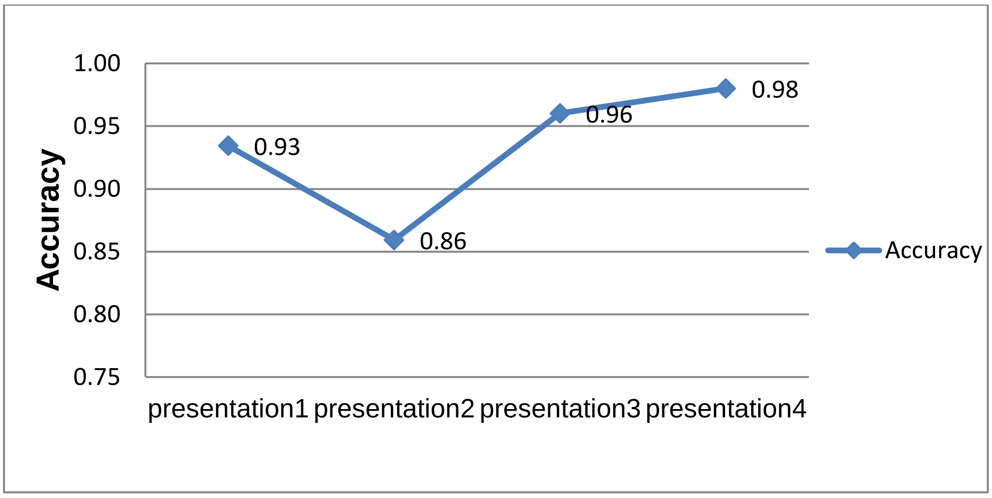

Figure 4.4. Mean accuracy (maximum=1) of each level of presentation condition generated by the three groups.

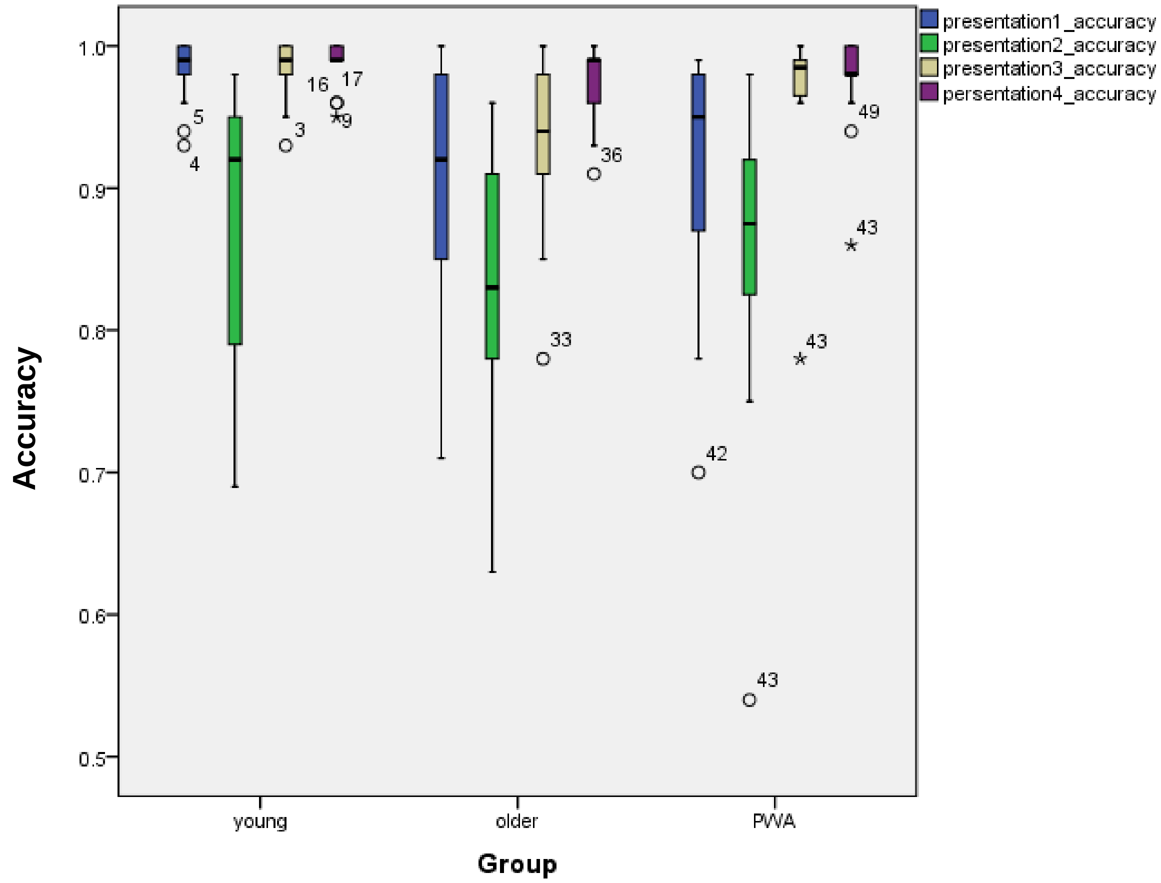

Figure 4.5. Improvement of accuracy (maximum=1) of the three groups at each level of presentation condition.

4.5. General discussion

The findings showed mixed results. The results supported the prediction that repeated presentations improved accuracy of recognition as well as reduced reaction time toward a picture that appeared repeatedly. Reaction time served as an index of the occurrence of implicit learning in the current experiment. It is arguable that reaction time decrease associated with the increase of presentations is the consequence of enhanced implicit memory. Moreover, in terms of accuracy and reaction time, the improved pattern found in PWA were similar to the patterns generated by the control groups, although the average reaction time of the PWA was significantly longer than the younger participants. This suggests that implicit learning occurred in PWA in the same fashion as observed in the control groups.

On the other hand, the results were contrary to the stated prediction in that the lag condition did not affect the performance on picture recognition; all three groups of participants performed equally across the lag durations manipulated in the experiment. In other words, when compared with pictures that were presented with short lag duration (i.e. after three or five intervening items), pictures that were presented with relatively longer lag duration (i.e. ten and 20 intervening items) yielded similar reaction times and response accuracy. That is, regardless of the lag duration, reaction time decreased steadily after each repetition. The repetition priming effect was not dissolved by the extension of lag duration; at least, not in the current experiment. It is possible that the lag durations chosen for the current experiment were all within the range that repetition priming was still valid. As reported among massed practice literature, the benefit of massing exists even when the two (or more) practice attempts are distributed far from one another. The upper limit for massing before its advantage disappears is not yet known (See chapter 5.2 for more details on the massing effect).

In sum, with the current results, we can conclude that implicit learning occurred in all three groups of participants. As a group, PWA demonstrated similar pattern of implicit learning to the two control groups and their reaction time was not significantly different from their age-matched participants. However, it is notable that in the current analysis, only data regarding correct responses were included. The number of errors at each level of repetition was unknown. Further investigation on whether longer lag duration resulted in having more error responses may provide more information on whether lag duration had an impact on the occurrence of implicit learning. Suggestions for further data analysis include the following aspects: 1) looking at how performance might be affected by different lag conditions from the perspective of the number of errors made at each level; 2) taking types of errors into consideration, such as the number of omission and false positive responses; and 3) exploring the individual data of PWA to determine whether the severity of aphasia present affects the performance on the recognition task (see chapter 6).

Chapter 5 Massed versus Spaced Learning with Pair-associative Paradigm

5.1. Introduction

The current chapter aims to investigate phenomena, including the effect of massed and spaced practice and the retrieval (or testing) effect, which are reported to have an impact on learning outcomes. Extensive literature has reported that these effects influence learning of linguistic material (word lists, word-pair association, and prose) as well as non-linguistic material (pictures and visuospatial learning). It has been found that massed practice leads to better immediate recall whilst spaced practiced yields better long-term retention (Kornell et al., 2010; Perruchet, 1989; Wahlheim et al., 2011). Moreover, providing opportunities for retrieving information during the study phase has been demonstrated as an important strategy that facilitates later recall of the same information (Carpenter & DeLosh, 2005; Karpicke & Blunt, 2011; Karpicke & Roediger, 2008; Roediger & Karpicke, 2006). Whilst there is extensive evidence from healthy individuals (young and old) and some information regarding people with dementia or other neurological impairment, these phenomena have not been studied in PWA. Examining the effect of these approaches on learning among populations with aphasia not only provides further understanding of how PWA may respond differently to such approaches compared to healthy participants but such investigations will also benefit decision-making regarding method(s) of practicing treated stimuli in a therapy context.

The first question to ask is whether learning outcomes are affected by the manipulation of the way that the to-be-learnt items are practiced during the study phase; in this case, massed versus spaced practice. That is, whether PWA also present better immediate recall for massed practice and better delayed recall for spaced practiced items as is consistent with what is reported in the existing literature. Secondly, despite Perruchet (1989) studying whether massed and spaced practice affects explicit and implicit memory in the same manner, little attention has been drawn to comparing the effects, if any, between the two memory systems. In Chapter 4, PWA showed a similar capability for learning implicitly; hence, in the current chapter, the effects of massed versus spaced practice on explicit and implicit memory are explored. Finally, although the benefit of spaced practice over massed practice has been found in learning of linguistic material (i.e. Cepeda et al., 2006) and non-linguistic material (i.e. Wahlheim et al, 2001) in healthy individuals, their effects on PWA are to be examined here. Therefore, whether there is a differential effect of linguistic and non-linguistic material is part of the current investigation.

To explore these issues, a pair-association learning task was developed according to two follow-up recall tasks (one immediately after learning, the other with a delay) and a delayed recognition task to assess learning outcomes. This was designed to investigate the learning of linguistic (word-pairs) as well as non-linguistic (picture-pairs) material. Therefore, word pairs and picture pairs were learnt and tested following the same procedures. Recall tasks gave straightforward scores of total number of pairs learnt whilst the delayed recognition task provided additional information on whether an implicit memory trace of a pair is formed; that is, the participants realised that a particular item was in the learning task(s) but failed to memorise the pair explicitly.

5.2. Background

The literature has reported robust effects on memory and learning from the spacing effect and testing effect. The *spacing hypothesis* predicts spaced practice to be a facilitator of long-term retention of newly learnt information (Cepeda et al, 2006; Karpicke & Roediger, 2007a; Middleton & Schwartz, 2012; Wahlheim et al, 2011). The *massing hypothesis* anticipates that immediate recollection of the information and self-confidence of participants toward learning benefits from massed practice (Kahana & Howard, 2005; Logan et al., 2012; Son, 2004). The effect of spaced practice over massed practice in terms of learning outcomes and retention is referred to as the *spacing effect*.

Massing is when participants learn one particular item within a fixed period of time with no interruption and/or no intervening items between repetitions. *Spacing* refers to when a to-be-learnt item(s) is repeated several times; yet, every repetition is separated with longer lags in between, compared to a massed practiced item. A *Spacing schedule* is usually created or manipulated by inserting various numbers of intervening items between two study episodes. *Intervening items* are designed specifically for the purpose of interrupting participants' learning experience without them noticing the interruption; for example, introducing another item of a similar condition (such as another pair of words in a word-pair association learning) to the to-be-learnt items. Among the current literature, a spacing effect is found when there is a lag of time between each study episode (Jackson et al., 2013; Sage et al., 2011;

Sobel et al., 2011) as well as when repetitions are spaced out by intervening items (Perruchet, 1989; Wahlheim et al., 2011). The former design, time lag between study episodes, involves two groups of participants being assigned to either a massed or spaced study group and both groups of participants being given equal learning opportunities. However, participants in a massed learning group are presented with all study episodes in different time slots within a day, whereas for a spaced learning group, each study episode is separated by days or weeks. Therefore, it is important to emphasise that the spacing schedule involved in the current study is not learning the same items under various circumstances allocated on different days but having a relatively longer lag duration or, so to speak, more intervening items between each repetition; therefore, the learning was completed in a single session.

The effect of spacing was first reported in late 1800s, with demonstration that distributing practice had a positive effect on learning outcomes (Ebbinghaus, 1885/1964). The effect was, then, intensively studied in neurologically intact young adults (Carpenter & DeLosh, 2005; Karpicke & Roediger, 2007a) and older adults (Balota et al., 2006). Only until recent decades, manipulation of spacing schedules to facilitate outcomes of cognitive rehabilitation in people with dementia (Balota et al., 2006; Middleton & Schwartz, 2012) and traumatic brain injury (Sumowski et al., 2010) has been reported. Whether PWA benefit from spaced learning in the same way as these groups is not yet known.

The early literature on memory defined the spacing effect as a strong and pervasive positive influence on long-term explicit memory (Perruchet, 1989), which involves conscious recollection. Implicit memory, on the other hand, occurs, independently from any conscious recollection, when performance changes as a result of prior events (Graf & Schacter, 1985; McKone & Trynes, 1999; Perruchet, 1989). However, explicit memory and implicit memory derive from two separate systems and are sensitive to different task variables. Also, little evidence indicates that effects found in explicit memory affect implicit memory in the same manner. That is, any effect observed in explicit learning task does not necessarily affect implicit learning, or, at least not in the same manner, and vice versa. A study by Perruchet (1989) with healthy undergraduate participants reported that spaced practiced items yielded longer reaction times than the massed practiced items in a later identification task. Therefore, although spaced items are consistently recalled better, there is no carry-over to implicit memory. It is also of interest to consider implicit and explicit memory and whether different effects of spaced learning are seen depending on how spacing schedules affect recall and recognition.

In addition to the effects of massed and spaced practice, *retrieval practice* (or the *testing effect*) may play a critical role in learning among healthy as well as various patient populations. A task that involves retrieval practice usually provides opportunities for participants to consciously retrieve target-related information. Retrieval practice emphasises the value of employing retrieval during learning to create a robust memory effect to boost learning outcomes. In healthy young participants, retrieval practice has been found to be more efficient than simply restudying the material (Karpicke & Roediger, 2008; Roediger & Karpicke, 2006). Roediger and Karpicke (2006) designed three experimental conditions each containing four phases. In the 'pure' study condition, participants were given four consecutive periods to repeatedly study the same material (a prose passage, in this case). In the 'single test' condition, participants were to study the prose passage three times before being given a test phase, in which they were directed to do a free recall task to recall as much information about the passage as possible. In the 'multi-test' condition, the participants studied the to-be-learnt prose passage once prior to starting the three follow-up tests, which also involved free recall tasks. It is notable that Roediger and Karpicke provided no feedback to their participants in the test phase(s), as an approach to avoid any opportunity of restudy. Nevertheless, Roediger and Karpicke still observed a retrieval/testing effect where participants who were in the two groups involving test(s) performed better than the participants in the 'pure' study group. Moreover, intriguingly, the number of tests received positively correlated with the performance in the delayed recall tasks taking place 2 days and a week later respectively. This phenomenon indicated that memory of the newly learnt information benefited from repeated retrieval practice rather than pure restudying even with no feedback being provided. The finding presented by Roediger and Karpicke (2006) suggested that although participants themselves rated restudy ('pure' study condition) as the most efficient way of learning and data analysis reported it as prompting better performance on immediate recall (5 minutes after study) compared to test conditions, restudy without having an opportunity to actively retrieve the newly learnt information showed a greater degree of forgetting over time.

Some studies involving undergraduate participants learning verbal/linguistic material have provided evidence for the long-term effect of spaced practice (Carpenter & DeLosh, 2005; Karpicke & Roediger, 2007b). Carpenter and DeLosh (2005) tested potential spacing effects in face-name association learning. They pointed out that the spacing effect appeared not only under the condition when participants were given opportunities to do retrieval practice but also under the circumstances when participants were only allowed to restudy the to-be-learnt items. That is, spacing out the opportunities for restudy of the same to-be-learnt material led to better retention than consecutive restudy. In addition, the benefit of spaced practice was not restricted to learning linguistic material, such as word-pairs, word lists, and text passage(s). Spacing seemed to improve across various types of learning, including non-linguistic conceptual material (Kornell et al., 2010; Kornell & Bjork, 2008).

Some doubts about the efficacy of spaced practice are raised by the possibility that delaying the opportunities of retrieval practice could increase error rate, which could be one of the factors to impair learning. This view is supported by the concept of error minimisation (Skinner, 1968), where it is claimed that producing an error while learning has a negative impact on the outcome even if immediate correction or feedback is provided. However, Pashler et al. (2003) present a contrasting view. They claimed that despite spacing involving relatively long delays between study and restudy/practice episodes and, therefore, increased error rates, greater temporal distribution of practice maximised learning outcomes. Furthermore, as reported by Pashler et al. (2003), the benefit of spacing was observed in both 24-hour and one-week delays. Pashler et al. used pair association learning of foreign-and-English word pairs, where the to-be-learnt pairs were presented once and followed by two retrieval practices (or test 1 and test 2, as Pashler et al. named them). The lag duration between the initial presentation and test 1 (the first retrieval practice) was two intervening items (filler word pairs) and the lag duration between test 1 and test 2 (the second retrieval practice) had six variations (1, 2, 4, 8, 16, or 32 intervening items). The participants were tested a day after completing the learning task. Pashler et al. found that during the study phase, the longer the lag between test 1 and 2 the higher the rate of forgetting was, yet the delayed test on the next day presented a reverse pattern. This therefore supported the suggestion that short lag creates efficient learning outcomes and relatively long lag improves retention of newly learnt information. Also, based on existing literature, no evidence has suggested that making mistakes while learning impaired memory, at least under the circumstance when feedback is available (Haslam et al., 2011; Pashler et al., 2003).

The efficacy of spacing is, however, not without its limit. The benefit dissolves once the lag duration has exceeded a 'modest' proportion (Crowder, 1976; Pashler et al., 2003). The most efficient condition of inter-stimuli interval that may produce an optimum spacing effect is varied and undetermined in the existing literature (Balota et al., 2006; Crowder, 1976; Karpicke & Roediger, 2007a, 2007b; Pashler et al., 2003). In the case of Pashler et al.'s (2003) study, lag durations between test 1 and 2 were further extended (lag 16, 32, 48, 64, 80, or 96) in a follow-up experiment. The error rate increased as the lag duration increased; furthermore, the delayed test on the next day reflected that performance benefited from longer lag (≥16) with possible optimum outcome between lag 32 and 96. Whether the spacing effect can be observed beyond this lag is unknown. Therefore, a point to note when investigating whether spacing facilitates learning in PWA is to employ a spacing schedule that has been previously reported to have a positive effect.

5.3. The current experiment

The major focus here was to investigate whether PWA can benefit from the robust spacing effect reported among healthy and other neurologically impaired populations in learning of linguistic (word-pairs) and non-linguistic (picture-pairs) material. In order to explore the research questions proposed earlier in the chapter, the current experiment consisted of three phases: 1) a study phase, 2) an immediate cued-recall task, and 3) a delayed recognition task and a delayed cued-recall task. The study phase was a learning task with a pair-association paradigm modified from previous studies that have investigated the spacing effect (Balota et al., 2006; Karpicke & Roediger, 2007a; Pashler et al., 2003). The to-be-learnt pairs of words or pictures were presented to the participants followed by three retrieval practice trials, which were either massed or spaced, giving the participants opportunities to not only study but also retrieve the newly learnt pairs. For the retrieval practice, instead of free recall, participants were provided with a cue (one of the items in a pair) to do cued-retrieval practice. Learning was assessed immediately, with only a brief break available after the study phase, with a cued-recall task to determine the learning outcome(s) and whether the spacing effect had occurred. Two days later, the participants were given a delayed recognition task and the same cued-recall task to examine the potential occurrence of implicit learning as well as the effect of massed and spaced practice on the rate of forgetting.

The existing literature has provided evidence of an effect of spacing that has a positive impact on learning in various tasks. In particular, the spacing effect is evident in the performance on tasks tapping explicit memory, such as recall tasks. Massed practice, on the other hand, facilitates immediate recollection; therefore, massed practice improves the accuracy of the cued-retrieval practice more efficiently compared to spaced practice. Based on previous findings, it is hypothesised that: 1) if massing effect facilitates immediate recollection, the accuracy of massed practiced pairs will improve more rapidly than spaced practiced pairs during the study phase; 2) if a spacing effect is observed, spaced practiced pairs would have higher accuracy in both immediate and delayed cued-recall tasks; and 3) if a spacing effect occurred in implicit memory, individual items from spaced practiced pairs would be better recognised in the delayed recognition task than massed practiced tasks.

In accordance with the hypothesis and the performance of PWA on the tasks in previous chapters, predictions could be made. Firstly, during the study phase, massed practiced pairs would better improve accuracy of retrieval after each cued-retrieval practice trial; on the contrary, spaced practiced pairs may have higher error rates. Nonetheless, the current study did not use a spacing schedule of long lag(s) between repetitions in order to ensure the occurrence of learning; as a result, the error rates of massed and spaced practice might only differ slightly. Secondly, the predictions for the performance in the immediate and delayed cued-recall tasks were in accordance with the robust effect previously reported in healthy participants. Despite the advantage that massed practice has on retrieval success during the study phase, massed practice also leads to higher rates of forgetting than spaced practice. Hence, the spacing effect was expected to be even more evident in the delayed cued-recall task because the greater forgetting rate of massed practice was likely to emphasise the difference between the two approaches to practice. Thirdly, although participants may not explicitly remember the to-be-learnt pairs, memory trace allows them to recognise the items belonging to the pairs. Therefore, participants were expected to be able to distinguish the items that had previously appeared (old) in the study phase and those that had not (new), as well as having better recognition toward the old and new items compared to the items shown for intervening purposes during the study phase. Moreover, if that spacing effect has an impact on implicit memory, spaced practiced items were expected to be recognised better than massed practiced items.

The current experiment involved linguistic and non-linguistic stimuli; based on the literature above, massing and spacing effects have been reported in learning of linguistic as well as non-linguistic material. Consequently, the effects should be observed in pair-association learning of word pairs and also picture pairs. Also, both control groups (young and age-matched) involved in the study were expected to be affected in the same way by the methods of practice. Further, if the impairments of participants with aphasia were purely in the linguistic domain, more errors could occur in the cued-retrieval practice trials and the outcomes of cued-recall and recognition would be significantly reduced than the controls in learning of word pairs; yet, the spacing effect should persist. As for learning of picture pairs, PWA may not necessarily perform much worse than their age-matched participants.

5.4. Methodology

The experiment involved a study phase, an immediate cued-recall task, a delayed cued-recall task, and a delayed recognition task. The study phase presented the to-be-learnt pairs in either a massed or spaced manner with three cued-retrieval practice opportunities for the target pairs. The participants completed the immediate cued-recall task which tested the learning outcome of massed versus spaced learning. To further investigate whether massing and spacing had a longer lasting effect, the participants were requested to return for assessments after two days. The delayed tests included a recognition test, which explored the potential occurrence of implicit learning, and a delayed cued-recall task, which was the same procedure as the immediate one and assessed whether massing and spacing affected the participants' ability to retain newly learnt material over time (2 days).

5.4.1. Participants

Two control groups of 18 participants were recruited for the experiment; one a group of young controls age between 18 and 30, the other a group of people age between 50 and 80 served as age-matched controls for the PWA. Only a few of the participants in the control groups participated in the previous experiments. Out of the 18 PWA who had taken part in earlier experiments, 11 of them took part in the current experiment. The information about the participants is summarised in Table 5.1.

Table 5.1. Average age (in years) of the participants

Group	Mean	Std. Dev.	Age range
Young control	21.06	3.76	18-30
Older control	69.00	7.35	50-80
PWA	70.64	9.30	50-80

5.4.2. Materials

As suggested in the previous literature (Cepeda et al., 2006), stimuli for the massed practice condition were presented in a list with no intervening items or, in the case of the current experiment, a lag duration of less than one second. Stimuli for spaced practice condition, on the other hand, were presented with four intervening pairs. A pair of to-be-learnt items was presented 4 times during the study phase, including the initial presentation of the pair and three follow-up cued-retrieval practices.

Method of practice (massed versus spaced) was manipulated in the study phase, in which the to-be-learnt pairs were introduced to the participants and practiced. Each pair of words or pictures contained a cue item and a target item. The cue item, which was always presented on the left of the screen, was the one that was used as a cue in the cued-retrieval practice. A target item, on the contrary, was presented on the right of the screen, alongside the corresponding cue item, in a presentation trial introducing a to-be-learnt pair. The target item was the response that participants were expected to choose to match with a cue given in a cued-retrieval practice trial. A retrieval practice trial consisted of a cue item, shown on the left of the screen, and three to-be-matched items on the right including the target. For the cued-recall tasks, both immediate and delayed, the to-be-learnt pairs were tested in the same fashion as they were presented in the cued-retrieval practice trials in the study phase. To investigate the effects of massed and spaced practice on pair-association learning of word-pairs and picture-pairs, two sets of stimuli (English real words and pictures of real-life scenes) were developed; examples are provided in Appendix C.

Word pairs (linguistic stimuli): The words involved were all concrete nouns of relatively low frequency in written and spoken English. A word was first selected from the word frequency list of nouns based on British National Corpus (Leech et al., 2001); all selected words were in the frequency range from 10 to 210 wpm (word per million). The selected words were then paired with a weakly semantically associated counterparts with an association strength of 2% - 4.8% between a cue word and a target word as listed in the Birkbeck word association norms (Moss & Older, 1996). These formed 30 to-be-learnt word-pairs. The example that is given in Table 5.2 demonstrates the associative strength between the word '*ruler*' and its associates. In this case, the word '*straight*' is considered to be relatively strongly associated to '*ruler*', yet '*wood*' is weakly associated to it.

Table 5.2. An example of word association norm - *Ruler*.

Ruler	
associates	*associative strength (%)*
Straight	22.2
Pencil	13.3
King	11.1
Line(s)	11.1
Measure	8.9
Pen	4.4
School	4.4
Wood	4.4
Above, Leader, Maths, Plastic, Rubber, Rule, Walk, Sovereign	2.2

The 30 word pairs were further assigned to the massed or spaced conditions, with 15 pairs for each condition. The pairs were counterbalanced across participants; that is, a pair of to-be-learnt words was practiced by one participant in the massed condition and by another participant in the spaced condition. In addition, to ensure the appropriate spacing schedule in the study phase, an extra 78 pairs of weakly related words, also based on the Birkbeck Word Association Norms (Moss & Older, 1996), were created as filler pairs, which the participants did not have an opportunity to do retrieval practice with. Each filler pair appeared only once in the study phase. The items within the filler pairs were not tested for cued-recall, though some of them were used in the delayed recognition as intervening items.

As mentioned earlier, in the study phase, a cued-retrieval practice trial consisted of a cue, its target, and two other nouns. One of the nouns was a filler of approximately the same range of frequency and had appeared in one of the filler pairs the participants had seen before. The other noun was a distractor, which like the target, had a weak semantic relation with the cue. Therefore, an additional 90 nouns were chosen from the Birkbeck Word Association Norms to serve as distractors in cued-retrieval practice trials. The association strength between a cue and a distractor was similar to the association strength between the cue and its target. Distractor and filler words were not the same in each follow-up cued-retrieval practice trial. That is, the two words that the participants saw along with the target in the first follow-up cued-retrieval practice trial would not appear again in the second and/or the third cued-retrieval practice trial. The purpose of having different distractors and fillers was to not only assure that the participants employ semantic knowledge to perform the task but also to minimise the possibility that the participants rely heavily on other learning strategies (i.e. elimination). Table 5.3 gives an example of how a to-be-learnt word-pair was first presented and followed by its three cue-retrieval practices trials in the study phase.

In the immediate as well as delayed cue-recall tasks, the to-be-learnt word-pairs were tested one after another. One of the cue-retrieval practice trials of a word pair that the participants had seen in the study phase was randomly selected to be used as a test trial. Therefore, the 30 trials involved in the immediate/delayed cued-recall task(s) were presented in the manner of the ‘cued-retrieval’ trial demonstrated in Table 5.3. The delayed recognition task, comprised 90 words, including 30 target words, distractors, and fillers; distractor words were those that only appeared once in the study phase and filler words were words that the participants had never encountered while study. Consequently, an extra 30 nouns in the same frequency range were chosen as the target words to be fillers.

Table 5.3. Examples of the trials in the linguistic study phase.

Trial name	Pairs of stimuli	Type of stimuli
Presentation	ruler wood	target
	leader	distractor
Cued-retrieval 1	ruler wood	target
	farm	filler
	wood	target
Cued-retrieval 2	ruler crown	distractor
	plastic	filler
	rubber	distractor
Cued-retrieval 3	ruler brush	filler
	wood	target

Picture pairs (non-linguistic stimuli): The to-be-learnt pictures were varied photographs of real-life scenes. These were used because they contained complex visual information, which was assumed to make it harder for the participants to use linguistic encoding. Overall, 294 pictures were involved and all the pictures fell into one of four categories: 1) portrait/ animal, 2) object, 3) water (i.e. lake, ocean, or river), and 4) scenery; that is, 40 pictures per category.

A picture-pair was created with two distinguishable pictures from the same category. The 30 picture-pairs, five from each category, were then equally distributed to the massed and spaced practice conditions. Corresponding to the design of word-pairs, the conditions with picture-pairs were counterbalanced among participants. In addition, 78 picture-pairs were used as filler pairs to create appropriate spacing; these pairs were shown once with no follow-up retrieval practice trials in the study phase. Apart from the picture pairs, 90 category-matched pictures were selected to be distractors in the cued-retrieval practice trials.

Using the same method as with word-pairs in the study phase, each picture-pair was introduced to the participants with a cue picture and its target picture. Then, in each cued-retrieval practice trial, a cue was presented alongside a choice of three pictures, including its target, a distractor, and a filler picture. A filler picture in a cued-retrieval practice trial was a picture of a different category from the pair and the distractor; it had been presented to the participants once prior to the current cued-retrieval practice trial as a part of a filler trial. Also, the distractor and the filler of a picture-pair were different in each cued-retrieval practice trials; the same distractor and/or filler never appeared twice. Table 5.4 illustrates the manner that a to-be-learnt picture-pair and its three follow up cued-retrieval practices were presented to participants.

In the immediate/delayed cued-recall task(s), the 30 to-be-learnt items were assessed using one of their cued-retrieval practice trials, demonstrated in the example in Table 5.4. The selection of the trials used in the two cued-recall tasks was completely random. The delayed recognition consisted of 90 individual pictures, including 30 targets, 30 distractors, and 30 fillers, being presented to the participants one at a time. The target pictures of the delayed recognition task were pictures of the to-be-learnt pairs, which were repeatedly presented during study; distractors, on the other hand, were the pictures that appeared once in the study phase. Pictures that the participants had never seen before were used as fillers.

Table 5.4. Examples of the trials in the non-linguistic study phase.

Trial name	Pairs of stimuli		Type of stimuli	category
Presentation			target	Portrait/animal
			distractor	Portrait/animal
Cued-retrieval 1			target	Portrait/animal
			filler	Scenery
			target	Portrait/animal
Cued-retrieval 2			distractor	Portrait/animal
			filler	Lake/river/ocean
			distractor	Portrait/animal
Cued-retrieval 3			target	Portrait/animal
			fillter	Lake/river/ocean al

5.4.3. Procedures

All participants who volunteered for the experiment attended two separate sessions. The participants were to come back for the second session between 36 and 60 hours after they had done the first session, any earlier or later than this time frame was considered as failing to complete the experiment. How the experiment proceeded is outlined in Table 5.5. This example shows presentations where word pairs were given first; this was randomised across participants.

Table 5.5. Procedures within the experiment sessions.

Session I	**Session II**
Study Phase – word-pairs	Delayed recognition – word-pairs
↓ *10-minute break*	↓
Immediate cued-recall – word-pairs	Delayed cued-recall – word-pairs
↓ *A short break, if wish*	↓ *A short break, if wish*
Study phase – picture-pairs	Delayed recognition – picture-pairs
↓ *10-minute break*	↓
Immediate cued-recall – picture-pairs	Delayed cued-recall – picture-pairs
↓	↓
[End of the session]	[Experiment Finished]

Before starting the study phase, instructions and a brief practice containing 10 mock trials were given to the participants. As mentioned earlier, all participants experienced both sets of stimuli (word-pairs and picture-pairs), which were done separately, in the same session. The order of which set of stimuli was presented to participants first was counterbalanced. That is, in the first session, half of the participants received the task with word-pairs first whilst the other half began with picture-pairs.

In the first session, the participants were directed to do two study phases for word-pairs and picture-pairs respectively, and also two immediate cued-recall tasks of items from the different conditions. The participants were tested individually and, in the study phase for each condition (word/picture), each participant received 198 trials, including 30 initial presentations of the to-be-learnt pairs, 90 follow-up cued-retrieval practices of the to-be-learnt pairs, and 78 filler pairs.

The study phase consisted of presentation trials of the to-be-learnt pairs as well as the intervening pairs, and cued-retrieval practice trials of the to-be-learnt pairs. The to-be-learnt pairs and intervening pairs were presented in the same way. On every trial, there was a brief (500 milliseconds) interstimuli interval, during which a blank screen with a cross (+) in the middle of the screen appeared, between trials to remind participants the next trial was about to come up. The presentation trials showed the two items side by side on the screen for 4 seconds before being removed from the screen for the presentation of the next trial. In cued-retrieval practice trials, a cue was presented on the left of the screen along with three items, a filler, a semantically related distractor, and the target, on the right of the screen. Participants had a maximum of 10 seconds to choose one of the three items to match with the cue using a mouse-click on the item of their choice. Once a response was received, auditory feedback (correct/wrong) was provided by the computer and the filler and the distractor were removed from the screen, leaving only the cue and the target. To ensure the participants realised that the target/correct response remained on screen, a red '√' was displayed on the screen, next to the target at the same time as feedback was provided.

Stimuli for massed and spaced practice conditions were counterbalanced and randomised throughout. Figure 5.1 provides an example, for word-pairs, of how presentation trials and cued-retrieval practice trials were presented to the participants during the study phase. Each square in Figure 5.1 represents the screen layout that the participants saw for a trial. Massed practice involved an initial presentation of a word-pair or picture-pair and 3 immediate cued-retrieval practice trials. With spaced practice, on the other hand, each trial was spaced out by 4 intervening trials, which could be filler trials, a set of massed practice trials (initial presentation plus the follow-up cued-retrieval practices), or cued-retrieval practice trials of other spaced practiced pairs. The blank space between the squares in Figure 5.1 represents the inter-stimuli interval.

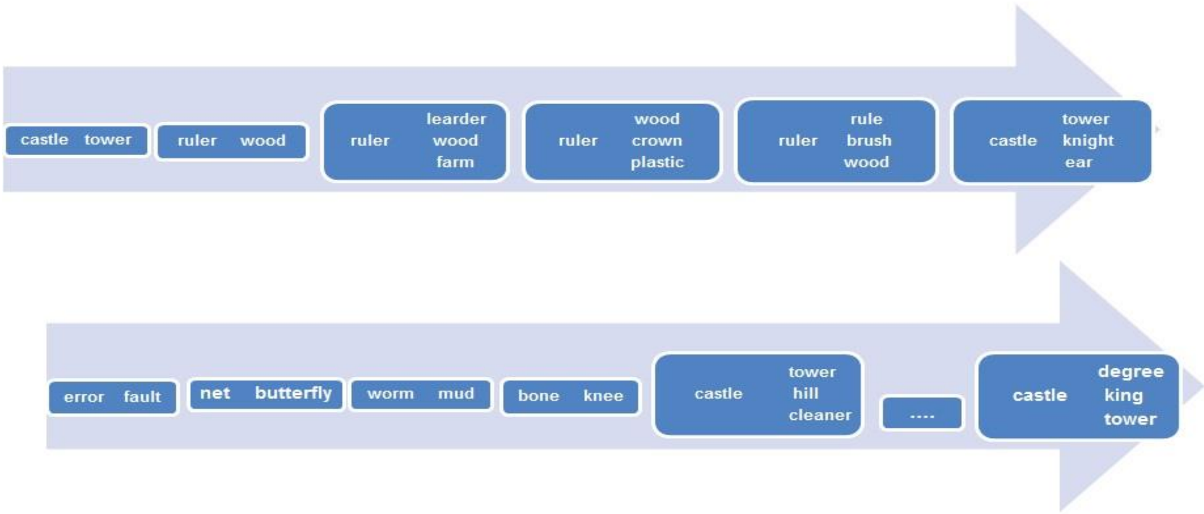

Figure 5.1. Presentations of trials in the study phase - linguistic stimuli.

Once the study phase terminated, participants were given a ten-minute-break, during which they were engaged in general conversation, before proceeding to an immediate cued-recall task. In the cued-recall task, all 30 to-be-learnt pairs were presented one by one with a cue on the left of the screen, and three choices, a distractor, a filler, and the target, on the right. The participants were told that they had a maximum of 10 seconds for each trial and were required to choose one from the three items to match the cue that they had received by clicking on their item of choice. Participants were informed that no feedback would be given in this task and once they had clicked on an item of their choice, the next trial would be presented. The first half of the session finished on the completion of the immediate cued-recall task. Before moving on to the second half, the participants could take a break if they wished to do so. In the second half of the session, the participants were given the other set of stimuli to learn and the procedure was repeated starting with a study phase followed by a ten-minute-break, then the immediate cued-recall task.

Delayed recognition tasks and a delayed cued-recall tasks were performed 2 days after completing the study phase; a delay interval at which a difference between massed and spaced practice has previously been reported (e.g. Balota et al., 2006; Karpicke & Roediger, 2007b). The word-pairs and picture-pairs were tested separately within the same session. Prior to the delayed recognition tasks, the participants were notified that some of the pictures or words were shown in the study phase and the others were not. The participants were asked to judge whether they had seen each picture or word in the study phase or not. A mouse with 'Yes' (the left button) and 'No' (the right button) labels was fixed in front of the participants, they were directed to click on one of the buttons to give their response. In each delayed recognition task, 90 items were presented, including 30 target items (which had appeared four times during the study phase), 30 fillers (new items), and 30 distractors (which had appeared once in the study phase). For each item (a word or a picture), the participants had a maximum of 5 seconds to respond and the next item was presented after their response; a 500msec blank screen intervened between items. No feedback was given in the delayed recognition tasks.

On completion of the delayed recognition task, participants were instructed to proceed to do the delayed cued-recall task, which was identical to the immediate cued-recall tasks. Participants could have a small break between delayed recognition tasks and the delayed cued-recall tasks if they so wished.

5.5. Results and Discussion

The analyses in this section were performed with SPSS, statistic software. Statistical significance was accepted at the level of 0.05 and lower; a significance value of 0.01 was considered to be highly significant. However, when a rigid value of significance (p value between 0.05 and 0.06) was spotted, it was treated as a significant value and follow-up tests(s) was applied. Effect size(s) was also reported using partial Eta squared provided by ANOVAs. Boxplots were used to demonstrate overall performance of the three groups of participants in certain experimental conditions. Outliers in the datasets, if any, were not eliminated from the analyses so that the data revealed potential individual difference among participants.

5.5.1. Study phase

The first analysis investigated whether the manipulated factors had effects on each cued-retrieval practice trial during the study phase. The issues investigated in this part of the analyses were: 1) whether word-pairs and picture-pairs were learnt differently, [linguistic condition (word vs. picture)]; 2) whether massed and spaced practice affected the accuracy of cued-retrieval, [(practice condition (massed vs. spaced)]; 3) whether repeated cued-retrieval practice might boost the performance, [(retrieval condition (cued-retrieval 1, cued-retrieval 2, & cued-retrieval 3)]; and 4) whether the three groups of participants showed different patterns of learning in the study phase, [group (young, older, & PWA)]. Figure 5.2 and Figure 5.3 indicate the performance of the three groups on learning of word-pairs and picture-pairs respectively. Except for PWA, the participants performed at ceiling level during the study phase, regardless of the linguistic condition of the to-be-learnt material.

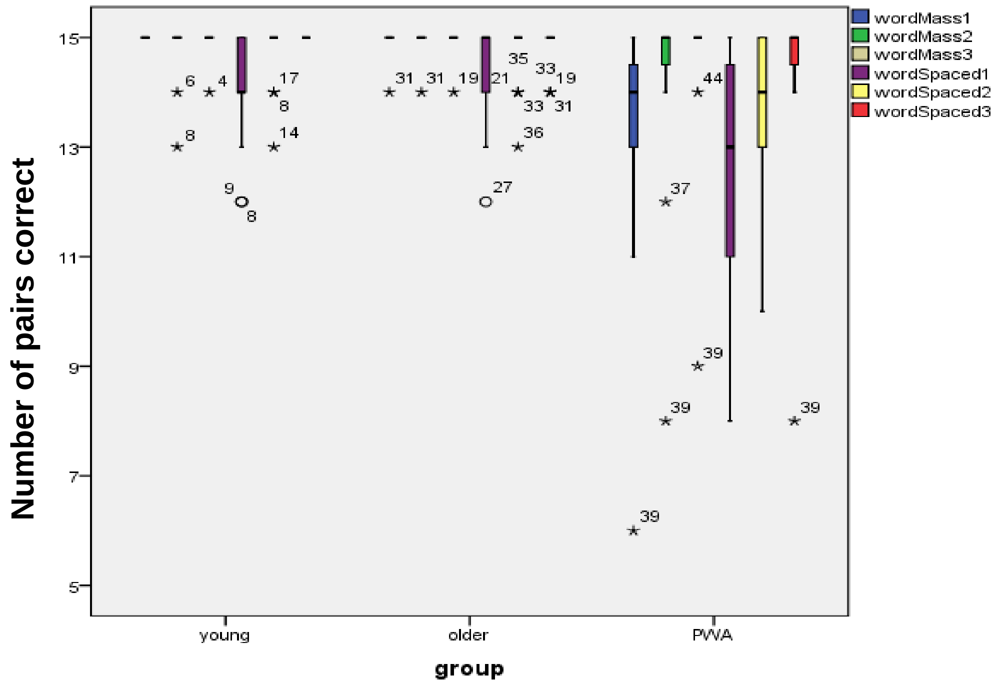

Figure 5.2. Average accuracy of cued-retrieval – word-pairs.

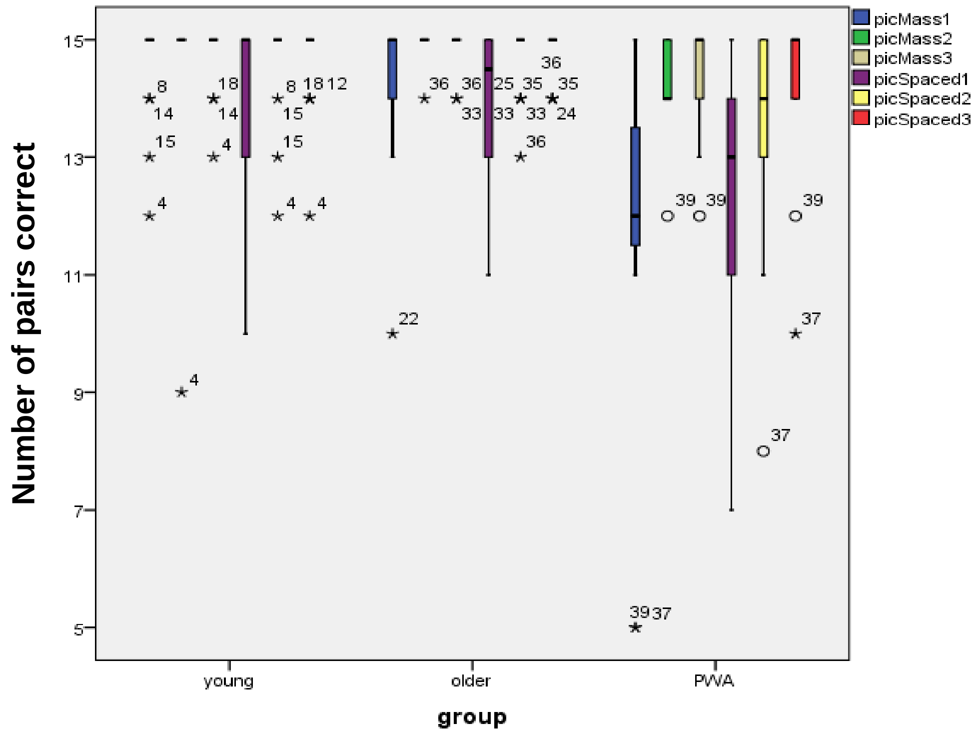

Figure 5.3. Average accuracy of cued-retrieval – picture-pairs.

The accuracy data were analysed with a mixed repeated-measures ANOVA by subjects. Descriptive data of the numbers of correct cued-retrieval practice trials are outlined in Table 5.6 with the standard deviations in brackets. There was a significant main effect of practice condition ($F_{(1, 44)}$ =15.978, p<0.001; η_p^2=0.266) on the accuracy of cued-retrieval practice, with performance during massed practice (14.39) being better than during spaced practice (14.09). Also, there was a main effect of retrieval condition ($F_{(2, 44)}$ =46.403, p<0.001; η_p^2=0.513), suggesting that each opportunity for cued-retrieval practice significantly improved performance on cued-retrieval trials. That is, participants successfully retrieved more pairs in the second cued-retrieval practice (14.45) than in the first cued-retrieval practice (13.66) and achieved an even higher success rate in the final cued-retrieval practice trial (14.63), regardless of the linguistic, practice, and/or group condition. Between-subject effect was also found to be significant ($F_{(2, 44)}$ =8.682, p=0.001; η_p^2=0.283), indicating that the patterns of improvement of the three groups were significantly different through the study phase. Pairwise comparisons revealed that the differences lay between PWA and the younger participants (p=0.001) and PWA and the older participants (p<0.001). The performance of the two control groups did not differ significantly. The difference between picture and word condition ($F_{(1, 44)}$ =3.968, p=0.053; η_p^2=0.083), on the other hand, showed no significant effect on performance on cued-retrieval practice trials. Paired-sample *t*-test was applied to further explore the rigid value of significance of the two levels of linguistic condition. The result of the *t*-test showed, again, that linguistic condition had almost significant effect on performance of study phase ($t_{(46)}$=2.003, p=0.051).

Table 5.6. Numbers of pairs correct in cued-retrieval practice trials.

	Word-pairs						Picture-pairs					
	massed			*spaced*			*massed*			*spaced*		
	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3
young	15.00 (0.00)	14.83 (0.51)	14.94 (0.24)	14.11 (0.96)	14.78 (0.55)	15.00 (0.00)	14.61 (0.85)	14.67 (1.41)	14.78 (0.55)	13.67 (1.97)	14.67 (0.84)	14.67 (0.77)
old	14.94 (0.24)	14.94 (0.24)	14.94 (0.24)	14.33 (0.91)	14.72 (0.58)	14.83 (0.38)	14.22 (1.26)	14.94 (0.24)	14.89 (0.32)	14.06 (1.21)	14.72 (0.58)	14.78 (0.48)
PWA	13.09 (2.66)	14.00 (2.19)	14.36 (1.80)	12.27 (2.57)	13.55 (1.52)	14.18 (2.09)	11.45 (3.39)	14.27 (0.91)	14.36 (1.03)	12.09 (2.43)	13.27 (2.15)	14.00 (1.61)
mean	14.53 (1.49)	14.68 (1.14)	14.81 (0.90)	13.77 (1.67)	14.47 (1.02)	14.47 (1.02)	13.72 (2.23)	14.68 (1.00)	14.72 (0.65)	13.45 (1.97)	14.36 (1.33)	14.55 (0.97)

Note – Mean number of pairs correct would not exceed 15 in each experimental condition. Standard deviations are shown in brackets. R stands for 'practice condition' (R1 = first practice; R2 = second practice; R3 = third practice).

In the study phase, there were a number of significant interactions among factors. A two-way interaction was found between linguistic condition and retrieval condition ($F_{(2, 88)}$ =7.751, p=0.001; η_p^2=0.150). This finding suggested that although linguistic condition did not show a main effect on performance, the outcomes of cued-retrieval practice of word-pairs and picture-pairs varied due to the number of presentations a trial had received. The interaction between linguistic and retrieval conditions is illustrated in Figure 5.4, showing that picture-pairs had much lower success rates of retrieval than word-pairs after one pair had been presented for a single time. The other two-way interaction reported was between retrieval and group condition ($F_{(4, 88)}$ =9.912, p<0.001; η_p^2=0.311). The effects of the two factors did not only independently affect the outcome but also co-occurred. Figure 5.5 shows that, the overall trends of improvement observed among the three groups of participants were similar. People with aphasia performed worse overall relative to the two groups of control participants with performance being much lower on the first trial.

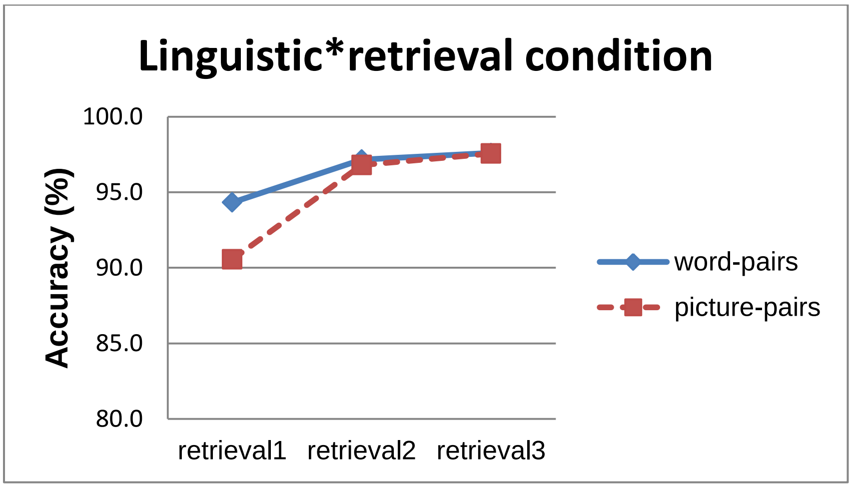

Figure 5.4. Outcomes of cued-retrieval practice of word-pairs and picture-pairs at each level of retrieval.

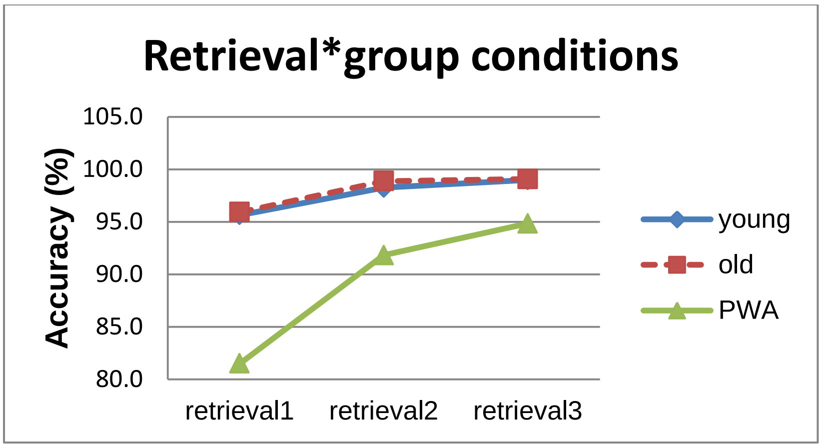

Figure 5.5. Outcomes of cued-retrieval practice of the three groups at each level of retrieval.

There was no other significant two-way interaction. Group condition did not interact with linguistic condition (p=0.903) or practice condition (p=0.803), suggesting that group performance was similar across linguistic and practice conditions. Moreover, the practice conditions did not interact with neither linguistic condition nor retrieval condition.

There was a significant three-way interaction between practice, linguistic, and retrieval condition ($F_{(2, 88)}$ =5.876, p=0.004; η_p^2=0.118). This suggested again, that the effect of linguistic condition on performance during the study phase was only significant when it interacted with certain level(s) of the other two conditions. The pattern of interaction is presented in Figure 5.6. There was also a significant interaction between group, practice, and retrieval conditions

($F_{(4, 88)}$ =3.282, p=0.015; η_p^2=0.130). An overview of this three-way interaction is shown in Figure 5.7. It is evident that all three groups of participants did worse in the first cued-retrieval practice trial of spaced pairs, compared to massed pairs, due to delaying the opportunity of doing cued-retrieval practice. Although the accuracy of spaced cued-retrieval practice significantly increased after having three practices, massed cued-retrieval practice still yielded higher overall accuracy. On the contrary, linguistic condition did not interact with practice and group conditions (p=0.694) or retrieval and group conditions (p=0.471). There was however, a significant four-way interaction ($F_{(4, 88)}$ =2.889, p=0.027; η_p^2=0.116).

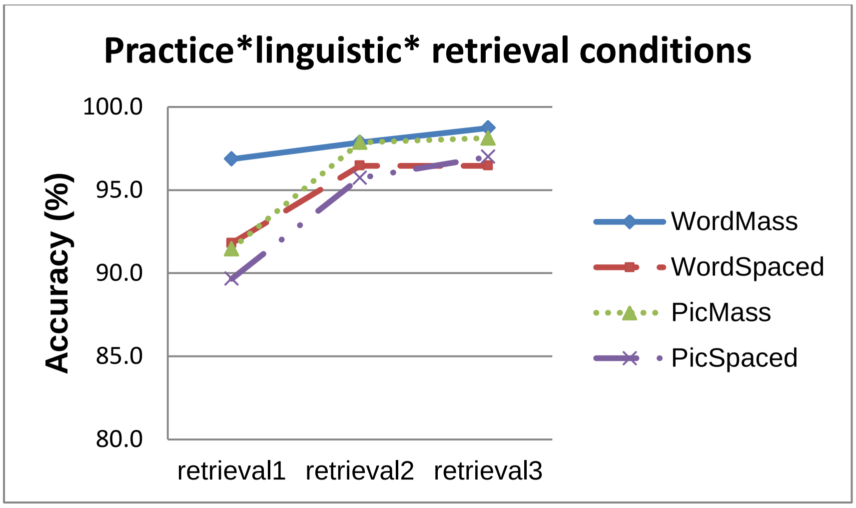

Figure 5.6. Outcomes of cued-retrieval practice of massed and spaced practiced word/picture-pairs at each level of retrieval.

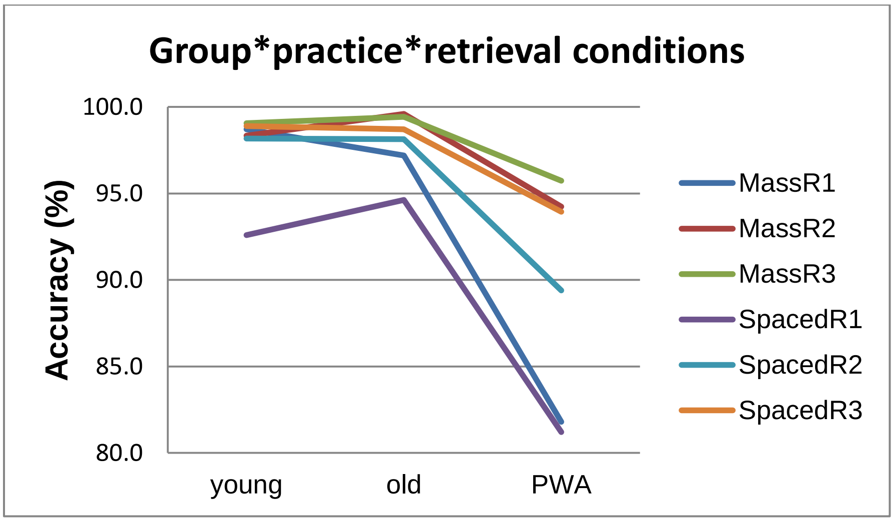

Figure 5.7. Outcomes of performances of the groups on cued-retrieval practice at each level in massed and spaced practice conditions.

To summarise, in line with the prediction, the benefit of spacing was absent during the study phase; instead, massed-practiced pairs led to higher accuracy in cued-retrieval practice trials. This effect was equally evident with words and pictures. Repetitions of cued-retrieval practices had improved accuracy significantly with the effect observed among all three groups of participants. Linguistic condition, in this case, did not affect the performance on cued-retrieval practice trials. There was a significant interaction between linguistic condition and the other two independent within-subject factors (practice and retrieval conditions) suggesting that they had influenced the performance on learning of word-pairs and picture-pairs in different fashions. In addition, the outcomes generated by PWA were significantly worse compared than both control groups, yet, the pattern of improvement was the same; accuracy of cued-retrieval practice increased along with the repetition of cued-retrieval practice trials.

5.5.2. Immediate and delayed cued-recall tasks

Analyses in this section address four issues of interest: 1) is there a difference between learning of word and pictures pairs?; 2) is there a difference between massed and spaced practice?; 3) is there a difference between immediate and delayed cued-recall?; and 4) are there differences between the three groups of participants?

A mixed repeated-measures analysis of variance (ANOVA) was performed to examine the potential effects of these factors on the two cued-recall tasks. The within-subject factors were 1) linguistic condition (word/picture), 2) practice condition in the study phase (massed/spaced), and 3) cued-recall condition (immediate/delayed). Each within-subject factor contained two levels. Group was the between-subject factor with three levels (young, older, and PWA). An overview of the average number of pairs recalled correctly under each experimental condition is provided in Table 5.7.

Table 5.7. Number of items recalled correctly in each experimental condition.

	Word-pairs				**Picture-pairs**			
	immediate		*delayed*		*immediate*		*delayed*	
	massed	spaced	massed	space	massed	spaced	massed	spaced
Young	13.39 (1.79)	14.67 (0.77)	13.78 (1.22)	14.67 (0.77)	12.67 (2.03)	14.06 (1.43)	12.61 (1.97)	13.28 (1.84)
Older	13.67 (1.28)	14.72 (0.57)	12.89 (1.75)	14.22 (1.22)	12.33 (1.57)	14.06 (1.26)	12.50 (1.58)	12.72 (1.90)
PWA	11.55 (2.30)	13.27 (2.28)	10.09 ((3.05)	12.18 (2.32)	11.18 (2.4)	12.27 (1.95)	10.82 (2.14)	11.45 (2.38)
mean	13.06 (1.92)	14.36 (1.36)	12.57 (2.40)	13.91 (1.70)	12.19 (2.00)	13.64 (1.66)	12.15 (1.98)	12.64 (2.08)

Note – Mean number of pairs correct would not exceed 15 in each experimental condition. Standard deviations were shown in brackets.

ANOVA by subjects showed that all four factors had a significant main effect on the performance in the cued-recall tasks. Significantly more word-pairs (13.26) were recalled correctly than picture-pairs (12.5) in both immediate and delayed cued-recall tasks ($F_{(1.44)}$=12.448, p=0.001; η_p^2=0.221). Also, there was a main effect of massed and spaced practice ($F_{(1.44)}$=66.235, p<0.001; η_p^2=0.601); recollection benefited from spaced practice. The average number of spaced-practice items recalled was 13.46 out of 15, which was higher than the mean of massed-practice items, 12.29. Unsurprisingly, the recall condition significantly affected the outcomes ($F_{(1.44)}$= 14.123, p=0.001; η_p^2=0.240); the average number of pairs correctly recalled in the immediate cued-recall task was 13.15 whilst it was 12.60 in the delayed cued-recall task. The between-subject factor was also significant ($F_{(2, 44)=}$10.790, p <0.001; η_p^2=0.329), indicating the three groups performed differently. The post-hoc tests with Bonferroni procedure showed that the PWA (*M* =11.60) were significantly worse compared to the young controls (*M*=13.64; p<0.001) and also the age-matched control participants (*M* =13.39; p=0.001). The two control groups did not differ significantly (p=1.00).

In addition to the main effects, there were several interactions. Recall condition interacted significantly with practice condition ($F_{(1, 44)=}$4.89, p=0.032;

η_p^2=0.100). As Figure 5.8 shows, the rate of accuracy of massed practice pairs was lower than spaced practice pairs. Although the rate of accuracy of recall significantly decreased in delayed cued-recall task, the spacing effect remained; spaced practiced pairs yielded better recollection even after a delay of two days. What is more, there was a three-way interaction among linguistic condition, recall condition, and practice condition ($F_{(1, 44)}$=5.421, p=0.025; η_p^2=0.110). Figure 5.9 demonstrates that, in the immediate recall task, participants successfully recalled more word-pairs than picture-pairs. Linguistic effect was also observed in the delayed cued-recall tasks; that is, word-pairs were retained better than picture pairs 48 hours post-study. Spaced-practiced word-pairs and picture-pairs had higher rates of accuracy in both immediate and delayed recall tasks compared to massed-practiced pairs. This suggested that practice condition played an equal role to linguistic condition in the two cued-recall tasks.

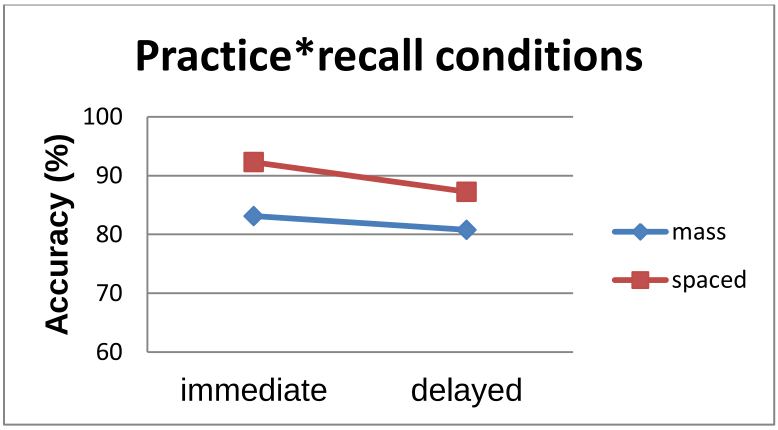

Figure 5.8. Mean accuracy in percentage – massed and spaced practice in each cued-recall task.

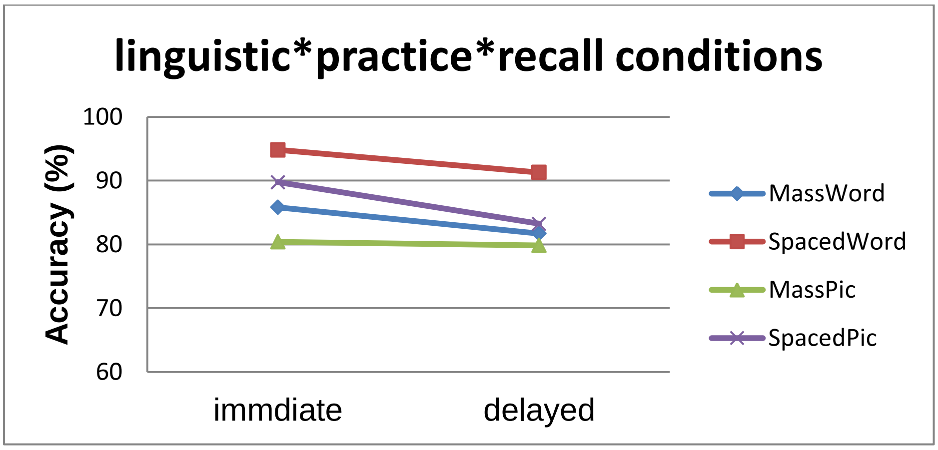

Figure 5.9. Mean accuracy in percentage – cued-recalls influenced by the interaction of linguistic, practice, & recall condition.

None of the within-subject factors (linguistic, practice, and recall conditions) interacted with the between-subject factor, group. Interaction between linguistic condition and group (p=0.452) was not significant; all three groups of participants recalled more word-pairs than picture-pairs. Also, neither interaction between practice condition and group (p=0.635) nor between recall condition and group (p=0.085) was significant. This suggested that all three groups benefited from the spacing effect and recalled more pairs in the immediate cued-recall task than the delayed cued-recall task. These patterns can be observed in Figure 5.10 and Figure 5.11, which illustrate the performance of groups of participants on each experimental condition in immediate and delayed cued-recall task respectively. Furthermore, no interaction was identified between linguistic condition and the other two within-subject factors, recall (p=0.842) and practice (p=0.135) condition.

A three-way interaction was absent in the analyses. That is, recall condition, linguistic condition, and group (p=0.059) did not have a combined effect on the outcomes. The interaction between linguistic condition, practice condition, and group (p=0.392) was also not significant and so was the interaction between recall condition, practice condition, and group (p=0.443). Overall, the four factors manipulated did not interact with each other (p=0.303). The lack of interaction between group and the other factors supported the finding that even though the three groups of participants performed at different levels of accuracy, the patterns of recall in under each condition were similar.

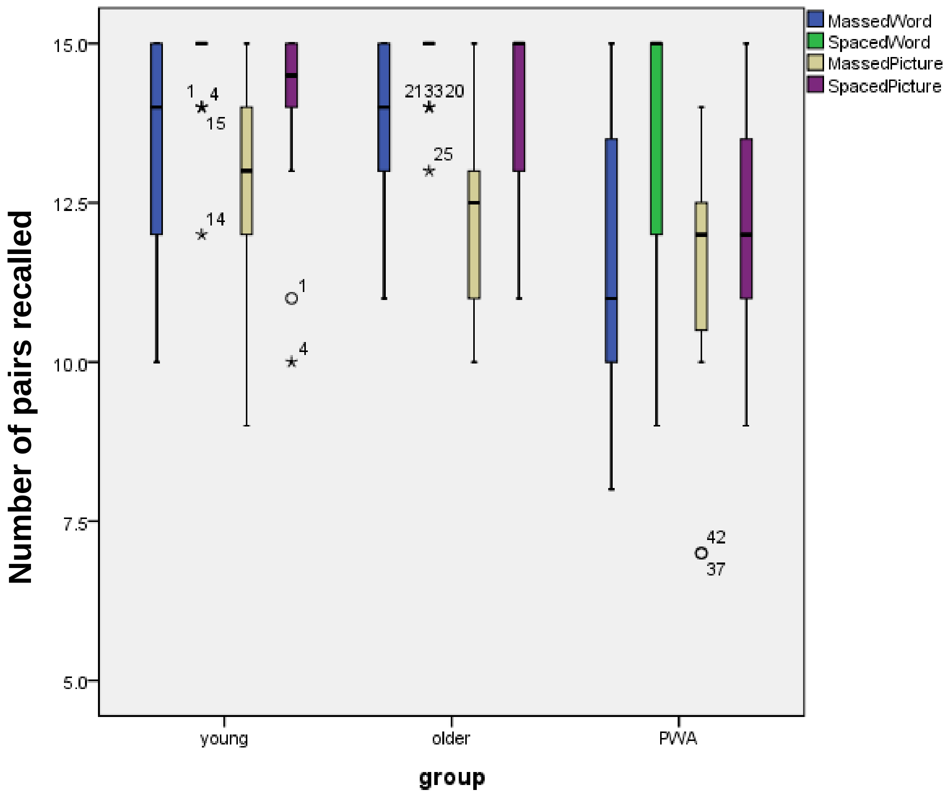

Figure 5.10. Numbers of item recalled in the immediate cued-recall task.

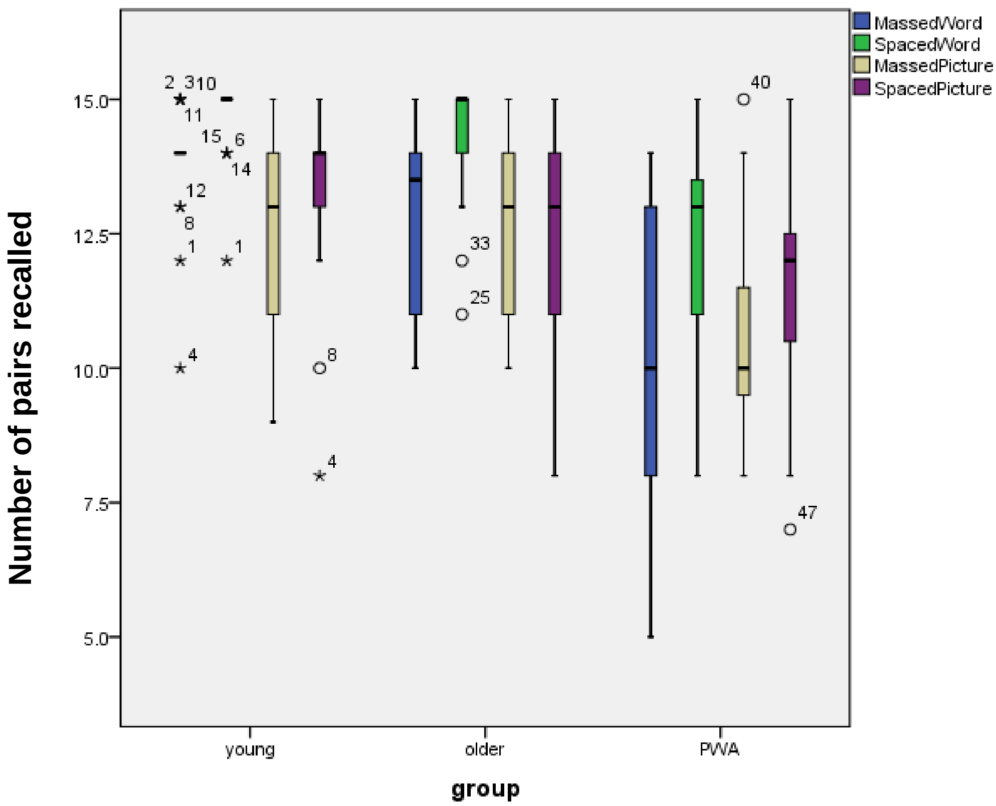

Figure 5.11. Numbers of item recalled in the delayed cued-recall task.

To sum up, the factors manipulated had significant main effects on the outcomes of cued-recall. The spacing effect was observed in all three groups of participants, with the spaced practiced pairs recalled more accurately than massed practiced pairs. Further, the spacing effect remained for two days and, again, was apparent in all groups of participants in the delayed cued-recall task. Also, the manipulation of linguistic condition affected cued-recall, where word pairs proved to be easier for the participants to recall than the picture pairs. As expected, the performance of all participants declined in the delayed cued-recall task compared to the immediate cued-recall task. Interestingly, the between-subject differences observed in the tasks were the reduced outcomes of PWA compared to the two control groups rather than extremely different patterns of performances. The lack of interaction between group and the independent factors also supported that practice condition, linguistic condition, and recall condition were the key factors that influenced recall, and not the group in which a participant belonged.

5.5.3. Delayed recognition task

The cued-recall task is thought to depend on explicit memory; on the other hand, the delayed recognition task only requires partial recollection of the learnt information. Therefore, performance on the delayed recognition task might detect whether implicit learning occurred. This section analyses the results of the delayed recognition task, conducted two days after the completion of the study phase. A point of note for the analyses of data of delayed recognition is that two separate tests of repeated measures ANOVA were conducted due to the nature of questions investigated.

In this section, the issues of interests are: 1) whether presentations as words or pictures (linguistic condition) affected the accuracy of delayed recognition; 2) whether massed and spaced practice (practice condition) resulted in different accuracy in delayed recognition; in other word, how massed and spaced practice might affect implicit memory; 3) whether the three types of stimuli [stimuli condition (target, distractor, & filler)] affected recognition outcomes; and 4) whether the three groups (young, older, & PWA) of participants performed differently on the task. The performance of the groups on the tasks of delayed recognition of words and pictures are summarised in Figure 5.12 and Figure 5.13 respective.

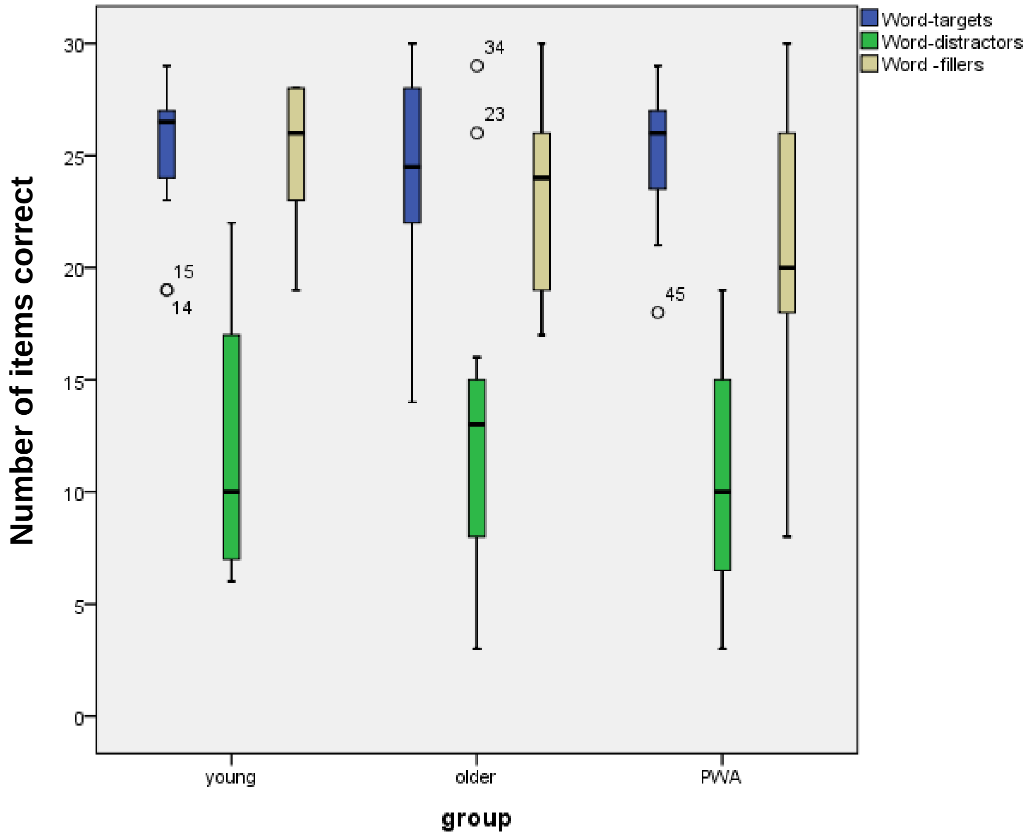

Figure 5.12. Number of words correctly recognised by the participants.

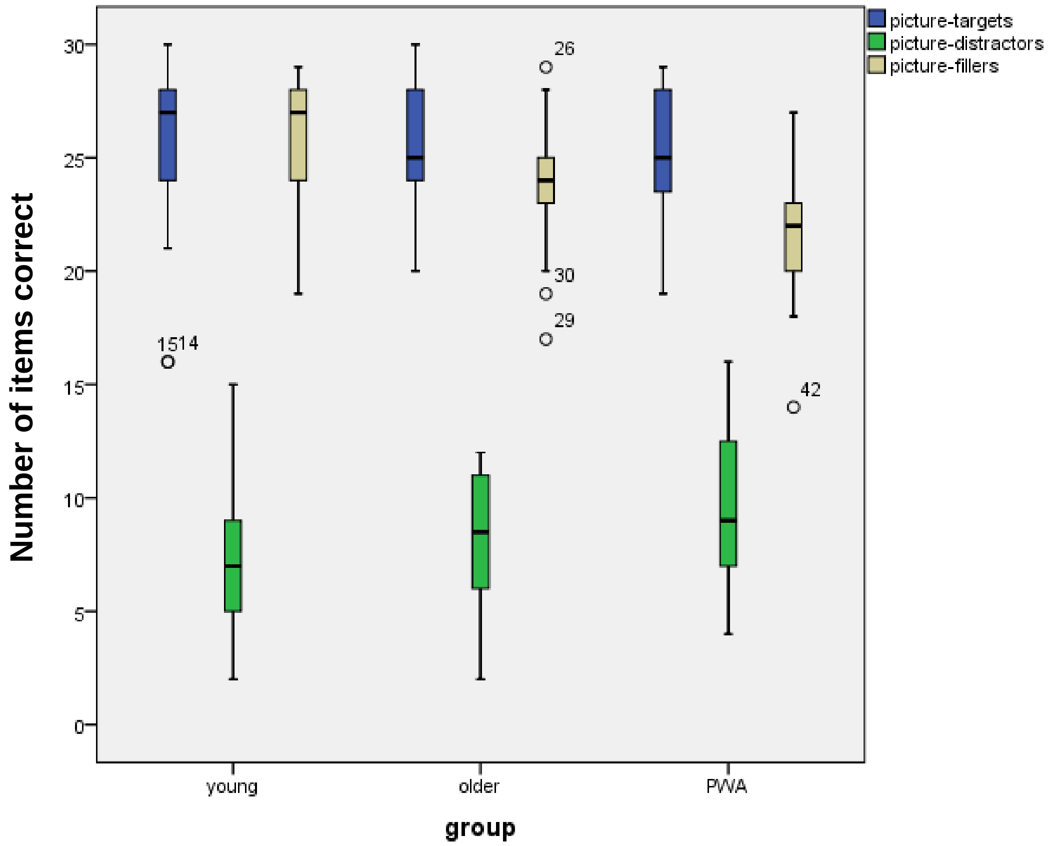

Figure 5.13. Number of pictures correctly recognised by the participants.

Firstly, a mixed repeated measure ANOVA was used to examine the potential effect of three factors, including two within-subject factors, linguistic and stimuli conditions, and the between-subject factor, group. An overview of the descriptive data of the numbers of items (out of 30 in each level of stimuli condition) successfully recognised under each experimental condition is given in Table 5.8 with standard deviations in parentheses. The results indicated that stimuli condition significantly affected delayed recognition ($F_{(2, 88)=}$242.64, p<0.001; η_p^2=0.846). It was revealed in the pairwise comparisons that repeated presentation of an item, target, in the study phase led to better delayed recognition than both distractors (p<0.001) and fillers (p=0.028). Also, more fillers were judged successfully as 'new' items than distractors judged as 'seen' items (p<0.001). On the other hand, a significant main effect of linguistic condition ($F_{(1, 44)=}$3.983; p=0.052; η_p^2=0.083) was missing and so was a between-subject effect (p=0.126); that is, participants' overall performance on word and picture recognition was at the same level and three groups of participants performed similarly on the task. The marginal significant effect of linguistic condition was further explored with paired-sample *t*-tests, in which the mean accuracy of the target words was directly compared the mean accuracy of target pictures and the same applied to distractors and fillers. The results showed that the significance lay between the accuracy of delayed recognition of words and pictures used as distractors ($t_{(46)}$=4.394, p<0.001) but not between the target (p=0.400) and filler (p=0.378) words and pictures.

Table 5.8. Numbers of items correct – linguistic*stimuli*group.

	words			**pictures**		
	target	*distractor*	*filler*	*target*	*distractor*	*filler*
young	25.50 (2.87)	12.00 (5.52)	25.17 (3.01)	25.28 (4.25)	7.06 (3.19)	25.89 (2.65)
older	24.00 (4.35)	12.89 (6.6)	23.06 (3.86)	25.50 (2.94)	8.00 (3.16)	23.89 (3.05)
PWA	25.09 (3.36)	10.76 (5.53)	21.36 (6.41)	25.00 (3.07)	10.00 (3.92)	21.36 (3.41)
mean	24.83 (3.60)	12.04 (5.89)	24.46 (4.48)	25.30 (3.46)	8.11 (3.48)	24.06 (3.41)

Note – Mean number of items correct would not exceed 30 in each experimental condition. Standard deviations are shown in brackets.

There was a significant two-way interaction between linguistic conditions and stimuli type ($F_{(2,88)}$=10.035, p<0.001; η_p^2=0.186) despite the fact that linguistic condition had no main effect on recognition. This suggests that the effect of linguistic condition differed depending on the stimuli condition an item belonged to. Figure 5.14 presents the percentages of words and pictures correctly recognised in each stimuli condition, target, distractor, and filler. Neither linguistic ($F_{(2,44)}$=0.610; p=0.548; η_p^2=0.027) nor stimuli ($F_{(2,88)}$=2.065; p=0.092; η_p^2=0.086) condition interacted with the between-subject factor, group. Moreover, the three factors did not interact with each other to affect participants' delayed recognition.

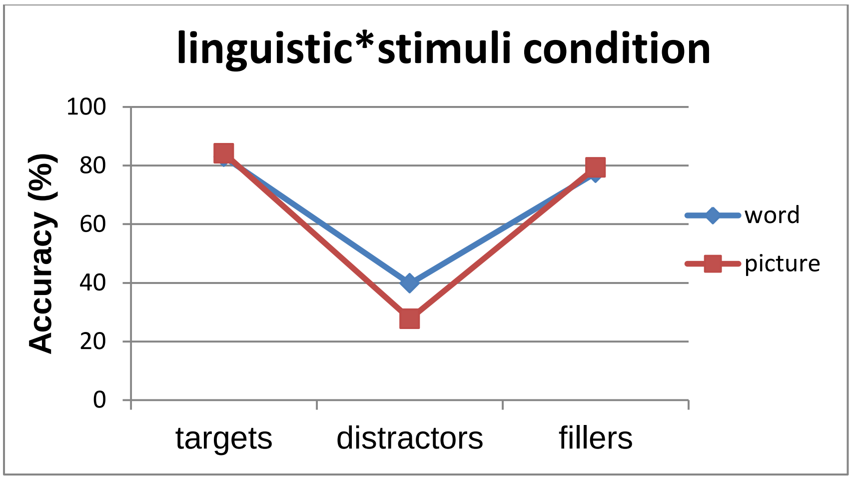

Figure 5.14. Percentage of word/picture recognised in each stimuli condition

Secondly, the effect of massed and spaced practice on recognition was explored. The analyses contained three factors, linguistic condition (word vs. picture), practice condition (massed vs. spaced), and group. However, only the target items in the delayed recognition task had been massed or spaced practiced; therefore, only 15 items were included in each practice condition. Table 5.9 summarises the outcomes of performances of each group under different experimental conditions. The effect of massed and spaced learning of word- and picture-pairs on delayed recognition was plotted in Figure 5.15.

Table 5.9. Numbers of items correct – linguistic*practice*group.

	Word		**Picture**	
	massed	*spaced*	*massed*	*spaced*
young	11.72 (1.84)	13.78 (1.44)	11.72 (2.95)	13.5 (1.54)
older	11.11 (2.89)	12.89 (2.17)	12.44 (1.95)	12.94 (1.39)
PWA	11.91 (2.30)	13.18 (2.23)	12.55 (1.57)	12.45 (1.69)

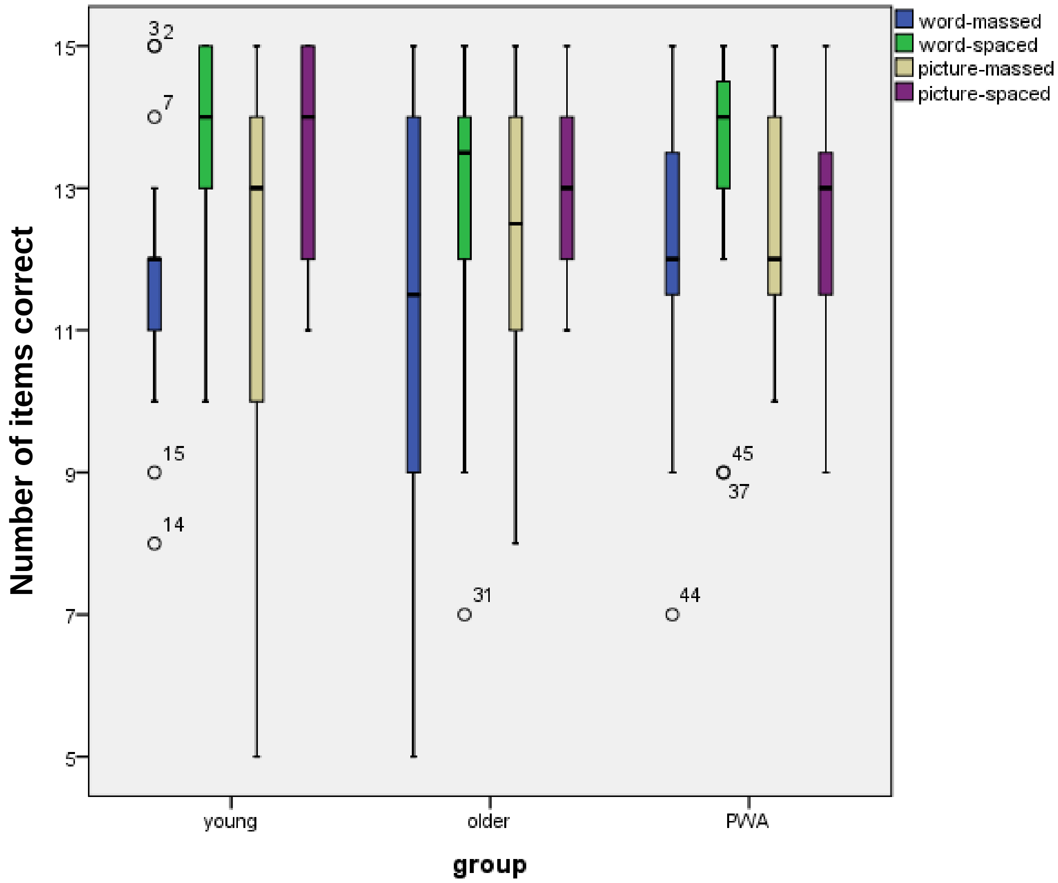

Figure 5.15. Outcomes of delayed recognition of words and pictures.

A mixed repeated measure ANOVA with linguistic and practice conditions as within-subject factors and group as a between-subject factor was applied. Practice condition was found to lead to significantly different results in the recognition task ($F_{(1, 44)}$=30.030, p<0.001; η_p^2=0.406). As shown in Figure 5.15, regardless of linguistic condition and group, spaced practice items resulted in better recognition compared to massed practice. The main effects of linguistic condition ($F_{(1,44)}$=0.357; *p*=0.553; η_p^2=0.008) and group ($F_{(2,44)}$=0.217; *p*=0.806; η_p^2=0.010) were both insignificant.

There was a significant interaction between the linguistic and practice condition ($F_{(1, 44)}$=4.939, *p*=0.031; η_p^2=0.101), indicating that the recognition outcomes were related to the ways of practicing words and pictures in the study phase. The outcomes of the interaction between the two factors are illustrated in Figure 5.16. Both spaced and massed-practiced word and pictures had higher percentages of accuracy in delayed recognition; yet, massed-practiced pictures were recognised better than massed-practiced words. However, in the spaced practice condition, the patterns were reversed. On the other hand, group interacted neither with linguistic condition ($F_{(2, 44)}$=0.988, *p*=0.380; η_p^2=0.043) nor practice condition ($F_{(2, 44)}$=2.929, *p*=0.064; η_p^2=0.117), suggesting that both factors had no effect on the group performances. Also, the three independent factors ($F_{(2, 44)}$=0.696, *p*=0.504; η_p^2=0.031) did not show a significant interaction. It is arguable that, in the current case, only practice condition (massed vs. spaced) had a strong influence on delayed recognition and the effect of presentations of words or picture was determined by how the stimulus was practiced and the patterns were similar across groups. Therefore, when the three factors were considered together, effect(s) on the performance was diminished.

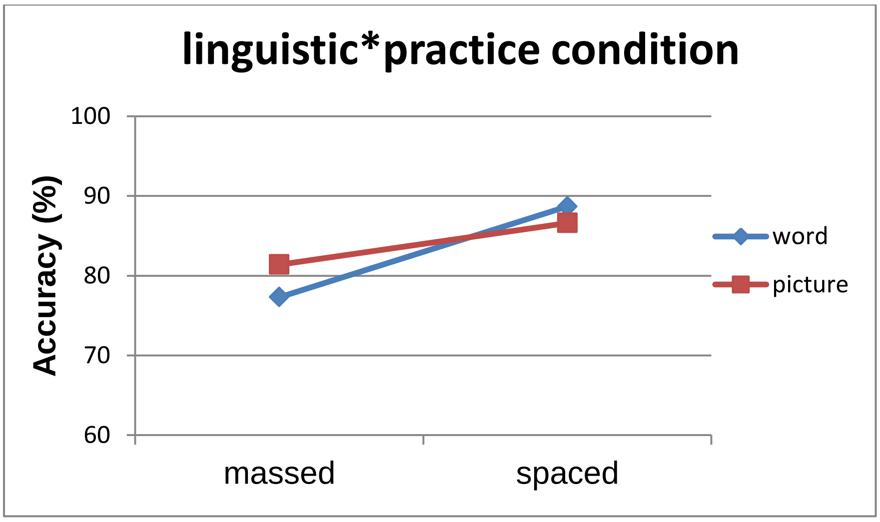

Figure 5.16. Percentage of word/picture recognised in each practice condition.

Based on the findings of the delayed recognition task, it was speculated that implicit learning had occurred in learning of both word-pairs and picture-pairs, since the participants were able to successfully recognise the target items. Also, the spacing effect was found to benefit delayed recognition. Moreover, a main effect of linguistic condition was absent, indicating that the possible implicit learning for both pictures and words was to the same degree. What is more, targets were significantly better recognised than distractors, showing that repeated presentations along with opportunities for retrieval practices enhanced memory of an item and resulted in better recognition. The participants were able to distinguish targets from filler items that were not presented before which suggests that repetition reinforced memory and the memory trace for distractors was much weaker. The group results of this task as a whole suggested that there was no significant difference between the participant groups. Although young participants slightly outperformed the other two groups of participants, PWA did no worse than their age-matched controls.

5.5.4. Reaction time data

Data of reaction time provided an opportunity to have a more in depth investigation on whether implicit memory traces were formed during learning and the impact on delayed recognition. One way of exploring implicit memory trace is to observe the change in reaction time; as implicit memory is enhanced, reaction time reduces. The analyses in this section only involved the reaction time of the target items in the delayed recognition task, since only the target items were either massed or spaced practiced during study. The questions of interest were 1) whether linguistic condition (word/picture) had impact on reaction time in the delayed recognition task; 2) whether practice condition (massed/spaced) resulted in significantly different reaction time; and 3) whether the three groups showed a uniform pattern on reaction time. The effect of massed and spaced learning of word- and picture-pairs on delayed recognition was plotted in Figure 5.17.

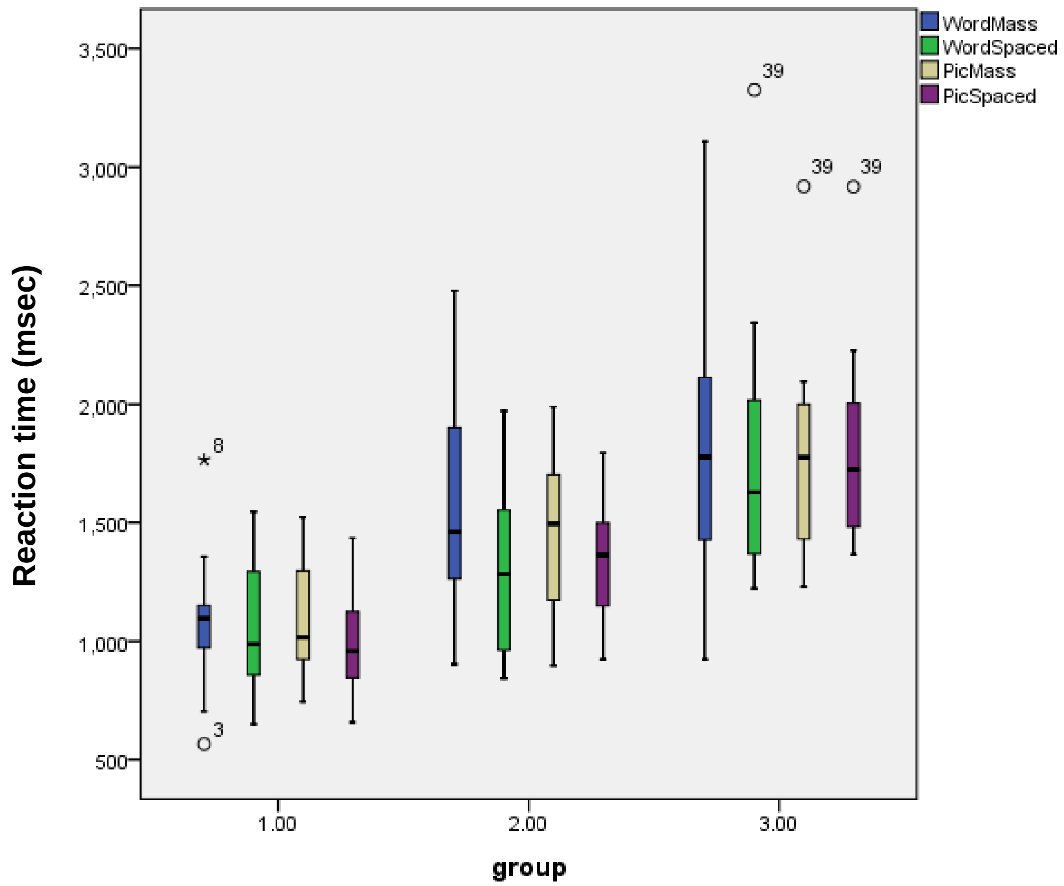

Figure 5.17. The effect of massed and spaced learning on the reaction time of words and pictures of the three groups in delayed recognition task.

The mixed repeated measure ANOVA involved two within-subject factors, linguistic condition and practice condition, as well as group as the between-subject factor. Reaction time was recorded in milliseconds. Table 5.10 presents the average reaction time of the three groups of participants of each condition in the delayed recognition task with standard deviations in parentheses. A significant main effect was observed in practice condition ($F_{(1, 44)}$=8.637, p=0.005; η_p^2=0.164), where spaced-practice items (1387.6 msec) yielded significantly shorter reaction times than massed-practice items (1462.6 msec). Group condition ($F_{(2, 44)}$=18.547, p<0.001; η_p^2=0.457) also showed a significant main effect on performance. The level of significance lay between all levels of group conditions; that is, young participants (*M*=1055.59 msec) had significantly shorter reaction times in delayed recognition than older participants (*M*=1406.74 msec) and also PWA (*M*=1812.97 msec). Also, PWA performed significantly worse than their age-matched control group. In contrast, linguistic condition did not have a main effect on reaction time.

Table 5.10. Reaction time, in milliseconds, generated by the participants under each experimental condition.

	Word		Picture	
	massed	*spaced*	*massed*	*spaced*
Young	1086 (263)	1045 (286)	1086 (231)	1004 (208)
Old	1539 (424)	1277 (335)	1448 (338)	1362 (277)
PWA	1817 (539)	1810 (619)	1789 (475)	1825 (454)
mean	1430 (505)	1313 (493)	1391 (434)	1333 (435)

A significant two-way interaction was found between practice and group conditions ($F_{(2, 44)}$=4.361, *p*=0.019; η_p^2=0.165), suggesting massed and spaced practice influenced the three groups of participants in different ways. Figure 5.18 demonstrates the patterns of reaction time of massed and spaced practiced items generated by the participants. Overall, PWA took longer to respond to the items compared to the control groups. Also, PWA, intriguingly, showed the opposite pattern to the control groups in the recognition task. The reaction time of both young and older controls was shorter when an item was spaced-practiced in the study phase, compared to when an item was massed-practiced. However, massed-practiced items seemed to reduce reaction time of PWA, though, from current analyses, it is not known whether the reduction was to a significant level. This issue is further investigated in the later section, *5.5.5*, where the data of PWA is analysed independently from the control groups. The other two-way interactions, linguistic condition and group (*p*=0.977) and linguistic and practice conditions (*p*=0.145), were not significant. That is, the three groups of participants did not perform differently on recognition of words and pictures; moreover, the method of practicing a word or picture during study did not affect the reaction time of that particular word/picture.

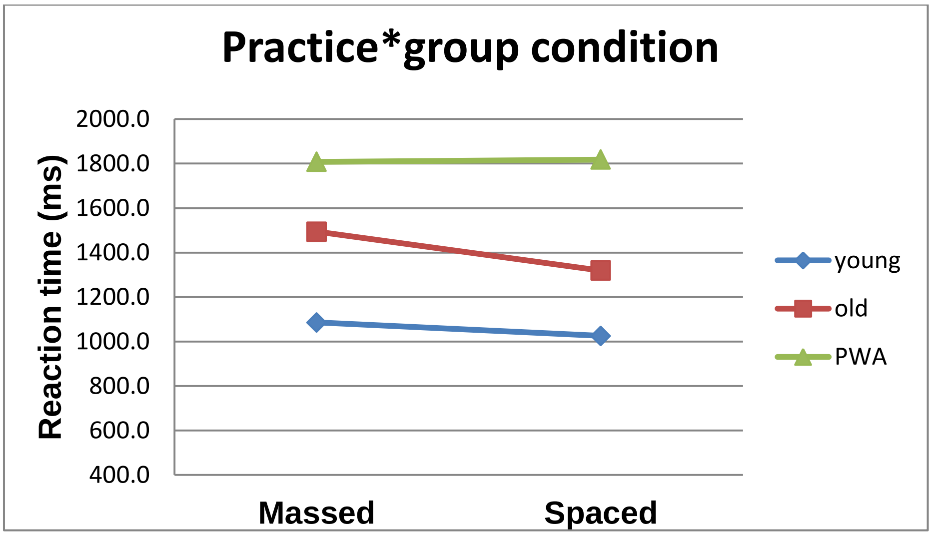

Figure 5.18. Reaction time of massed and spaced practiced items of the groups.

There was a significant three-way interaction between linguistic, practice, and group conditions ($F_{(2, 44)}$=3.32, p=0.045; η_p^2=0.131) indicating that the outcomes of reaction time were potentially affected by the levels within all three factors. The overall reaction time data generated by the participants under each experimental condition is presented in Figure 5.19. It is evident that, unlike the control groups, the reaction times generated by PWA were similar under each experimental condition.

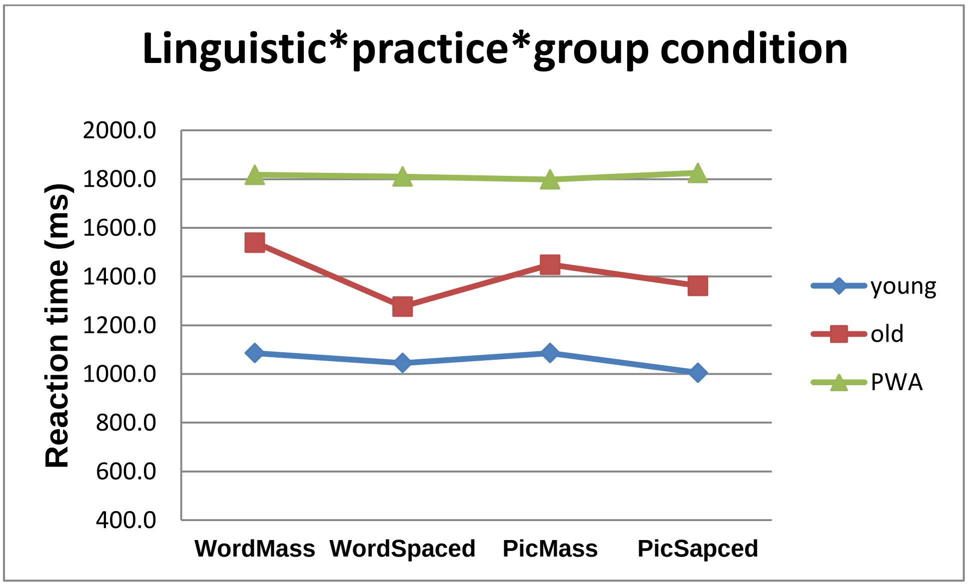

Figure 5.19. Reaction time of each experimental condition.

In general, the spacing effect was found in the delayed recognition task. Spaced practiced items yielded shorter reaction time than massed-practiced items, with the reduced reaction time indicating a positive impact on implicit memory. Also, unsurprisingly, the young participants had the shortest reaction times among the groups across all experimental conditions and PWA showed overall longer reaction times, which was even more delayed than their age-matched control group. Nevertheless, there was no difference in reaction time in recognition of words and of pictures. Moreover, the lack of interaction between linguistic condition and two other factors suggested, again, that linguistic condition was not the influential factor in this case. However, when all three factors were considered together, it was found that the three groups of participants performed differently in word and picture recognition as well as in massed and spaced practice items.

5.5.5. Performance of PWA on the tasks

The analyses in the previous sections were derived from data generated by all three groups of participants. These analyses showed that PWA had a distinct pattern of performance compared to the two control groups. The only task where PWA's performance was close to the controls' was the delayed recognition task, in which no between-subject effect was found, although the outcomes between PWA and young controls were still very different. In the other two tasks, the young participants and the age-matched participants generated similar outcomes; however, PWA had relatively worse performances on these tasks. Therefore, we further investigated whether the effects reported from the group data also appeared in the group of PWA. To do this, the data generated by PWA was extracted and analysed independently to look at the potential effects of linguistic, practice, and group conditions in the study phase, immediate and delayed cued-recall tasks, and the delayed recognition task.

First of all, the performance of PWA in the study phase was investigated in an attempt to determine: 1) whether PWA had different learning patterns of word-pair and picture-pair learning; 2) whether PWA also benefit more from massed rather than spaced cued-retrieval practice during study; and 3) whether repeated retrieval practice improved accuracy of cued-retrieval. A repeated measure ANOVA with linguistic (word/picture-pair), practice (massed/spaced), and retrieval (retrieval1, retrieval2, & retrieval3) conditions as within-subject factors was applied. The descriptive data of the performance of PWA under each experimental condition is presented in Table 5.6 in 5.5.1. The results of the analyses were consistent with the group result. A significant main effect was only observed in the levels of retrieval condition ($F_{(2, 20)}$ =48.364, p<0.001; η_p^2=0.631). Accuracy increased significantly after each cued-retrieval practice of a pair. The other two factors, linguistic condition (p=0.428) and practice condition (p=0.136), did not have any significant main effect. The boxplot, shown in Figure 5.20, reveals the improvement on accuracy of retrieval as the number of cued-retrieval practice increases. No two-way interaction was observed.

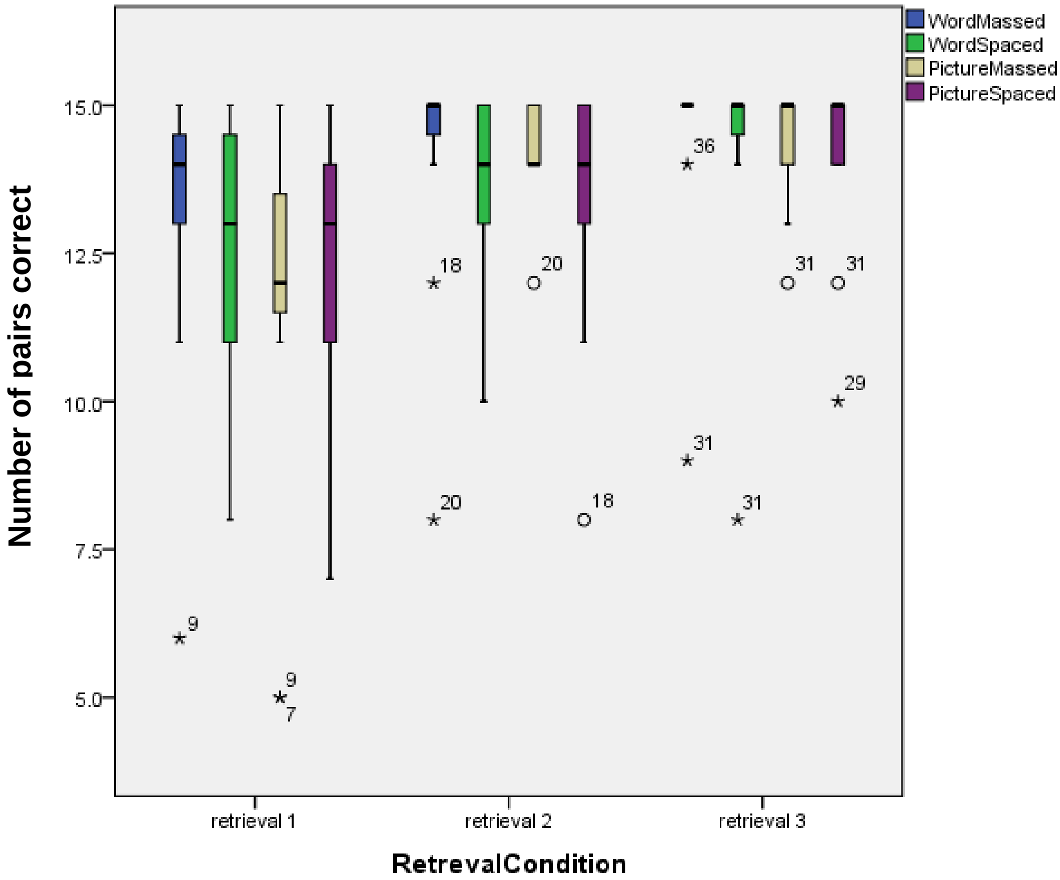

Figure 5.20. Number of word/picture-pairs successfully retrieved in the three cued-retrieval practices by PWA in the study phase.

However, linguistic, practice, and retrieval conditions had a significant three-way interaction ($F_{(2, 20)}$ =3.652, p=0.044; η_p^2=0.268), suggesting that the three levels of retrieval condition had effects on linguistic and practice conditions and, therefore, the performance changed accordingly. The significant three-way interaction is presented in Figure 5.21, showing the average percentage of accuracy of each cued-retrieval practice under each experimental condition. Despite linguistic condition showing no main effect on the performance of cued-retrieval practice, picture-pairs had a lower rate of retrieval accuracy after the pairs had been presented once compared to word-pairs. Also, massed practice boosted the performances in the second retrieval practice trial, although the first cued-retrieval did not necessarily benefit from the immediate follow-up retrieval practice after a pair had been introduced.

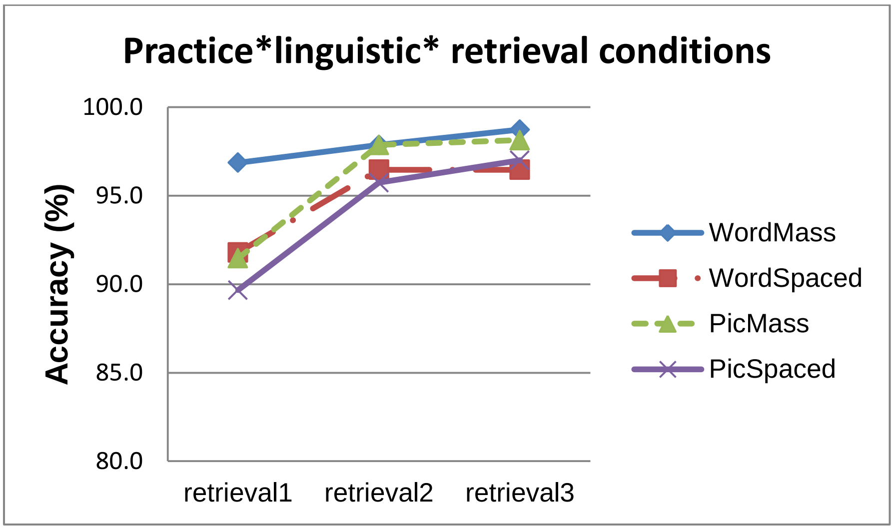

Figure 5.21. Accuracy of cued-retrieval generated by PWA in all experimental conditions.

Secondly, the potential effects that linguistic, practice, and recall (immediate/delayed) conditions had on the performances on the two cued-recall tasks was investigated. As reported in 5.5.2, PWA were the only group of participants to have an outstanding difference among the three groups. Therefore, analysing the individual data generated by PWA may help to inform: 1) whether linguistic condition affected their outcomes of cue-recall; 2) whether massed and spaced practiced pairs were recalled differently; and 3) whether the memory trace for the newly learnt pairs reduced significantly in the delayed cued-recall task compared to immediate cued-recall. The group performance of PWA is summarised descriptively in Table 5.7 in 5.2.2. A repeated measure ANONA with recall condition (immediate/delayed), linguistic condition (linguistic/non-linguistic), and practice condition (massed/spaced) as within-subject factors was applied.

Consistent with the main effects reported in the group data, recall condition significantly ($F_{(1, 10)}$ =5.454, p=0.042; η_p^2=0.353) influenced the performance of PWA on the cued-recall tasks, with averagely 12.07 pairs being recalled successfully in the immediate cued-recall task and 11.14 pairs recalled in the delayed cued-recall task. Also, practice condition significantly influenced ($F_{(1, 10)}$ =13.492, p=0.004; η_p^2=0.574) outcomes of cued-recall, where spaced practice (M=12.30) was more efficient to PWA than massed practice (M=10.91). Linguistic condition (p=0.587), yet, had no significant effect on the performance of PWA, the number of word-pairs (M=11.77) recalled was at similar to the number of picture-pairs recalled (M=11.43). Figure 5.22 demonstrates the accuracy of cued-recll under the effects of practice, linguistic, and recall condition. Furthermore, no interaction between the three factors was found.

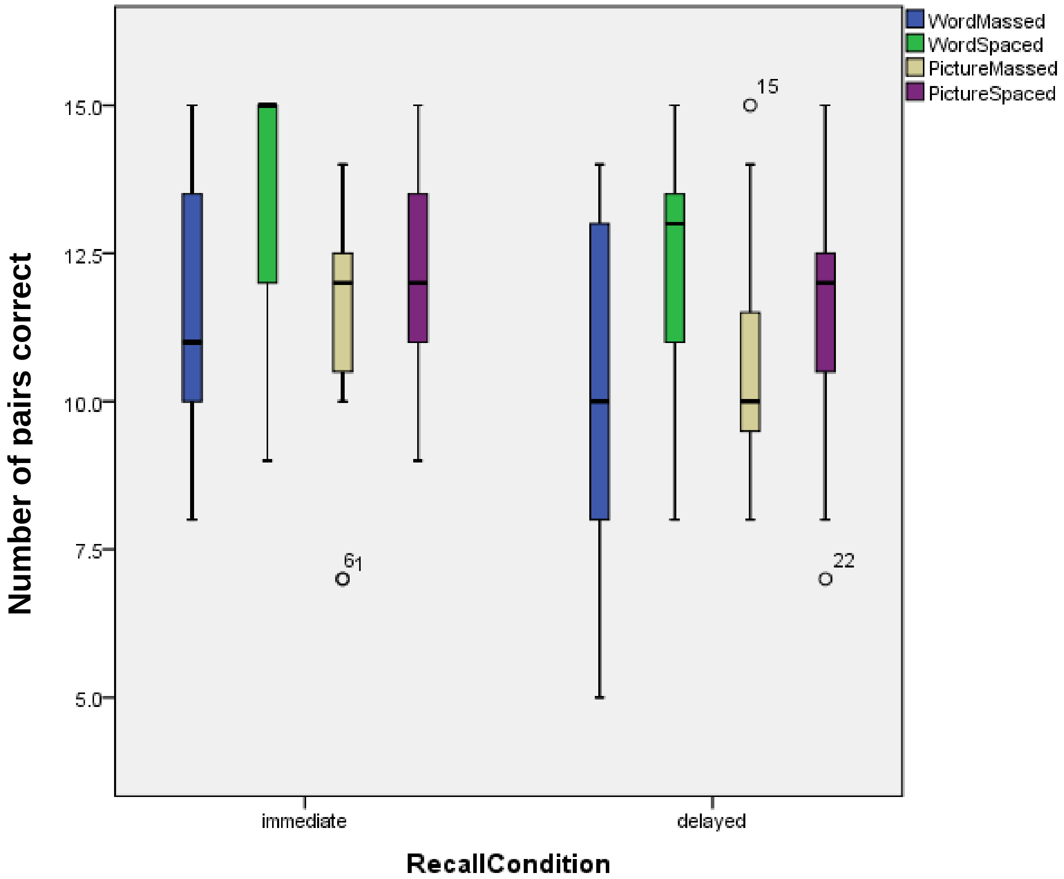

Figure 5.22. Number of pairs successfully recalled by the PWA in the immediate and delayed cued-recall tasks.

Finally, the performance of PWA on the delayed recognition task was investigated. This attempted to explore how linguistic (word/picture) and stimuli (targets, distractors, fillers) conditions affected the PWAs' performance. For instance: 1) whether words and pictures were recognised equally well as shown in the previous analyses of group data; 2) whether PWA also had better recognition of target items and filler items than of distractors; and 3), whether spaced practiced items were recognised better than spaced practiced items. Summaries of the descriptive data of the performances of PWA on the delayed recognition task were presented in Table 5.8 and Table 5.9. One repeated measure ANOVA included linguistic condition, stimuli type, and practice condition as the independent factors was performed. The findings suggested again, that stimuli condition ($F_{(2, 20)}$ =31.432, p<0.001; η_p^2=0.759) significantly influenced the outcomes of recognition whereas the linguistic condition did not (p=0.661), meaning that PWA performed equally on word and picture recognition but differently across three levels of stimuli condition. However, the levels of significance were found between the items that the participants had only seen once and the other two types of stimuli, target (p<0.001) and filler (p=0.001). Figure 5.23 outlines the performance of the PWA under the experimental conditions in the delayed recognition task. Furthermore, no interaction was reported between linguistic and stimuli conditions (p=0.921).

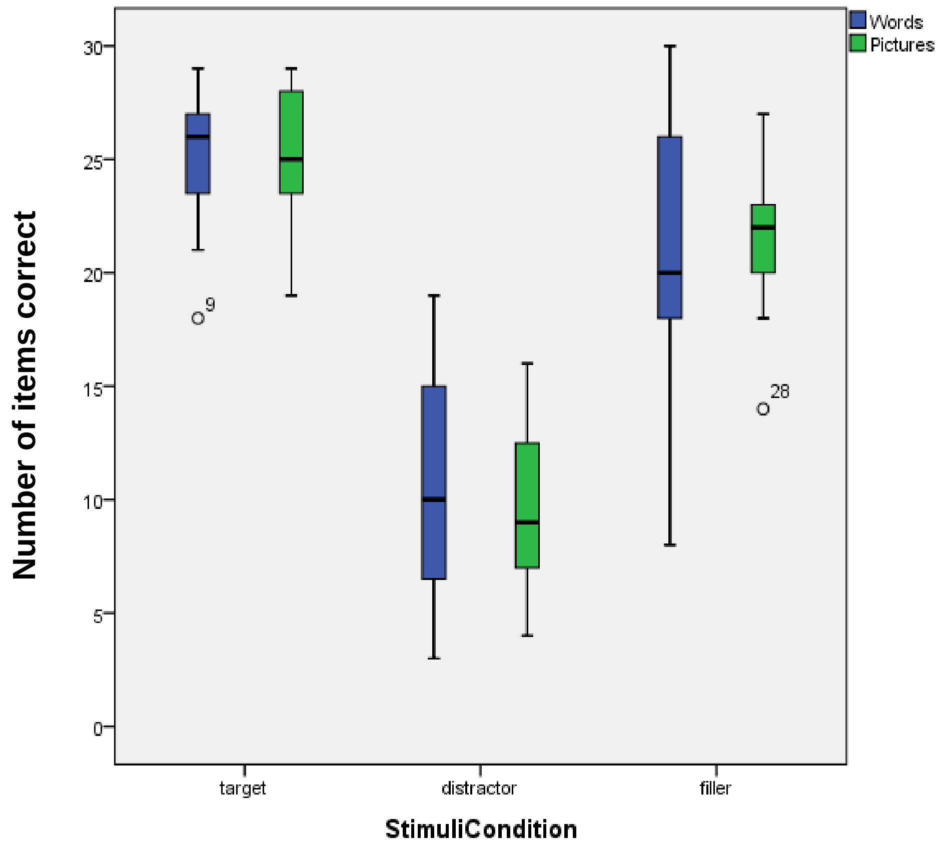

Figure 5.23. Number of items correctly recognised by PWA under the influence of linguistic and stimuli condition in the delayed recognition task.

The other repeated measure ANOVA examined the potential impact of linguistic condition (word/picture) and practice condition (massed/spaced) on the outcomes of recognition. Neither linguistic condition (p=0.898) nor practice condition (p=0.190) had an impact on the performance of PWA. That is, rates of the accuracy of recognition of words and of the accuracy of pictures were within the same range. What is more, the standard deviations reveal that the individual difference among the performance of PWA on word recognition was more evident than the recognition of pictures. On the other hand, the data generated by PWA indicate that, unlike the controls, PWA did not benefit from spaced practice in delayed recognition. The performance of PWA was shown in Figure 5.24. No interaction was found between the two factors (p=0.242). This suggests that the outcome of word recognition would not change because of the way a word had been practiced in the study phase, with the same case applying to that of picture recognition.

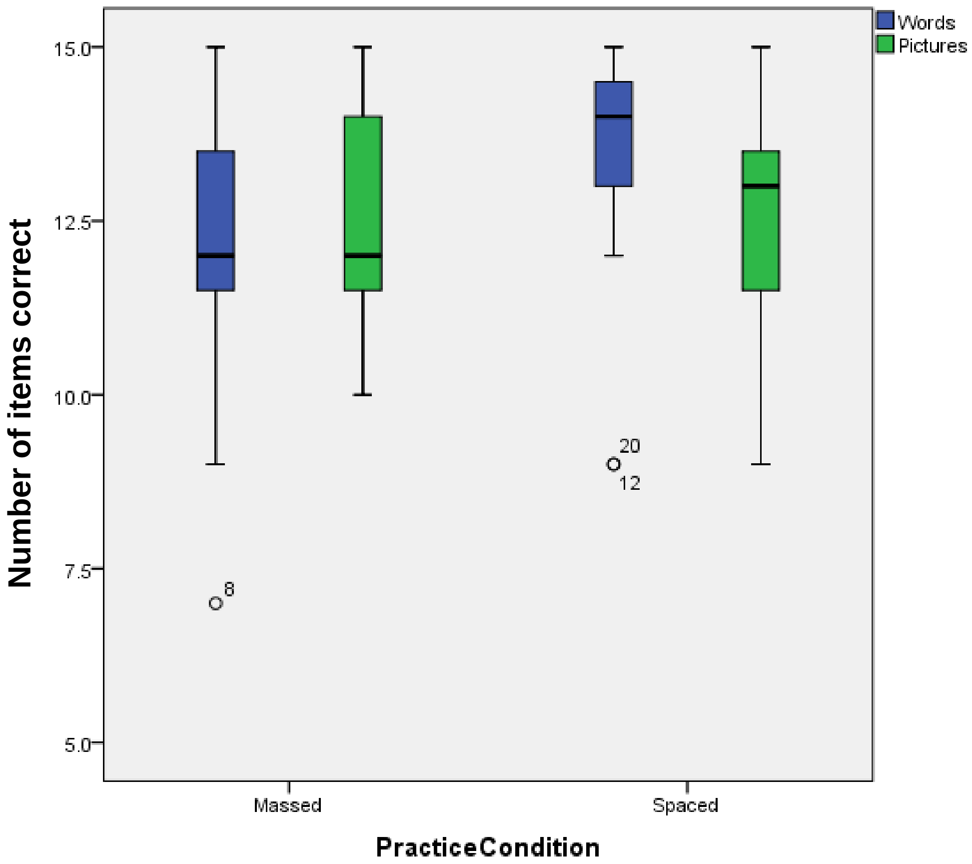

Figure 5.24. Number of items correctly recognised by PWA under the influence of practice and linguistic condition in the delayed recognition task.

Further, reaction time data were analysed in order to provide more evidence on whether an implicit memory trace was formed in PWA. The analyses in 5.5.4 have shown that PWA not only had overall reduced reaction times but also almost a reverse pattern of reaction time of each experimental condition in contrast to the control groups. Moreover, the mean reaction times and standard deviations presented in Table 5.10 reveal that the individual difference among the group of PWA was wider than the controls. Therefore, an independent analysis of reaction time data of PWA was conducted to explore: 1) whether the linguistic condition affected their reaction time; and 2) whether the spacing effect observed in the group data could also be found in PWA.

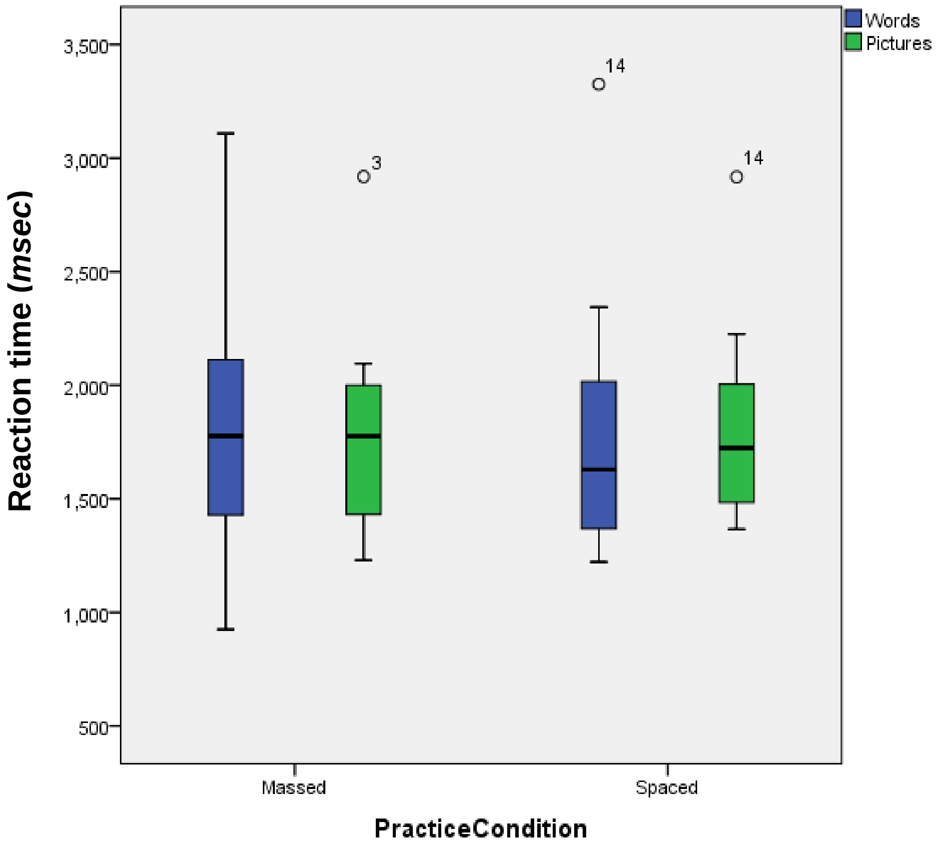

Figure 5.25. Reaction time of the practice condition generated by PWA.

A repeated measure ANOVA with linguistic (words/pictures) and practice (massed/spaced) conditions as within-subject factors failed to produce a significant main effect with either factor. The reaction time, data plotted in Figure 5.25, of PWA did not vary in word and picture recognition (p=0.984) and what is more, the average reaction time of massed and spaced practiced items (p=0.858) were also similar. No interaction was observed between the two factors (p=0.661), indicating that the reaction time generated by PWA did not change significantly as a result of how a word/picture was practiced during study.

In short, looking at the individual data of PWA as a group, the overall patterns of performance were consistent with the findings reported from the group data except for the case of reaction time during delayed recognition. The spacing effect was evident in cued-recall of word-pairs as well as of picture-pairs, indicating the effect was cross domain and was maintained for at least 48 hours. Nonetheless, linguistic condition was absent in the cued-recall tasks. That is, PWA as a group did not recall more word-pairs that picture-pairs. Their language impairment(s) might account for the findings. The two control groups benefited from their intact language function, which is crucial for rehearsing newly-learnt pairs. People with aphasia, by contrast, have no advantage maintaining word-pairs over picture-pairs due to their impaired linguistic knowledge. In addition, another finding that stood out from the analyses was that the spacing effect found on delayed recognition and the reaction time during the task in the group data did not appear among PWA. Therefore, we can only assert that the spacing effect did not benefit PWA in delayed recognition. Also, the similar reaction times across all experimental conditions make it difficult to determine whether an implicit memory trace for the newly learnt information was formed.

5.5.6. Summary of the findings

The current chapter set out to investigate whether spacing affects pair-association learning of word-pairs and picture-pairs and more importantly, whether the spacing effect has the same impact on healthy participants and PWA. It was hypothesised that: 1) massed practice would facilitate immediate cued-recall and spaced practice would benefit retention; 2) a spacing effect would be observed in current learning task; and 3) a spacing effect would not be restricted to tasks tapping explicit memory. Accordingly, the initial predictions were: 1) accuracy of massed-practiced pairs should be higher than the spaced-practiced pairs in the study phase; 2) spaced practice would lead to better cued-recall; and 3) spaced-practiced stimuli should be better recognised than the massed-practiced stimuli and the RT of spaced-practiced stimuli would be relatively shorter. The results reported here supported these predictions. What is more, PWA generated similar outcomes in all tasks despite their overall reduced performance. The findings of main effects in the tasks are summarised in Table 5.11.

Table 5.11. Overview of results of analysis of the current chapter.

Condition	Study Phase	Cued-recall Task	Delayed Recognition
Linguistic	✗	✓	✗
Practice	✓	✓	✓
Recall	N/A	✓	N/A
Retrieval	✓	N/A	N/A
Stimuli	✓	N/A	✓
Group	✓	✓	✓

I. Study phase

During the study phase, regardless of the linguistic condition (word-pairs/picture-pairs), the performance of the participants favoured massed pairs over spaced pairs, where the accuracy of cued-retrieval practice improved faster when the practice was massed rather than spaced. Also, accuracy improved significantly with more learning trials. However, the number of pairs matched correctly by PWA after each cued-retrieval practice was lower not only than young participants but also their age-matched controls, suggesting PWA learnt less efficiently during the study phase. Further, within the groups, all participants learnt word pairs and picture pairs equally well. Linguistic condition only affected performance when retrieval condition and/or practice condition was taken into account. More word pairs were successfully matched than picture pairs in the first cued-retrieval practice; massed word pairs and picture pairs yielded higher accuracy compared to spaced word pairs and picture pairs across all three cued-retrieval practice trials.

II. Immediate and delayed cued-recall

The two cued-recall tasks support the spacing hypothesis that spacing facilitates recall outcomes. Further, recollection is sensitive to all the factors involved, including, linguistic, practice, recall, and group condition. More word pairs are recalled correctly than picture pairs in the cued-recall tasks possibly because of the semantic relation between the two words reinforcing memory.

Also, spaced-practiced pairs were recalled better than massed-practiced pairs. The number of pairs recalled correctly dropped significantly in the delayed cued-recall, which took place two days after completing the study phase. In addition, although the performance of PWA was reduced relative to the two control groups, the patterns generated by the three groups were identical in terms of how performance was affected by each factor. Linguistic, practice, and recall condition showed interactions. Participants recalled spaced-practiced word-pairs the best, followed by spaced-practiced picture-pairs, then massed-practiced word-pairs, with massed-practiced picture-pairs having the lowest accuracy in immediate as well as delayed cued-recalled tasks. However, the effect of linguistic condition was restricted to the two control groups, PWA performed at similar level on the cued-recall of word- and picture-pairs.

III. Delayed recognition

The delayed recognition task was the only task where the PWA showed a slightly different pattern of learning in relation to the control groups. Stimuli condition affected results of delayed recognition, participants were able to distinguish items appearing in the study phase from the fillers but did worse with the distractors. This indicates that repeated presentation of an item also benefitted delayed recognition. Moreover, spaced-practiced items had higher accuracy of recognition regardless of their linguistic condition. All three groups performed similarly in terms of the accuracy. Nevertheless, the reaction time data revealed difference between PWA and the two control groups. The spacing effect was observed in the recognition task, with spaced-practiced items not only better recognised by the participants but also leading to shorter reaction times compared with massed-practiced items. However, the effect of linguistic condition was restricted to the control groups. In addition, although PWA benefitted from spacing in the cued-recall tasks, spacing showed no advantage in delayed recognition.

IV. Summary

Overall, the patterns of performance of PWA were very similar to the control groups in spite of delayed improvement during learning and reduced accuracy in the cued-recall tasks and recognition task. Massing reinforced learning during the study phase and spacing facilitated delayed cued-recall and recognition. These effects are found in healthy participants of two age groups as well as PWA in pair-association learning of both word-pairs and picture-pairs. The spacing effect, in the current study, remained for at least 48 hours post-study. The few differences between control groups and PWA were found in the delayed recognition task, in which the spacing effect was found in controls but not in PWA, revealing no higher accuracy or shorter reaction time toward spaced-practiced items. The delayed recognition is thought to reflect that implicit learning occurred; yet, implicit memory of PWA does not benefit from spacing.

5.6. General Discussion

The findings of the present experiment with a pair-association learning paradigm largely supported the hypothesis and predictions. In general, all three groups of participants showed similar trends in the cued-retrieval practice during the study phase, the two cued-recall tasks, and the delayed recognition task. Massing and spacing effects were observed in all the tasks involved, including the study phase, the immediate/delayed cued-recall tasks, and the delayed recognition task. In line with the prediction(s), in the study phase, massed cued-retrieval practices resulted in more efficient learning during the study phase compared to spaced cued-retrieval practice. The benefit of massing over spacing was evident in word-pair learning as well as picture-pair learning in all three groups of participants in the study phase.

Spaced-practiced pairs were retained better by all participants and had higher accuracy in the delayed cued-recall task in comparison with massed-practiced pairs. Even though the numbers of massed- and spaced-practiced pairs recalled in the delayed cued-recall task were significantly lower than the numbers reported in the immediate cued-recall task, the positive spacing effect remained significant two days post-study. On average, more word-pairs were correctly recalled than picture-pairs by all three groups of participants. Nonetheless, more spaced-practiced picture-pairs were recalled in the two cued-recall tasks than massed-practiced word-pairs, suggesting that, regardless of the linguistic condition of the stimuli used, spaced practice was more efficient for later recollection for healthy controls as well as PWA. In addition, the positive spacing effect on word/picture recognition was observed in the delayed recognition task. Overall, spaced-practiced items yielded higher success rates of recognition and shorter reaction times than massed-practiced items. Furthermore, items that were repeatedly presented during study were better recognised than items that appeared once. People with aphasia showed the same patterns as the two control groups in terms of being able to distinguish the items they had seen during the study phase. Yet, linguistic condition and practice condition had no effect on their recognition, which differed to what was found in the controls.

However, evidence that failed to support some of the original hypotheses was also reported. People with aphasia were expected to perform much worse than the control groups on learning of word-pairs in comparison to learning of picture-pairs. However, despite the presence of language deficits and overall reduced performance, PWA successfully recalled more word-pairs than picture-pairs, which corresponded to the patterns generated by the controls. In the current discussion, results are discussed from two perspectives: 1) how spacing affects pair-associative learning; and 2) whether the spacing effect facilitates explicit memory as well as implicit memory.

5.6.1. Spacing effect and learning

The current experiment fills a gap among the existing literature on massed versus spaced learning within a pair-association paradigm by investigating the robust massing and spacing effect found in participants without brain damage and in people with aphasia. Overall, the patterns of learning generated by PWA were reduced but not to distinct from their age-matched controls and young participants. The difference among PWA and the two control groups lay in the performance on the delayed recognition task, which taps implicit memory. In this section, existing theories for spacing as well as massing hypotheses are discussed from the perspective(s) of what might account for the similarities and differences between PWA and the other two groups of participants.

Spacing over massing on long-term retention has been tackled by different accounts of memory and processing. The majority of these accounts argue that massed retrieval practice results in insufficient processing or encoding of a newly learnt item compared to spaced retrieval practice. Explanation(s) for the massing and spacing effect includes, first of all, which memory system is involved in retrieval. Having cued-retrieval practice immediately after a pair is presented only allows participants to retrieve the newly learnt information from short-term memory instead of (long-term) episodic memory. Information recalled from short-term memory does not always transfer into long-term retention (Craik, 1970; Craik & Watkins, 1973; Watkins, 1977); consequently, massed practice only benefits immediate retrieval but not the spaced one.

Secondly, deficit processing theory suggests that the amount of focus an information received changes based on learners' familiarity of the particular information. Therefore, when information is repeated in massed fashion, learners allocate less attention or time for rehearsal due to the immediate increase of familiarity of the information. Derived from deficit processing theory, the attention-attenuation theory further claims that massed practice impairs recollection because of the difficulty paying full attention to the subsequent presentation of the same item (Kornell et al., 2010). That is, when the inter-stimuli interval is relatively short, processing of the second presentation is reduced in quality as well as quantity.

Thirdly, encoding variability theory (Martin, 1968, Melton, 1970) has been previously employed by Balota et al. (2006) to account for the effect of spacing. According to the theory, performance on memory tests depends on the interval between the time of study and the time of retrieval. The two factors correlate with one another; the shorter the interval between study and time of retrieval the greater success rate. However, when recall/retrieval occurs immediately after study or the previous opportunity of recall/retrieval, the time for the information to drift between study/first retrieval and subsequent retrieval is limited; consequently, it results in relatively poor retention. The theory suggests that spacing out the study/retrieval opportunities creates higher probability of later recall because it allows the newly learnt information to fluctuate to a greater extent compared to massing. Therefore, the likelihood that information activated during study overlaps with information activated at the time of retrieval.

The above theories can account for the findings of the current experiment that massed practice benefits immediate retrieval but not delayed recollection. All three groups of participants performed better with massed-practiced pairs than spaced-practiced pairs during the study phase. However, the current experiment only involved a relatively short spacing schedule (four intervening pairs); therefore, the accuracy of cued-retrieval of spaced pairs was not much lower than massed pairs. It is plausible to claim that, at least, with the current spacing schedule, PWA learnt in the same fashion as the two control groups during pair-association learning of word-pairs as well as picture-pairs.

Spaced pairs, on the other hand, may facilitate cued-recall after a short (ten minutes) delay as well as a relatively long (two days) delay. The robust spacing effect previously reported in healthy participants (Carpenter & DeLosh, 2005; Karpicke & Roediger, 2007a) and other groups of people with cognitive deficits (Balota et al., 2006; Middleton & Schwartz, 2012; Sumowski et al., 2010) is observed in PWA and has been shown to facilitate learning within the pair-association paradigm involving word-pairs and picture-pairs. Despite the overall reduced performance, PWA employed the same memory process in pair-association learning as the two control groups of participants; hence, they also benefit from spacing. Furthermore, the efficacy of spacing did not restrict to word-pair learning; the spacing effect was also evident in pair-association learning of picture-pairs. The finding contradicts the deficient semantic processing hypothesis (Challis, 1993), which suggests that spacing improves performance on pair-association learning only when a pair is processed semantically. That is, based on the level of processing (Craik & Tulving, 1975), the spacing effect on a pair depends on the level of processing it received during study; therefore, the effect should not be evident when learning of pairs containing complex semantic information for encoding or non-linguistic pairs, such as pictures. Nonetheless, in the current experiment, on average, all three groups of participants performed better on spaced-practiced picture-pairs compared to not only massed-practiced picture-pairs but also massed-practiced word-pairs. Accordingly, the deficit processing hypothesis fails to account for the current findings, which suggests that the effect of the amount of semantic information the stimuli carries was independent from the effect of spacing schedule. Although the higher success rate in cued-recall of word-pairs than picture-pairs indicates that the amount of semantic information the stimuli carries did affect learning outcome(s) and retention, no sufficient evidence supports that it is a relevant factor to the spacing effect observed.

One of the tasks involved in the experiment was delayed recognition, which was designed to tap potential implicit learning occurring during the study phase. The participants in the two control groups benefited from spaced practice in delayed recognition; yet, spacing did not facilitate recognition for PWA. This finding points out that although PWA generated similar outcomes of cued-recall tasks, the process of learning might not be exactly the same as the controls. Alternatively, it is possible that other cognitive functions rather than language influenced the outcomes of the delayed recognition task. Besides, across all three groups of participants, words and pictures had equal rates of accuracy in delayed recognition, suggesting that, again, spacing effect and the amount of information the stimuli carry did not co-occur as claimed by the deficit processing hypothesis. The difference in performance between PWA and the two control groups indicates that spacing did not boost implicit learning, at least in the current experiment, in PWA.

5.6.2. Spacing effect in explicit and implicit memory

Explicit memory and implicit memory have long been discussed as memory supported by two distinct systems that dissociate from each other (Schacter, 1994). Therefore, what is observed in explicit memory may not appear in implicit memory and vice versa. The majority of evidence regarding the spacing effect has been found in tasks involving explicit memory (Perruchet, 1989). Evidence regarding the spacing effect in implicit memory is, however, more inconsistent. Also, previous studies suggest that both recall and recognition require explicit retrieval from memory (Perruchet, 1989; Russo et al., 2002). However, the delayed recognition task involved in the current experiment required the participants to retrieve partial information of the pairs they had learnt during the study phase; therefore, it is considered as a task to examine whether implicit learning of the pairs occurred. Furthermore, to enhance the efficacy of the delayed recognition task as a test of implicit memory used in the current experiment, reaction time was recorded and considered as an index of the occurrence of implicit learning.

The findings of current experiment support the suggestion that explicit memory benefits from spaced learning. In the two cued-recall tasks, all three groups of participants performed better on spaced-practiced items compared to massed-practiced items. That is, items that were spaced practiced during the study phase had higher accuracy of cued-recall tasks than items that were mass practiced. Nevertheless, despite the outcome of the delayed recognition task being inconsistent across the groups in terms of accuracy and reaction time It is notable that the linguistic effect found in cued-recall tasks was not found in delayed recognition task. The performances on word and picture recognition were at the same level, which contradict the picture superiority effect reported among existing literature (Hockley, 2008). However, previous studies (Hockley, 2008; Stenberg et al., 1995) employ study of lists of pictures or picture-pairs whilst, in the current experiment, participants were required to retrieve only partial information of a pair; this could explain the lack of difference between word and picture recognition.

A spacing effect was observed in the two control groups in accuracy and reaction time data. Words and pictures presented as parts of the spaced-practiced pairs were better recognised than those presented as parts of the massed-practiced pairs. Moreover, words/pictures that were spaced-practiced yielded shorter reaction times than massed-practiced pairs. However, a spacing effect was not observed in the group of PWA; both the accuracy and the reaction time data showed no significant difference between spaced- and massed-practiced items. The distinct performance between PWA and the two control groups on the delayed recognition task is intriguing and suggests possible differences underlying the learning process.

Chapter 6 Cognitive functions and learning: what is the role of cognitive functions in learning and to what extent do they affect learning outcomes?

6.1. Introduction

A striking finding from the learning experiments reported in chapters 3, 4 and 5 was the variability of learning performance of the people with aphasia. In each experiment some participants were within the range of the age-matched control participants and others performed poorly. The aim of this chapter is to investigate whether the differences in learning of PWA across the learning tasks are related to cognitive and linguistic functions as assessed by the background tests reported in chapter two. It has been suggested, though contradictive, that cognitive abilities correlate with language ability, in the way that they are influential to performance but are in no way predictive (Kalinyak-Fliszar et al., 2011; Martin et al., 2012; Murray, 2004; Seniow et al., 2009; Wright & Shisler, 2005). It is also suggested that cognitive abilities may even predict outcomes of therapy and/or various language tasks (Caspari et al., 1998; Francis et al., 2003; Koenig-Bruhin & Studer-Eichenberger, 2007; Lambon Ralph et al., 2010; Salis, 2012).

Evidence on how linguistic factors (such as word-length, imageability, and semantic knowledge) affect performance of people without brain damage (Avons et al., 1994, Bhatarah et al., 2009; Evans et al., 2012; Rodd et al., 2004) and PWA (Best et al., 2002; Rogers et al., 2004; Tuomiranta et al., 2011) has been widely reported. In the case of learning or new words, Kelly and Armstrong (2009) have argued that severity of language impairment determines the outcomes of learning, based on their findings that PWA with less impaired ability to communicate verbally and/or in the written form achieved better learning outcomes. If it is the case that linguistic knowledge is the paramount factor that supports learning of new information, it may be expected that correlations may be observed between the assessments that tap language functions with the learning tasks.

As reviewed in chapter one, successful learning cannot be achieved without the new information being processed and rehearsed in STM with possible facilitation by linguistic representations from long-term memory (Baddeley, 2003; Majerus et al., 2012; Patterson & Shewell, 1987). People with aphasia have been reported to demonstrate reduced STM across verbal and non-verbal tasks (Burgio & Basso, 1997). Also the performance on WM tasks worsens as the linguistic information carried by the stimuli decreases

(Christensen & Wright, 2010). Based on the existing literature, it was hypothesised that memory will affect performance on the learning tasks, regardless of whether the tasks were linguistic or non-linguistic, due to the fact that reduced performance on both verbal and non-verbal memory tasks have been observed (Burgio and Basso, 1997; Christensen & Wright, 2010). This led to the prediction that PWA with more severe language impairment were expected to perform worse on learning compared with those with milder language impairments.

Moreover, verbal STM capacity has been reported to predict outcomes of treatment and performance on language tasks that tap the same domains of language function (Caspari et al., 1998; Friedmann & Gvion, 2003; Martin et al., 2012). For instance, Caspari et al. (1998) claimed that PWA who had higher reading spans were better at reading comprehension tasks in comparison to those with significantly reduced reading spans. If this is the case, and the effect has an impact on learning in general, lower verbal memory capacity should lead to decreased performance as the number of to-be-learnt items becomes more and the memory load increases. Further, if the assumption holds, verbal STM span is most likely to correlate with learning of linguistic tasks.

In addition, attention and executive function are two domains of cognition that have been identified as determining factors of task performance. Murray (2000) argues that attention affects language performance, based on findings of the relation between word retrieval and attentional demand. As attentional demand for the task increased, word retrieval accuracy decreased accordingly. Similar findings have been reported with executive function and language processing. Martin and Allen (2008) claimed that reduced executive function leads to difficulty inhibiting irrelevant verbal representations and, thus, poor semantic processing at single word as well as sentence level. If the above findings on attention and executive function can be generalised to both linguistic and non-linguistic learning, hypothetically, they would influence the performance of PWA across all learning tasks. Therefore, PWA with reduced attention and/or executive function are less likely to focus on the tasks, particularly on those with higher demands on attention, such as pair-associative learning of visuo-auditory pairs, which require collaboration of visual and auditory attention and processing of information from two domains.

6.2. Results

In this section, the four domains of cognitive function (language, memory, attention, & executive functions) were assessed with a variety of cognitive assessments as reported in chapter two. In this chapter, it is examined as to whether any of these functions had an impact on learning. Prior to the analyses, the scores that PWA generated in the previous experiments and cognitive assessments were transformed into *z*-scores before conducting any further analysis in order to be able to compare them directly. These transformations into *z*-scores did not impact on correlations performed later in this chapter as they are linear. A *z*-score is calculated by taking each score and subtracting from it the mean of all scores; then, dividing the resulting scores by the standard deviation. The equation is presented below.

$$\boldsymbol{z} = \frac{(\text{data point} - \text{mean})}{\text{standard deviation}}$$

A point of note here is that the values for mean and standard deviation involved in converting *z*-scores for the current experiments were different to the ones used for the *z*-scores of cognitive assessments. For the cognitive assessments, the mean and standard deviation are of the group of PWA so that an individual with aphasia is compared to the rest of the group on how he/she performed on a particular test. In the case of converting a *z*-score of an experiment, the values for the mean and standard deviation of age-matched control groups were used in order to make more objective comparisons between the performance of PWA and their age-matched controls on the experimental tasks (Crawford & Howell, 1998). Strong correlations between individual tests, if any, are reported. Moreover, any significant correlation found was used as the basis for creating composite scores, which were formed by grouping factors that were closely related to each other. Further analyses with composite scores of the cognitive factors and the learning tasks were conducted to check potential effects and to increase the reliability of the analyses.

6.2.1. *Correlations among the tasks*

The focus of this section is to establish whether there was a relationship between the performances on cognitive assessments (see chapter two for the tasks involved) and the learning tasks conducted in the experiments. Pearson's correlation coefficient was applied to the data to obtain preliminary results. Bivariate correlation procedures of Pearson's correlation coefficient were adapted to explore whether there was a relationship between the cognitive variables. The findings were expected to reveal the relationship, if any, between cognitive ability and learning ability. The variables involved in the analysis fell into one of the two categories of cognition or learning. Although some of the cognitive assessments used (described in chapter two) contain sub-scores, the overall-scores were taken for the current analysis. Only in cases when sub-scores are generated by a task that examines distinct aspects of a cognitive function, were the sub-scores taken into consideration. For instance, the integrity of auditory attention was interpreted on the basis of the three sub-scores generated by the task, including accuracy, auditory sustained attention and auditory WM. Due to the independence of these domains of auditory attention, each sub-score is considered to be an independent variable in the preliminary analysis.

As for the learning tasks, there are a few sub-scores in each learning experiment as more than one factor was measured in each experiment. The incremental versus non-incremental learning experiment generated two sets of scores for three factors of different linguistic load (linguistic-heavy, semi-linguistic, & non-linguistic). The experiment which investigated implicit learning included four scores for the reaction time improvement slope of four lag conditions (lag 3, 5, 10, & 20) of picture recognition. The experiment looked at massed versus spaced learning generated 12 sub-scores between the experimental conditions, including learning approaches (massed vs. spaced), two types of stimuli (word-pairs and picture-pairs), condition of cued-recall (immediate & delayed), and recognition (delayed only).

Overall, the Pearson's correlation coefficient conducted consisted of 20 cognitive variables and 30 learning variables, as presented in the tables below. Significance was accepted at the level of 0.05, without correction. The results demonstrated that the correlations lay mainly between either two cognitive variables or two learning variables; few correlations were observed between performance of a cognitive task and a learning task. The correlations reported among cognitive variables are presented in the following tables according to the cognitive function a task required, including language (Table 6.1), memory

(Table 6.2), and attention and executive functions (Table 6.3). As for the correlations found between the learning tasks, the variables generated from incremental versus non-incremental learning (detailed in chapter three) and implicit learning (detailed in chapter four) in relation to other learning tasks are presented in Table 6.4. The variables of massed versus spaced learning and how they correlate with other learning tasks are demonstrated in Table 6.5. All significant values in the tables are shaded.

The preliminary Pearson's correlation coefficient revealed that cognitive function did not correlate with learning which goes against the predictions that were made. Firstly, looking at the correlations between language and the other cognitive variables (see Table 6.1) assessed in this thesis, it is unsurprising that performance in language tests correlate. Except for the correlations reported between language tests, tests of story recognition, which assessed the ability to form new episodic memory, also correlated with most language tests (four out of five). This could be interpreted as showing that building new episodic memory relies heavily on language function and/or the test itself was linguistic-heavy. The correlation between language and the other variables were minimal.

The correlation between memory tests and other cognitive functions are presented in Table 6.2. The memory tests chosen here were broadly correlated with language tests rather with one another. These patterns of correlations indicated potential need for linguistic knowledge to perform memory tasks; also, it showed that some memory tests were independent from the other, which was predictable because the tests were selected to examine various aspects of memory. In terms of the correlations between tests of attention as well as executive function and other cognitive variables, as presented in Table 6.3, the significant correlations observed were mainly between the sub-tests of one cognitive assessment, which assessed sub-domains a cognitive function. Learning tasks, on the other hand, demonstrated minimal and non-systematic correlations with all cognitive variables; moreover, the correlations found among learning tasks showed that sub-tests of one learning experiment largely correlated with each other but correlations across experiments were minimal.

Summarising the preliminary analysis: scores of learning tasks did not correlate with the cognitive variables. However, there is a possibility that individual cognitive assessment focusing on a single aspect of a cognitive function together with the small sample sized involved in the current study, may not be enough to show correlation. To investigate further, composite scores (see 6.2.2) were created by combining the significantly correlated tests as a new variable that assessed more general aspect of a certain cognitive function. This allowed further exploration of the relationship between cognitive functions and learning outcomes.

Table 6.1. Pearson's correlations between language and other cognitive variables.

	word repetition	complex word repetition	non-word repetition	naming	picture description
word repetition	-				
complex word repetition	.594*	-			
non-word repetition	.515*	.239	-		
naming	.698**	.601*	.396	-	
picture description	.547*	.571*	.316	.706**	-
digit strings repetition	.681**	.562*	.403	.400	.534*
digit repetition by pointing	.655**	.617*	.435	.552*	.672**
Corsi's blocks	-.231	-.270	.009	-.248	-.048
PPT	.273	.458	.211	.579*	.509*
face recognition	.195	.281	.054	.457	.427
map search 1	.380	.400	.117	.634**	.344
map search 2	.545*	.519*	.202	.648**	.578*
visual attention – accuracy	.188	.367	.214	.227	.506
visual attention – RT	-.140	-.308	-.196	-.309	-.471
story recognition – immediate	.579*	.566*	.557*	.400	.643**
story recognition – delayed	.693**	.505	.456	.310	.459
auditory attention – accuracy	.236	.444	.254	.574*	.584*
auditory attention – sustention	.039	-.303	.013	.190	-.301
auditory WM	-.102	.288	.248	.269	.383
M-WCST	-.263	.066	.035	.083	.316

Note ***p*<0.001; **p*<0.05

Table 6.2. Pearson's correlations between memory scores and other cognitive variables

	digit strings repetition	digit repetition by pointing	Corsi's blocks	PPT	face recognition	story recognition - immediate	story recognition - delayed
M-WCST	-.225	-.093	-.148	.143	.068	.301	-.125
word repetition	.681**	.655**	-.231	.273	.195	.579*	.693**
complex word repetition	.562*	.617*	-.270	.458	.281	.566*	.505
non-word repetition	.403	.435	.009	.211	.054	.557*	.456
naming	.400	.552*	-.248	.579*	.457	.400	.310
picture description	.534*	.672**	-.048	.509*	.427	.643**	.459
digit strings repetition	-					.287	.217
digit repetition by pointing	.885**	-				.397	.328
Corsi's blocks	.106	-.017	-			.071	.246
PPT	.010	.359	-.135	-		.767**	.848**
face recognition	-.080	.120	.101	.909**	-	.649**	.820**
map search1	.220	.257	-.132	.421	.579*	.081	.156
map search2	.435	.437	.058	.358	.515*	.222	.195
visual attention – accuracy	.598*	.619*	-.368	.331	-.412	.275	.125
visual attention – RT	-.361	-.424	.122	-.015	-.296	-.182	.066
story recognition - immediate	.287	.397	.071	.767**	.649**	-	
story recognition - delayed	.217	.328	.246	.848**	.820**	.898**	-
auditory attention - accuracy	.319	.432	-.341	.418	.112	.415	.261
auditory attention – sustention	-.313	-.193	-.275	-.132	.202	.001	.202
auditory WM	.003	.155	-.019	.358	.279	.186	-.196

Note: $^{**}p<0.001$; $^{*}p<0.05$

Table 6.3. Pearson's correlations between attention scores/executive function score and other cognitive variables

	M-WCST	**map search 1**	**map search 2**	**visual attention – accuracy**	**visual attention – RT**	**auditory attention - accuracy**	**auditory attention – sustention**	**auditory attention – WM**
M-WCST	-	-.076	-.087	.306	-.306	.545*	-.178	.762**
word repetition	-.263	.380	.545*	.188	-.140	.236	.039	-.102
complex word repetition	.066	.400	.519*	.367	-.308	.444	-.303	.288
non-word repetition	.035	.117	.202	.214	-.196	.254	.013	.248
naming	.083	.634**	.648**	.227	-.309	.574*	.190	.269
picture description	.316	.344	.578*	.506	-.471	.584*	-.301	.383
digit strings repetition	-.225	.220	.435	.598*	-.361	.319	-.313	.003
digit repetition by pointing	-.093	.257	.437	.619*	-.424	.432	-.193	.155
Corsi's blocks	-.148	-.132	.058	-.368	.122	-.341	-.275	-.019
PPT	.143	.421	.358	.331	-.015	.418	-.132	.358
face recognition	.068	.579*	.515*	-.412	-.296	.112	.202	.279
story recognition - immediate	.301	.081	.222	.275	-.182	.415	.001	.186
story recognition - delayed	-.125	.156	.195	.125	.066	.261	.202	-.196
map search1		-	.873**	.088	-.632*	.585*	.269	.170
map search2			-	.059	-.521	.487	-.004	.179
visual attention – accuracy				-	-.474	.664*	-.487	.330
visual attention – RT					-	-.663*	.137	-.559*
auditory attention - accuracy						-	-.109	.626*
auditory attention – sustention							-	-.305
auditory WM								-

Note **p<0.001; *p<0.05

Table 6.4. Pearson's correlations between learning tasks – non-incremental vs. incremental learning and implicit learning.

		non-incremental			incremental			picture recognition			
		words	non-words	animal sounds	words	non-words	animal sounds	lag3	lag5	lag10	lag20
non-incremental	*words*	–									
	non-words	.535*	–								
	animal sounds	.644**	.404	–							
incremental	*words*	.742**	.519	.766**	–						
	non-words	.525	.531	.672*	.643*	–					
	animal sounds	.652*	.589*	.770**	.595*	.698*	–				
picture recognition	*lag 3*	-.207	-.285	-.131	-.051	-.532	-.535	–			
	lag 5	.203	.286	-.061	.026	.216	-.058	.070	–		
	lag 10	-.140	.107	.161	-.148	-.105	-.498	.502*	.541*	–	
	lag 20	-.325	.030	-.366	-.117	-.111	-.475	.381	.393	.569*	–
immediate cued-recall	*massed-words*	.774**	.607*	.686*	.835**	.531	.521	.084	.304	.270	.126
	spaced-words	.570	.467	.605*	.735*	.524	.314	.303	.603*	.511	.243
	massed-pictures	.172	.404	.580	.238	.365	-.002	.056	.388	.768**	.462
	spaced-pictures	.406	.174	.501	.010	.385	.736*	.274	.165	.231	-.036
delayed cued-recall	*massed-words*	.460	.357	.431	.634	.500	.140	.110	.705*	.550	.510
	spaced-words	.278	.231	.366	.460	.249	-.003	.525	.664*	.631*	.357
	massed-pictures	.062	.031	.234	.168	.692*	.508	-.064	.336	.286	.477
	spaced-pictures	.167	-.106	.162	.204	.545	.575	.191	.486	.191	.205
delayed recognition	*massed-words*	.013	.075	-.414	-.094	.048	.000	-.407	.200	-.105	.448
	spaced-words	-.144	.286	-.117	-.143	.265	-.565	.448	.533	.748**	.716*
	massed-pictures	.053	-.112	-.156	-.206	.011	-.266	.124	.315	.361	.688*
	spaced-pictures	.058	-.168	-.330	.074	.257	-.047	-.020	.329	-.019	.624*

Note ***p*<0.001; **p*<0.05

Table 6.5. Pearson's correlations between learning tasks – massed vs. spaced learning.

		immediate cued-recall				delayed cued-recall				delayed recognition			
		massed–words	***spaced–words***	***massed–pictures***	***spaced–pictures***	***massed–words***	***spaced–words***	***massed–pictures***	***spaced–pictures***	***massed–words***	***spaced–words***	***massed–pictures***	***spaced–pictures***
non-incremental	*words*	.774**	.570	.172	.406	.460	.278	.062	.167	.013	-.144	.053	.058
	non-words	.607*	.467	.404	.174	.357	.231	.031	-.106	.075	.286	-.112	-.168
	animal sounds	.686*	.605*	.580	.501	.431	.366	.234	.162	-.414	-.117	-.156	-.330
incremental	*words*	.835**	.735*	.238	.010	.634	.460	.168	.204	-.094	-.143	-.206	.074
	non-words	.531	.524	.365	.385	.500	.249	.692*	.545	.048	.265	.011	.257
	animal sounds	.521	.314	-.002	.736*	.140	-.003	.508	.575	.000	-.565	-.266	-.047
picture recognition	*lag 3*	.084	.303	.056	.274	.110	.525	-.064	.191	-.407	.448	.124	-.020
	lag 5	.304	.603*	.388	.165	.705*	.664*	.336	.486	.200	.533	.315	.329
	lag 10	.270	.511	.768**	.231	.550	.631*	.286	.191	-.105	.748**	.361	-.019
	lag 20	.126	.243	.462	-.036	.510	.357	.477	.205	.448	.716*	.688*	.624*
immediate cued-recall	*massed-words*	–	.808**	.451	.253	.749**	.543	.165	.206	.143	.018	.021	.058
	spaced-words		–	.573	.318	.901**	.897**	.277	.434	-.166	.186	-.073	.042
	massed-pictures			–	.372	.611*	.515	.416	.124	-.104	.293	.183	-.121
	spaced-pictures				–	.129	.297	.564	.572	-.215	.057	.176	.050

		immediate cued-recall				delayed cued-recall				delayed recognition			
		massed–words	***spaced–words***	***massed–pictures***	***spaced–pictures***	***massed–words***	***spaced–words***	***massed–pictures***	***spaced–pictures***	***massed–words***	***spaced–words***	***massed–pictures***	***spaced–pictures***
delayed cued-recall	*massed-words*					–	.819**	.401	.449	.173	.233	.198	.320
	spaced-words						–	.230	.474	-.165	.361	.080	.156
	massed-pictures							–	.804**	.180	.113	.302	.441
	spaced-pictures								–	.082	.059	.142	.416
delayed recognition	*massed-words*									–	.103	.653*	.703*
	spaced-words										–	.509	.215
	massed-pictures											–	.761**
	spaced-pictures												–

Note ***p*<0.001; **p*<0.05

6.2.2. *Composite scores*

The results of correlation analyses show that none of the cognitive assessments correlated with learning tasks. Most correlations that reached significance were observed between tasks/assessments that draw on common cognitive functions or are similar in task design. Composite variables were transformed based on either the categorisation of the assessment manuals or the positive correlations that were reported between assessments/learning tasks. Assessment(s)/task(s) that did not correlate strongly with others were retained as possible independent predictors. That is, not all the scores (listed in 6.2.1) were combined into one of the composite scores. If an assessment was originally taken as an independent assessment and showed no significant correlation with others, it remained independent. One example is Corsi's blocks, which was used to test non-verbal STM, in all three tables (Table 6.1, Table 6.2, & Table 6.3) demonstrating correlations among cognitive assessments, no correlation was reported.

The Pearson's correlation coefficient included eight cognitive variables, five of which were composite, and six composite variables from the three learning experiments. The cognitive variables were the four composite variables and non-verbal STM, semantic memory, and executive function. The formula of each composite score is presented in

Figure 6.1. Following these principles, the following composite variables of cognitive functions were developed:

(i) *Language* – As suggested by the CAT manual (Swinburn et al., 2004), scores of verbal repetition (words, complex words, and non-words), naming, and spoken picture description were clustered as one group and were combined into a language production score.

(ii) *Verbal short term/working memory* – In this experiment, accuracy of digit strings repetition and repetition of digit strings by pointing were significantly correlated (r=0.672, p=0.023); hence, the two were combined into a verbal STM score.

(iii) *Recognition memory* – The recognition score is composed of the score of the face recognition sub-test of Camden Memory Tests (Warrington, 1996) and story recognition [immediate (r=0.649, p=0.007) & delayed (r=0.820, p<0.001) sub-tests of BCoS, which were significantly correlated with each other.

(iv) *Visual Attention* – The two sub-tests taken from TEA (map searching and visual elevator: Robertson et al., 1994) rely on the same factor, visual attention; therefore, the scores of the sub-tests were combined into one composite score.

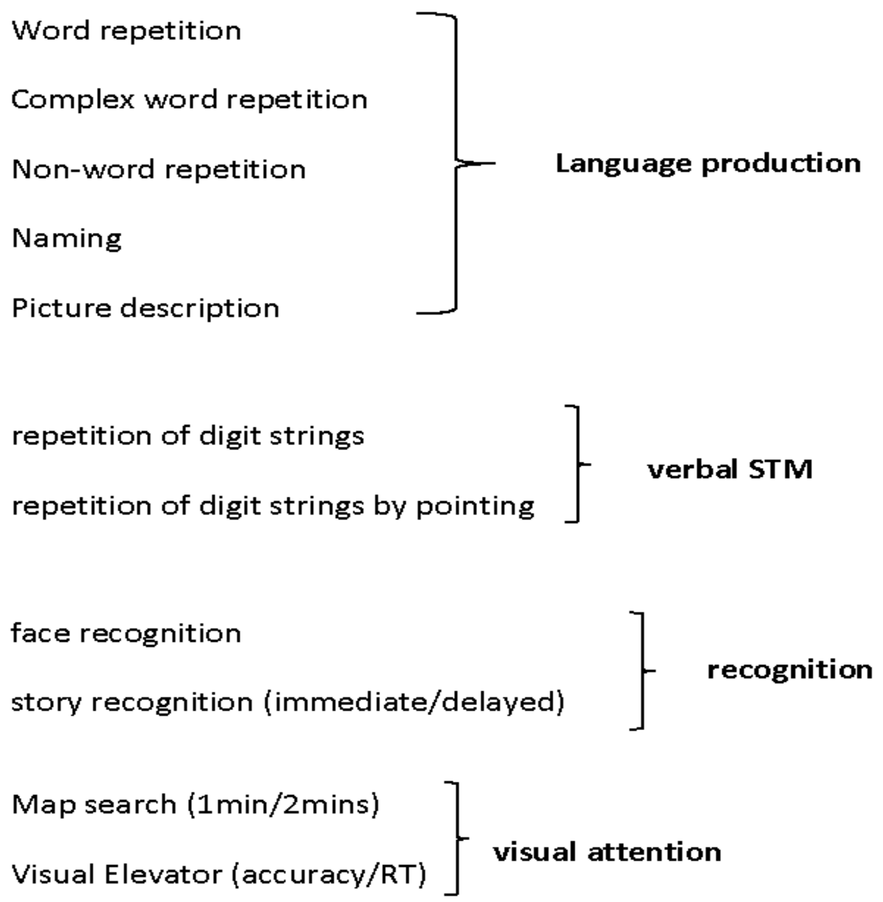

Figure 6.1. Composites scores – cognitive assessments

The sub-scores of the learning experiments were, generally, significantly correlated with each other. Hence the sub-scores were combined into one or two composite scores that reflect the main objective(s) of an experiment. Six composite variables of learning, presented in Figure 6.2, were created: pair-associative learning, implicit learning, massed learning, spaced learning, delayed recognition of massed-practiced items, and delayed recognition of spaced-practiced items. The composite score of pair-associative learning covers both incremental and non-incremental learning because the two approaches did not affect learning in different ways and, therefore, are not examined separately. Moreover, across the participants with aphasia the overall accuracy in incremental and non-incremental learning was found to be correlated.

The composite score of implicit learning consisted of the scores of the mean accuracy over the four lag durations in the experiment (see chapter four for details). In the analysis of this experiment lag condition did not affect performance and accuracy across the lags was significantly correlated (see Table 6.4.), justifying them being combined into a single score. On the other hand, learning outcomes were significantly affected my massed and spaced approaches of learning (discussed in chapter five). Although some correlation was found between massed and spaced learning/recognition, it was considered to be worthwhile looking at these two methods of practice independently. That is, the accuracy of massed- and spaced-learnt pairs/items was considered separately in both cued-recall tasks (immediate & delayed) as well as the delayed recognition task.

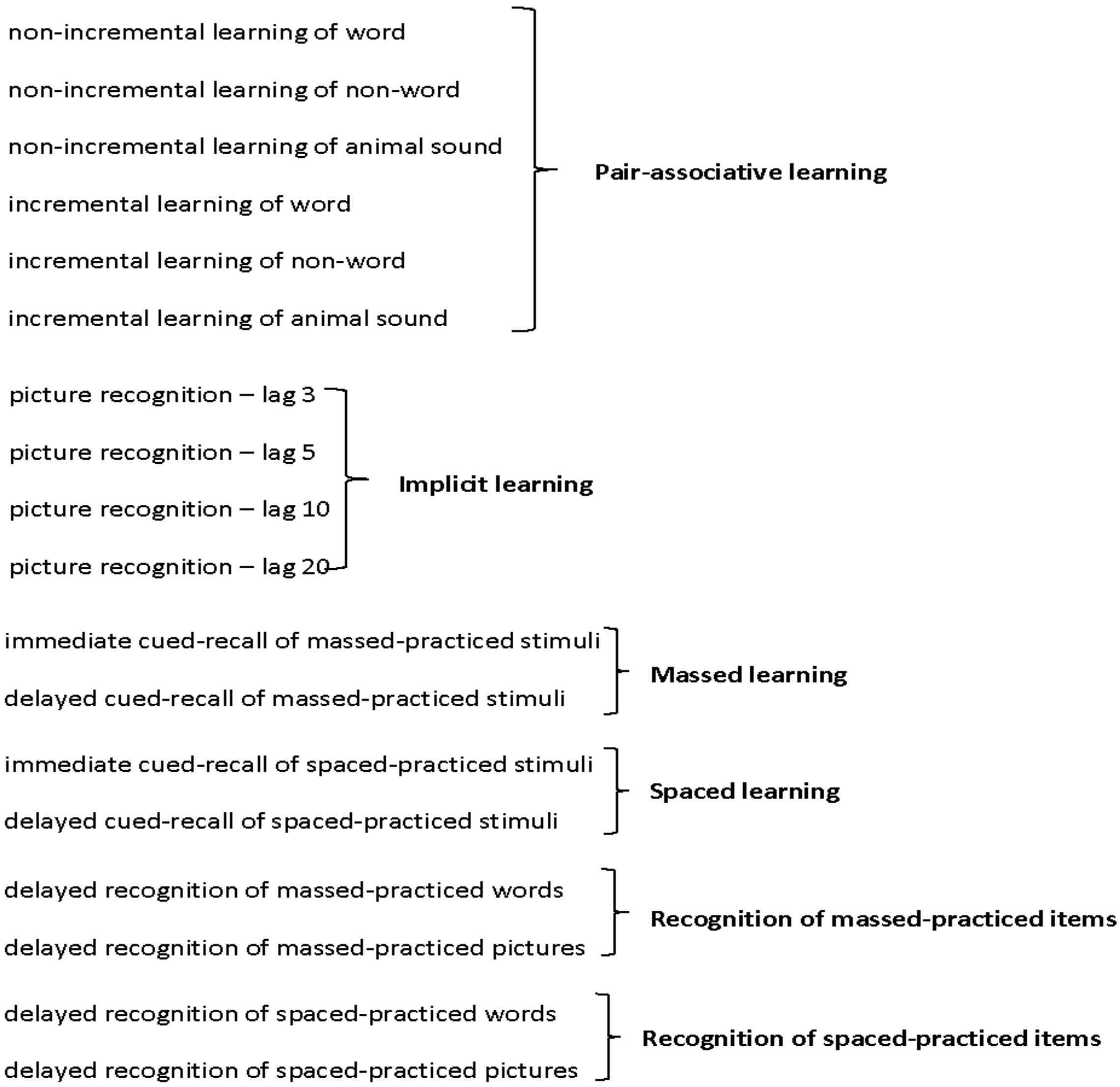

Figure 6.2. Composite scores – learning experiments.

6.2.3. *Cognitive functions and learning outcomes*

Bivariate correlation analyses of Pearson's correlation coefficient were applied to the dataset with (composite) variables of cognitive functions and learning tasks to determine whether there was a relation between cognitive functions and learning. The cognitive variables were language production, verbal STM, non-verbal STM, semantic memory, recognition memory, visual attention, auditory attention, and executive function. Variables of learning, on the other hand, were pair-associative learning, implicit learning, massed learning, spaced learning, recognition of massed-practiced items, and recognition of spaced-practiced items. If learning did relate to the cognitive functions as predicted, positive correlations between cognitive factors and learning outcomes were expected.

The results of these correlational analyses are shown in Table 6.6. In considering these results, it is important to realise that they include multiple comparisons of 14 variables (that is, 91 tests). In considering statistical significance, the Holm-Larzele & Mulaik procedure was adopted (see Howell, 2010), which incorporates adjustment for multiple comparisons. Therefore, significance was accepted at the level of 0.05 after Holm correction. Considering first the correlations within the participants' performance in the learning tasks, correlations between learning tasks were explored.

The learning abilities probed in chapters three and five (incremental/non-incremental learning and massed/spaced paired associate learning) were generally closely related (*r* between 0.628 and 0.716); this suggests that they tap a common ability in establishing pairings between items regardless of the form of the items (they vary between sounds, pictures, words). None of the scores in these tasks correlated positively with the implicit learning probed in chapter four. Indeed the correlations were generally negative, showing that the abilities probed in the recognition memory task were independent from the abilities recruited in the paired associate learning tasks.

Table 6.6. Pearson's correlation between cognitive functions and learning – composite scores.

	language production	verbal STM	recognition	visual attention	auditory attention	executive function	semantic memory	non-verbal STM	pair-associative learning	implicit learning	massed learning	spaced learning	Recog. of massed items	Recog. of spaced items
language production	–													
verbal STM	.774**	–												
recognition	.756**	.268	–											
visual attention	.558*	.577*	.345	–										
auditory attention	.166	-.174	.308	.165	–									
executive function	.060	-.165	.199	-.128	.689**	–								
semantic memory	.519*	.245	.854**	.111	.028	.143	–							
non-verbal STM	-.240	.040	.231	-.208	-.078	-.148	-.135	–						
pair-associative learning	-.189	-.285	-.308	-.037	.081	.312	.002	.063	–					
implicit learning	.091	.233	-.118	.294	-.277	-.338	.073	-.444	.320	–				
massed learning	-.315	-.372	-.210	-.219	-.293	-.225	-.074	.383	.716*	-.617*	–			
spaced learning	-.539	-.396	-.549	-.135	-.301	-.091	-.357	.164	.628	-.575	.784**	–		
Recog. of massed items	.393	.326	.663	.526	-.012	.178	.826**	.331	-.160	-.279	.182	-.049	–	
Recog. of spaced items	-.195	-.138	.457	-.048	.064	.276	.510	.618*	-.071	-.657*	.266	.228	.757**	–

Note ** $p<0.001$; * $p<0.05$

In the experiment reported in chapter six, recognition memory for the items presented during learning was probed at a 24hr follow-up. There was a moderate but significant correlation between accuracy for items presented in the massed and spaced conditions (r= 0.757, p= 0.007). Performance in these tasks showed no significant correlation with performance in any of the other tasks reported in the experiment, with the exception of a *negative* correlation between performance in spaced recognition learning (r=-0.657, p=0.028), which was no longer significant once Holm's correction was applied. Interestingly, this suggests that recognition memory in the spaced/massed experiment is unrelated to either recognition memory (as probed in the experiment in chapter four) or paired-associative learning (probed in the experiments reported in chapters three and five). The lack of correlation between the learning tasks shows three separable abilities in the people with aphasia:

(i) *Paired associate learning* – This is an ability recruited in both the learning effects in experiments 1a and 1b reported in chapter three, and in the massed and spaced associate learning, reported in chapter five. Nonetheless, PWA who demonstrated learning in massed versus spaced learning task did not necessarily learn the pairs in the pair-associative learning task.

(ii) Immediate recognition – This is the ability used in the implicit learning tasks reported in chapter four, where items were 80 items were to-be-recognised over lags extending up to 20 intervening items before their subsequent presentations.

(iii) Long-term recognition – The ability tapped in the recognition memory of massed-and spaced-practice items at a 48hr delay, described in chapter five. The lack of correlation between immediate and long-term recognition is interpreted as delayed recognition requiring explicit retrieval and, therefore, a different type of memory from what is required for immediate recognition.

Due to the similarities shared by the two tasks involving learning of visually presented material, performance was anticipated to be along the same lines; especially in the case of implicit learning and the two recognition tasks. However, the evidence indicated otherwise. It is arguable that the two tasks differed in the way that one required the ability to perform pair-association whilst the other relied purely on visual recognition and, therefore, correlations were not found across all tasks. Alternatively, it is also possible that once the sample size increased, spaced learning and recognition of massed-practiced items would correlate with implicit learning significantly. However, no current evidence supports this possibility. Moreover, an account for the negative correlations between the tasks of visual learning and recognition is still needed.

Cognitive functions – the original predictions were that cognitive functions would correlate with learning and this did not foresee potential correlation(s) between various cognitive domains. Nonetheless, according to the analyses of Pearson's correlation coefficient, the performances on some cognitive assessments were correlated with each other. Understanding the correlations between the cognitive function provides further information on whether the chosen task relied too much on only a few cognitive abilities and might, potentially, account for the lack of correlation between cognitive functions and learning.

The language production score was found to strongly correlate with four out of the eight cognitive factors in the study, including visual attention (r=0.558, p=0.048), recognition (r=0.756, p=0.001), verbal STM (r=0.774, p<0.001), and semantic memory (r=0.519, p=0.033). Yet, once the significance value was corrected, only repetition, recognition, and verbal STM remained strongly correlated with the language score. The correlation between language production and recognition was further investigated due to the unprecedented relationship reported. Looking at the two scores (face recognition and story recognition) that are included in the composite score of recognition, story recognition scores correlated with four out of five language production sub-scores whereas face recognition correlated with none of the language sub-scores. This could be due to the fact that face recognition is a non-linguistic task and involves different memory systems compared to story recognition.

The correlation between language production and verbal STM, consisting of repetition of digit strings verbally and by pointing, showed that both sub-scores of verbal STM correlated with most of the language sub-scores, suggesting the possibility that the STM tasks relied heavily on linguistic knowledge. The same account can explain the correlation detected between semantic memory and recognition (r=0.854, p<0.001). This was considered as an indication that the ability of visual recognition may have influence on performing the task chosen, i.e. the three-picture version of Pyramid and Palm Trees test, in order to assess semantic memory. In addition, executive function was found to correlate with auditory attention (r=0.689, p<0.004). However, when investigated further, this correlation between the two tasks of very different cognitive domains was a result of a strong correlation between executive function and one of the aspects of auditory attention, i.e. focus of auditory attention (r=0.545, p<0.036). It is arguable that this finding indicates the potential auditory factor required during performance of the card sorting task.

In addition, the composite score of language production indicated a comprehensive range of language ability, in terms of production, of the PWA involved in the study. It led to the speculation that severity of language impairment might be sensitive to the chosen analysis and, therefore, null result was reported in the correlation between cognitive functions and the three perspectives of learning ability. To further investigate the potential confounding factor, PWA were divided into two groups, high versus low language production score, using a median split, in this case the language production score of zero. The group of high language production score consisted of seven PWA who scored above zero; the group with low language production score included eight PWA whose score was below zero. Bivariate correlation procedures of Pearson's correlation coefficient were used to analyse the two sets of data to determine whether there was a relationship between cognitive and learning ability and if the chosen analysis was indeed sensitive to severity of language impairment. The level of significance was accepted at the level of 0.05 with Holm-Larzele & Mulaik procedure applied. The results, however, were largely in line with the findings above. No correlation between cognitive and learning variables was found in either group. The outcomes of the two separate Pearson's correlation coefficient analyses were enclosed in Appendix D.

Although multiple regression analyses may be used to provide further information on if one or more of the cognitive factor(s) can be a predictor on the learning outcomes, the statistic method is not appropriate for the data of this study for two reasons. One reason is that few participants had complete record for cognitive tasks that are supposed to be taken as predictors; the other reason is that the sample size is too small to perform this type of analysis.

6.3. General discussion

The current findings demonstrate that the ability to learn can be considered to be independent from one's cognitive abilities, at least in the case of PWA. As revealed by the analyses of Pearson's correlation coefficients, PWA with less impaired cognitive functions did not necessarily have higher performance on the learning tasks involved in the current study, in comparison to those who had relatively intact cognitive abilities. Instead of correlating with cognitive functions as predicted, the learning outcomes generated by PWA in most learning tasks tended to correlate with one another. The trends of the performances of individuals with aphasia are presented in Figure 6.4, Figure 6.3, Figure 6.5, and Figure 6.6 below. As reported in this chapter, cognitive functions did not predict the performance on learning, PWA of various levels of severity of language impairments are grouped[1] based on their composite scores (*z*-score) of language production in order to observe the overall learning performance of individuals with aphasia across experiments. Putting together the individual patterns of learning generated by PWA provides further evidence that even PWA of similar degree of language (production) impairment showed distinct performance across learning tasks.

[1] The two participants, JHH and JG, who only took part in one learning task and dropped out of the study were not included in the graphs.

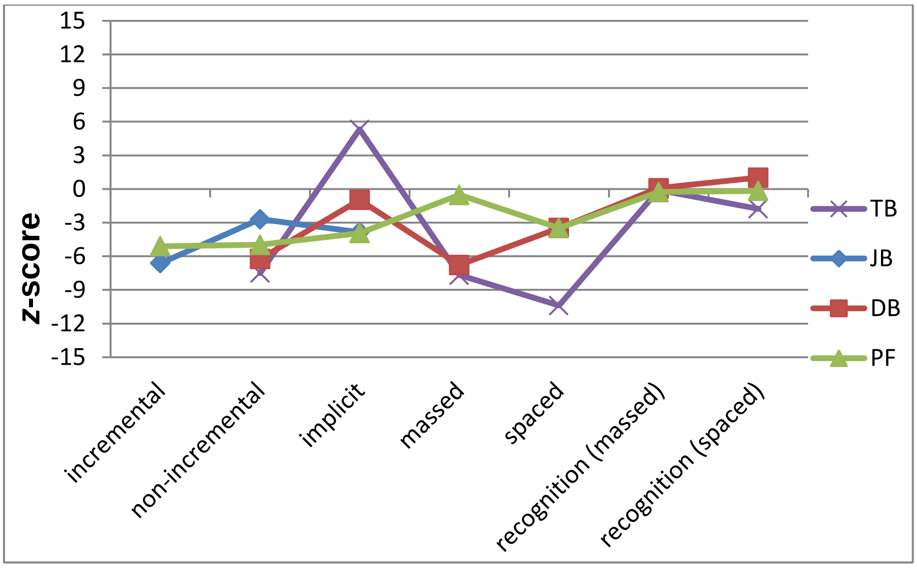

Figure 6.3. Performance across learning tasks – PWA with language production score between -1.99 and -0.50.

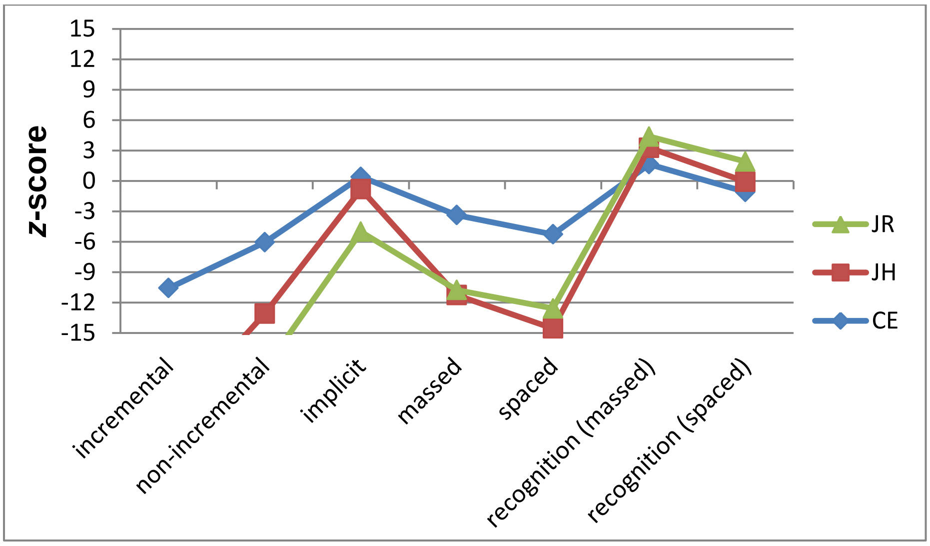

Figure 6.4. Performance across learning tasks – PWA with language production score lower than -2.00

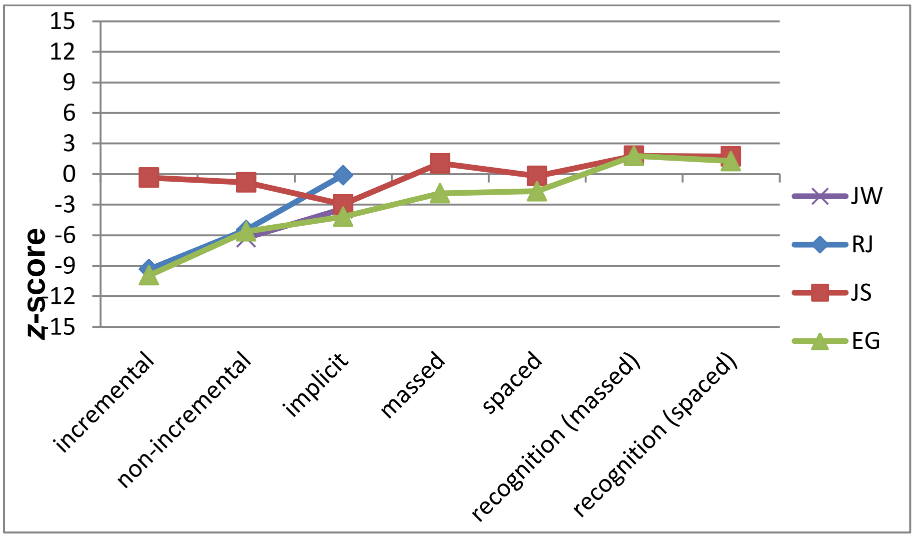

Figure 6.5. Performance across learning tasks – PWA with language production score between -0.49 and 2.00.

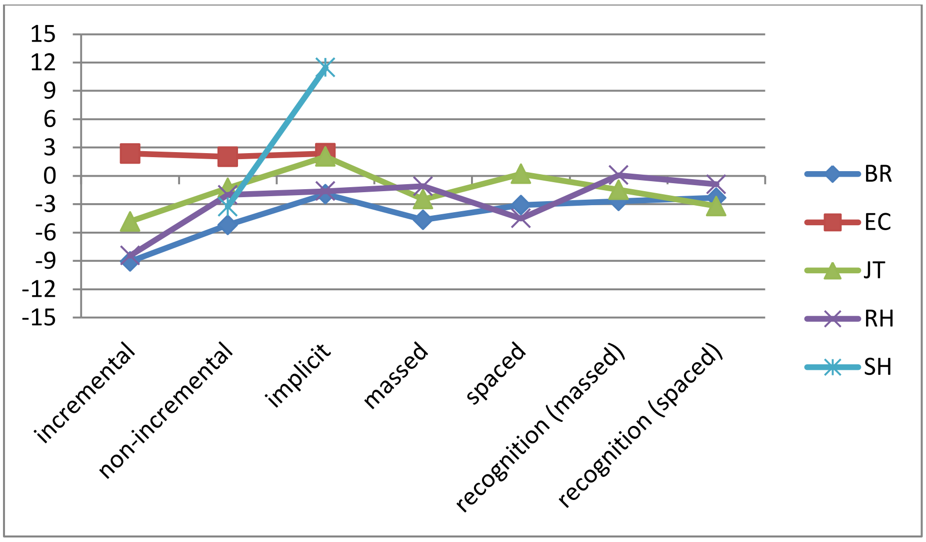

Figure 6.6. Performance across learning tasks – PWA with language production score between 2.00 and 6.00.

The correlations observed between the learning tasks indicate that the performance on the pair-associative learning task was positively correlated with the performance of massed and spaced learning. Neither of the two learning tasks showed correlations with the outcome of implicit learning nor the recognition of massed-/spaced-practiced items. A few possibilities are suggested to account for the findings. Despite pair-associative learning and massed/spaced learning tasks involving materials of different types, in terms of modality of presentation of the stimuli (visuo-auditory vs. visual only), and distinct approaches of directing learning, they were essentially learning of paired items. Therefore, it was not unexpected that PWA who were good at the pair-associative learning also did well in massed/spaced learning.

Moreover, to achieve success in both of these learning tasks takes conscious retrieval of the to-be-learnt pairs; that is explicit memory or explicit learning were crucial. It is possible that PWA have reduced explicit memory or it is more challenging for individual with language impairment(s) to form explicit memory traces. This is because the formations of explicit memory of newly learnt information benefits from a deeper level of processing; however, the process relies heavily on linguistic knowledge. If the difficulty indeed lies in explicit memory, it may further account for the lack of correlation between implicit learning/recognition of massed-/spaced-practiced items and the two tasks involved learning of paired stimuli.

A question that could rise from considering pair-associative learning massed/spaced learning as the same type of task is why the learning outcomes of PWA as a group were much better than the outcomes of pair-associative learning. This issue are accounted for from two perspectives, cognitive demand of the tasks and approaches used to direct learning. The to-be-learnt pairs were visually presented in massed/spaced learning; therefore, a single modality of processing was involved. Pair-associative learning, by contrast, involved visual as well as auditory processing and coordination of the processed information from the two modalities. Hence, it is arguable that the task demand was higher. Based on the existing evidence, the majority of PWA who participated in the experiments had intact or mildly impaired recognition memory as assessed by a visual recognition task (Camdem – face recognition), consequently, they were likely to learn better with visually presented material. On the other hand, despite impaired auditory processing or ability to process joint information received from visual and auditory modalities being a possible alternative account for the reduced learning outcomes, no evidence in the current study could support this account further.

In terms of the approaches used to direct the tasks, the results should be interpreted with caution. Pair-associative learning was directed with an incremental and non-incremental approach, which was hypothesised to reduce the occurrence of proactive interference in memory, however no difference was found. One explanation is that the task demand might have already overloaded PWA, as a result, the benefit of incremental over non-incremental was dissolved. However, this argument requires further study before it can be verified. On the other hand, PWA performed relatively well with massed/spaced learning regardless of the approach employed. Nevertheless, whether the benefit of these approaches can be generalised to other learning tasks is unknown.

In addition, the correlation found between implicit learning and recognition of spaced-practiced items not only supports the claim that explicit and implicit learning occurs differently but also further suggests that instead of taking learning as a whole concept, the investigation might need to be more specific to tasks of a similar/different nature. In other words, some PWA demonstrating learning in implicit learning did not show equal ability in learning involving explicit memory.

As for the role(s) that cognitive functions play in learning, we can only make the claim that learning and cognitive functions are independent from each other. However, this claim should not be generalised and needs further evidence to be supported. On one hand, the current study does not contain whole ranges of learning tasks and the sample size was relatively small; on the other hand, the correlations reported among the assessments of cognitive function might suggest that the assessments chosen for the current study rely too much on the same cognitive function(s). Consequently, they may not touch on a wide enough range of cognitive functions. Also, the results might indicate that cognitive skills rely heavily on each other - language and memory domains in particular - and are difficult to disentangle within the tests used at the stage of research.

Chapter 7 Conclusion: Summary of findings on learning and cognitive functions in PWA.

7.1. Introduction

This final chapter attempts to synthesise the findings of the experiments presented in the previous chapters, and to consider their contribution to the principal research questions this thesis set out to investigate:

1) Are PWA able to demonstrate learning?
2) What is the relationship, if any, between cognitive functions and learning in PWA?

The investigations involved in this thesis looked at learning in PWA as well as two groups of healthy control participants, young (age 18-30) and older (age 50-80, matching the age range of PWA), with the consideration that aging could be one of the factors that affect learning. The series of experiments involved in this thesis have demonstrated evidence of learning in PWA, although overall performance was reduced compared to both control groups and learning was more evident in some conditions than others. This chapter begins by summarising the learning tasks and their findings by chapter, before moving on to the discussion of the findings on the ability to learn and its relationship with cognitive functions among PWA.

7.2. Summary of previous chapters

Chapter one started by reviewing the existing literature on learning of linguistic (Kelly & Armstrong, 2009; Tuomiranta et al.; 2011) and non-linguistic (Brookshire, 1969; Tikofsky and Reynolds; 1962, 1963) material in PWA, and then moved on to works that looked at four cognitive functions, namely language, memory, attention, and executive function, and how these functions affected PWA in terms of performing various language tasks. The gap among the existing works mainly lies in a lack of systematic evidence on whether PWA demonstrate ability to learn both linguistic and non-linguistic material in the same learning tasks. Moreover, whether cognitive impairments influence the performance of PWA or whether the deficits observed in cognitive domains stem from their language impairments. In addition, a few methods that have been consistently reported to benefit learning among healthy subjects as well as PWA were discussed as the foundations of the design of the series of experiments presented in the later chapters (chapter three, four, and five).

Chapter two further extends the discussion on cognitive functions and their potential effects on performance. The rationale of selecting appropriate assessments to investigate the impact, if any, of reduced cognitive functions on learning was presented, followed by descriptions of the assessments chosen. Finally, a cognitive profile of each individual with aphasia involved in this study was built based on their performance on the cognitive assessments. Brief reports on individual participants with aphasia were given in the end of the chapter, with attention drawn to any outstanding performance on the cognitive assessments. Tables were used to summarise the performance of PWA in various cognitive assessments.

In *chapter three*, the first two learning tasks of the series of experiments were presented. The non-incremental (experiment 1a) and incremental (experiment 1b) learning tasks set out to examine one of the fundamental research questions – whether PWA can learn new information. Since the study aims to examine the ability to learn not only linguistic information but also non-linguistic information, the materials involved were varied in terms of ‘linguistic load’. It was expected that, due to the language impairments, PWA would show, most evidently, reduced performance on learning of linguistic-heavy material, in comparison to the control groups; as the linguistic load of the material decreased (from real words to non-words to animal sounds) control participants lost the benefit of using language knowledge to facilitate learning, and the patterns of learning generated by PWA might be closer to those observed in the control groups, though still at reduced level. What is more, the two approaches employed to direct learning offered further insight into potential influence of memory. If aphasia is accompanied by reduced STM, incremental learning, which is an approach to minimise memory load and to prevent proactive interference, should benefit PWA as well as the two control groups.

The results showed a great range of individual difference among PWA. However, as a group, the learning outcomes of PWA were not sensitive to the manipulation of linguistic load; that is, reduced learning was found across all conditions [linguistic (real words), semi-linguistic (non-words), & non-linguistic (animal sounds)] of the to-be-learnt stimuli. Looking at the two control groups, young participants performed at ceiling level in all linguistic conditions; on the other hand, the learning of older participants was influenced by linguistic conditions, as more visuo-auditory pairs of real words were learnt than non-words and animal sounds. In addition, none of the groups benefitted from incremental learning.

Chapter four describes a picture recognition task with old-new paradigm that aimed to detect the potential occurrence of implicit learning in visual modality and to what extent implicit memory is affected by the lag duration between repeated presentations of a visual stimulus. This experiment was inspired by the unexpected main effect of visual stimuli on learning reported in experiment 1a in chapter three. Whether implicit learning happened was determined via observing the change in reaction time toward repeatedly presented pictures, whilst how lag duration might influence outcome(s) of implicit learning was determined by recording the accuracy of the responses. The results suggested that PWA demonstrated the ability to learn implicitly. The patterns of improvement in reaction time and accuracy generated by PWA were similar to the their age-matched control group; each repeated presentation of a picture significantly shortened the participants' reaction time and increased the accuracy of responses, indicating that implicit memory trace had formed. Also, implicit learning was observed even when the lag durations were extended to up to 20 intervening items, suggesting that the repetition priming effect could last for at least 20 intervening items, or possibly further.

Chapter five comprised massed and spaced learning tasks; it has been frequently reported that massed practice boosts immediate recollection whilst spaced practice leads to better long-term retention of information. This experiment set out to look at whether learning outcomes are affected by the manipulation of the way that the to-be-learnt items are practiced during the study phase. What is more, since PWA were capable of learning visually presented items implicitly (reported in chapter four), this experiment further investigated whether massed and spaced practice affects explicit and implicit memory in the same manner regardless of the to-be-learnt material involved, linguistic or non-linguistic.

The experiment (detailed in chapter five) involved learning of visually presented word-pairs as well as picture-pairs in two separate learning tasks of exactly the same experimental design. The experiment consisted of two sessions: one involved a study phase followed by an immediate cued-recall task (10 minutes after study) and the other, approximately two days apart from the first one, consisted of a delayed recognition task and a delayed cued-recall task. The findings showed that all three groups of participants generated similar trends in the cued-retrieval practice during the study phase, the two cued-recall tasks, and the delayed recognition task. The benefit of massing over spacing was evident in word-pair/picture-pair learning in the study phase. Spaced-practiced pairs were retained better in the delayed cued-recall task in comparison with massed-practiced pairs; this effect extended to delayed recognition, in which spaced-practiced items were recognised more accurately.

In *chapter six*, the analysis focused on exploring the relation between the learning outcomes (reported in chapter three, four, & five) and the cognitive functions assessed in this study (reported in chapter two). Prior to the analyses, assessments and learning outcomes were conveyed into *z*-scores (details in chapter 6.2). Then, a preliminary analysis of Pearson's correlation coefficient was applied to the dataset, in which scores for each assessment and learning task were considered for individual participants. The results indicated that tests of cognitive functions largely correlated with one another and the same patterns were observed among learning tasks; only minimal correlations were found between cognitive functions and learning outcomes.

To investigate whether lack of correlation between cognitive functions and learning resulted from lack of statistic power of individual tests, composite scores for various cognitive domains and learning tasks were created (detailed description in chapter 6.2.2.). A further Pearson's correlation coefficient was conducted to examine whether correlation existed among the cognitive variables (language production, verbal STM, non-verbal STM, semantic memory, recognition memory, visual attention, auditory attention, & executive function) and variables of learning (pair-associative learning, implicit learning, massed learning, spaced learning, recognition of massed-practiced items, & recognition of spaced-practiced items). Yet, the results were in line with the preliminary analysis; that is, cognitive functions mostly correlated with one another and some correlations were observed among learning tasks but no correlation was shown across the two types of variable.

7.3. Learning deficit and impaired cognitive functions

7.3.1. Impaired learning ability?

In this section, the discussion focuses on whether aphasia is accompanied by learning deficit(s) based on the synthesised evidence reported in this thesis. To answer the fundamental question of the current study, whether PWA retain the ability to learn, the patterns of learning in each experiment were examined as a whole. In two out of the three experiments involved in the current study, PWA generated learning patterns that mirrored their age-matched control participants but at a reduced level. The findings suggest that, to certain extent, PWA are capable of learning new information. According to the results of Pearson's correlation coefficient conducted in chapter six, the learning tasks included in the thesis were further categorised into three types of learning, namely pair-associative learning, immediate recognition, and long-term recognition. The claim that PWA are able to learn new information is elaborated through unveiling the evidence presented throughout the thesis.

First of all, *pair-associative learning* ability was involved in non-incremental/incremental learning (experiment 1a & 1b) as well as massed/spaced learning (presented in chapter five). Although both learning tasks consisted of paired linguistic and non-linguistic materials, non-incremental/incremental learning employed visuo-auditory pairs whilst massed/spaced learning involved visually presented pairs. People with aphasia as a group performed much worse on non-incremental/incremental learning than massed/spaced learning. Moreover, in massed/spaced learning, PWA benefited from spaced practice for the cued-recall tasks and massed practice for immediate retrieval during study; these patterns were in line with the two groups of control participants. Yet, the patterns observed for non-incremental/incremental learning suggested otherwise; PWA not only performed at a significantly reduced level but also responded similarly to the two approaches of learning. Although PWA learnt real words better than the two conditions with decreased linguistic load, indicating that the patterns of learning were still similar to the controls, the wide range of individual difference among PWA made it hard to conclude whether the ability to learn was intact. In other words, in non-incremental/incremental learning tasks, some PWA demonstrated learning; others did not.

Two potential explanations are proposed to account for the differences observed in the two learning tasks. One possibility is that PWA have reduced ability to learn new information and incremental learning was not a beneficial approach to boost learning outcomes. This may explain why PWA who demonstrated learning in the non-incremental learning task (experiment 1a) also performed well in the incremental learning task (experiment 1b); for PWA who did not show learning at above chance level in the non-incremental learning task, the outcomes of learning did not improve via an incremental approach. Also, most PWA struggled as the number of to-be-learnt pairs increased and, therefore, took more trials to successfully match the pairs. By contrast, the age-matched control participants improved steadily trial by trial. Since making perseverative errors is one common phenomenon found in learning in PWA, it appears that the incremental learning approach did not efficiently prevent this from occurring, at least not in the current study. On the other hand, massing and spacing were two approaches that benefited immediate retrieval and delayed cue-recall respectively. However, whether the advantages of massing and spacing can be generalised to other learning tasks is yet to be explored.

The other possible explanation is that, in comparison with massed/spaced learning, non-incremental/incremental learning was more complex in nature due to the way the stimuli were presented. The materials for non-incremental/incremental learning were visuo-auditory pairs, which required participants to incorporate visual as well as auditory modality. As reviewed in chapter one, to be able to do so takes a fully functional language system to process visual and auditory input(s). Impaired processing route(s) in any of the modalities may lead to reduced ability to learn the pairs. By contrast, massed/spaced learning involved only visually presented pairs. Hence, regardless of deficit of processing auditory input, PWA with intact visual processing were likely to be able to learn the pairs, although PWA were still expected to perform worse than the control participants due to their language impairment, and they did, particularly in the case of learning word-pairs.

The second ability to be assessed was *immediate recognition*, which was involved in performing the picture recognition that tapped into implicit learning (described in chapter four). People with aphasia as a group demonstrated the capability of performing immediate recognition of pictures over a lag period of up to 20 intervening items before the subsequent presentations. Moreover, the benefit of repeated presentation was observable via increased accuracy as well as decreased RT. The patterns of improvement generated by PWA in the implicit learning tasks fully mirrored the patterns generated by the control participants. Although the overall RT generated by PWA was significantly longer than the two control groups, this was not interpreted as a potential learning deficit due to the fact that reduced RT was recorded across all learning tasks and could result from impaired motor control, which is not discussed in the thesis. The findings indicate that PWA had intact immediate recognition ability, at least in the case involving pictorial stimuli; also, learning occurred implicitly via repeated presentations of a to-be-learnt item. Nevertheless, the benefit of repeated presentations reported here cannot be generalised without further evidence. Since the experiment involved presentations of single pictures one at a time, the same effect might not be found in tasks with a pair-associative learning paradigm.

Thirdly, the ability to perform long-term (or delayed) recognition was examined with delayed recognition of massed- and spaced-practiced items. The task was originally aimed at exploring whether massed- and spaced-practiced pairs were learnt implicitly by testing participants' delayed recognition of individual items belonging to the to-be-learnt pairs. That is, although participants might not be able to explicitly recall the two words/pictures in a pair, it is likely that they would remember seeing the words/pictures in the to-be-learnt pairs. However, the performance on delayed recognition did not correlate with immediate recognition; this finding is interpreted as delayed recognition requiring explicit retrieval. That is, explicit memory, rather than implicit memory, was involved in the delayed recognition task. Furthermore, although being considered as an explicit memory task, no correlation was found among delayed recognition and pair-associative learning tasks. It can be argued that explicit retrieval of single items and making pair associations are two tasks of different nature; therefore, performance did not correlate.

In general, this thesis provides evidence that supports the argument that PWA are capable of learning new information, although the ability to learn is reduced. Also, the difficulties reported in learning seem to be task-specific. It is likely that an overly-complex task could overload the reduced learning ability in PWA.

7.3.2. Co-occurrence of learning and cognitive deficits?

In this thesis, the purpose of examining cognitive functions in PWA is to identify potential cognitive factors that impact learning. As the amount of literature on the relationship between cognitive functions and the performance of PWA on language tasks grows (see chapter one and two for the review of literature), this study aimed to further investigate the statements that 1) the integrity of cognitive functions influence task performance and 2) scores on cognitive assessments might predict outcomes of learning.

Four perspectives, cognition, language, memory, attention and executive function, were assessed with sub-tests (listed in chapter two) that tapped into various domains of the cognitive functions. The row scores of individual assessments generated by the PWA who took part in the study were presented in the tables in chapter two with outstanding performances highlighted. The results of cognitive assessments demonstrated that the study had recruited a group of PWA with a variety of cognitive profiles (individual case reported in chapter 2.4). The row scores of these sub-tests were converted into *z*-scores (see chapter 6.2) prior to the preliminary analysis that examined potential correlation(s) between cognitive functions and learning outcomes.

The findings in the current study contradict earlier studies suggesting positive correlations between the outcomes of cognitive assessments and performance on various language tasks (Caspari et al., 1998; Gupta & Tisdale, 2009; Lambon Ralph et al., 2010). The correlations observed were restricted among outcomes of cognitive assessments and did not extend to the performance on learning tasks. These patterns of correlation remained even when the sub-scores were categorised and merged into composite variables that tapped into more general aspects of cognitive functions.

The lack of correlation between the four cognitive perspectives assessed and the performance on learning indicates that learning ability is independent from cognitive functions, at least in the cases of the learning tasks and cognitive assessments involved in this thesis. It can be argued further that the previous findings that reported correlation between cognitive functions and learning usually involved assessments of language functions and learning of linguistic material or language tasks; therefore, the effect reported could be task-specific and cannot be generalised.

In summary, despite the fact that the PWA who took part in the study demonstrate various deficits in different cognitive domains, cognitive functions were not found to be the key factors that determined their ability to learn new information. Instead, correlations were observed among the cognitive functions assessed in the current study (details described in chapter 6.2.2), suggesting the possibility that cognitive skills rely heavily on each other and can be difficult to disentangle within tasks.

7.4. Implications and future research

7.4.1. Potential implications for speech and language therapy

The current study has demonstrated that PWA as a group are capable of learning not only new linguistic but also non-linguistic material. The patterns of learning generated by PWA broadly mirrored age-matched control participants, indicating that, despite the language deficits, PWA are likely to benefit from most learning approaches that have been reported to boost learning outcomes. Nonetheless a wide range of individual difference was found in non-incremental versus incremental learning, suggesting that individuals with aphasia responded to the learning approaches differently. Hence, in clinical settings, it is important to take individual differences into account.

Although the findings in the current study lead to the consideration that learning is independent from cognitive ability, building a cognitive profile for individual with aphasia is still important, based on the synthesis of findings among the existing literature and in this thesis. It is possible that cognitive functions as a whole might not be able to determine one’s ability to learn new information. Yet, a cognitive assessment that examines the specific sub-domain of cognition that is also required in a learning task might still reveal potential relationship between the two abilities. For example, PWA showed distinct learning outcomes on the two pair-associative learning tasks; the majority of PWA failed to learn visuo-auditory pairs but were able to maintain the newly learnt visual pairs for up to 48 hours, at least. This phenomenon pointed to potentially impaired visual and/or auditory processing or reduced ability to integrate the two. A detailed assessment that examines sub-domains of cognitive functions might unveil the deficit(s) at an early stage and help the therapist to develop tasks that suit a participant better.

Moreover, the benefit of spaced learning was evident among the PWA who took part in the experiment and its long-term effect was observed at 48-hour delay. It is worth considering incorporating this approach in terms of distributing the to-be-learnt material in single therapy session. Also, the benefit of spaced learning could be maximised with repeated presentations of the target stimuli.

7.4.2. Limitations and future research

The main objective of the thesis is to investigate whether PWA retain the ability to learn; since the answer is positive, more systematic design of learning tasks should be developed to further explore under what circumstances the learning of PWA benefits the most. The current study is insufficient in the way that different approaches to directing learning were examined with different sets of stimuli. For instance, PWA did not respond differently to non-incremental and incremental learning approach; yet, this conclusion was drawn under the circumstance that the to-be-learnt material was visuo-auditory pairs. It is unknown whether the result(s) would vary if a different set of to-be-learnt items was used; the same issue applies to the benefit found in massed/spaced learning.

Moreover, when taking cognitive functions into account, the choice of cognitive assessment(s) should be more domain-specific as well as task-related. The current study reported correlation among language production and other variables of cognition. Although it can be argued that cognitive functions are closely related and not to be disentangled easily, an alternative account is that the tasks chosen for the study were mostly verbal and, therefore, performance on the cognitive assessments was influenced by language deficit(s). Also, the cognitive assessments involved in the thesis were originally chosen to examine more general aspects of cognition. That is, the cognitive functions these assessments tapped into were not necessarily involved in the learning tasks selected; this could potentially account for the lack of correlation between cognitive functions and learning. To further investigate learning and what might be the factor(s) of impact, the choice of cognitive assessment should be more specific to the type of learning the study aims to explore.

Appendix A. Samples of Information sheet and consent form (for the participants) used in the learning experiments.

Information sheet of participants

Investigating pair-association learning of novel items

My name is Natalie Yu-Hsien Wang, I am a PhD student in Speech and Language Sciences at Newcastle University. I am doing a research study looking at the learning in people with aphasia and people without brain injuries and would like to invite you to participate. The research is based in Room B1, KGVI Building, Newcastle University.

The purpose of my study is to investigate how learning in people with aphasia differs from normal and how this can be used in developing possible treatments. You have been invited to take part because you meet one of the following criteria: people with aphasia, **native speakers** between **age 18 and 30**, or **age 40 and 80**.

I would be grateful if you would think about helping me in this study. This is voluntary and you have the right to withdraw your consent at any time.

As part of this study you will be asked to **attend three sessions** lasting about 45 minutes; the first session may be longer due to the necessity of completing two memory span assessments. There should be a week interval between the session(s) you have attended. In this you will be asked to learn 10 paired (novel) objects and sounds and will be assessed immediately after learning. Each session finishes when you learn all ten items or, alternatively, you have experienced 6 runs of the assessment. In the first session, all participants will have to go through two memory assessments, a verbal span task and a nonverbal span task, before starting the learning trials.

The data that I collect will be confidential and not traceable to you. I would, however, be happy to share the results with you if like. I will keep your results in a secure place at Newcastle University and it will be available only to me, my supervisor, my examiners and other members of the research team. It will only be used for research purposes.

Thank you very much for considering this. If you agree to take part, please sign one of the enclosed consent forms and return it to me. Please keep this information sheet and the other consent form for future reference.

This project was approved by the Speech and Language Sciences Research Ethics Committee at the University.

Experimenter's contact details:

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Consent Form for Participant

Investigating pair-association learning of novel items

I agree to take part in the study looking into the patterns of learning in people with aphasia and people without brain injuries with Natalie Yu-Hsien Wang and her supervisors, Prof. David Howard and Dr. Julie Morris, at Newcastle University.

I have listened to the debriefing about the procedures and read or listened to and understood the information sheet for people taking part. Natalie has answered any questions that I have had.

I understand that my results will be stored in a secure location at Newcastle University and that the data will be used only for research purposes.

I understand that my results will also be treated confidentially.

I also understand that I can withdraw from the study at any time without explanation or penalty.

Experimenter's contact details:

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Signature

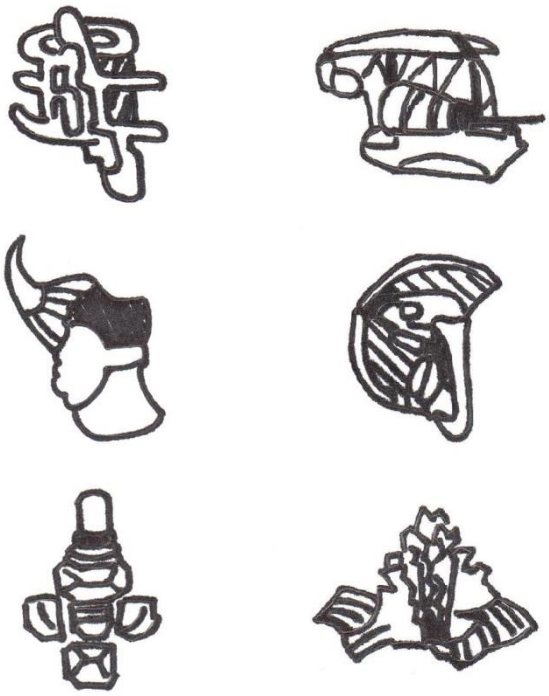
Name (in capitals)

Date

Person taking consent

Appendix B. Material for non-incremental and incremental learning tasks (see chapter three)

Table B.1 The three sets of visual stimuli used in the learning tasks.

stimuli type	stimuli	
Chinese characters	夜	他
	巾	己
	甲	父
	明	安
	玉	山
non-objects		

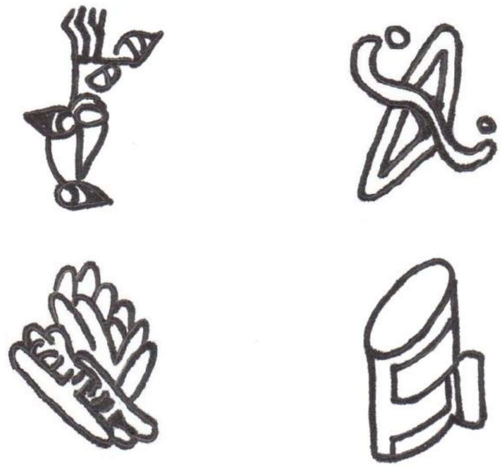
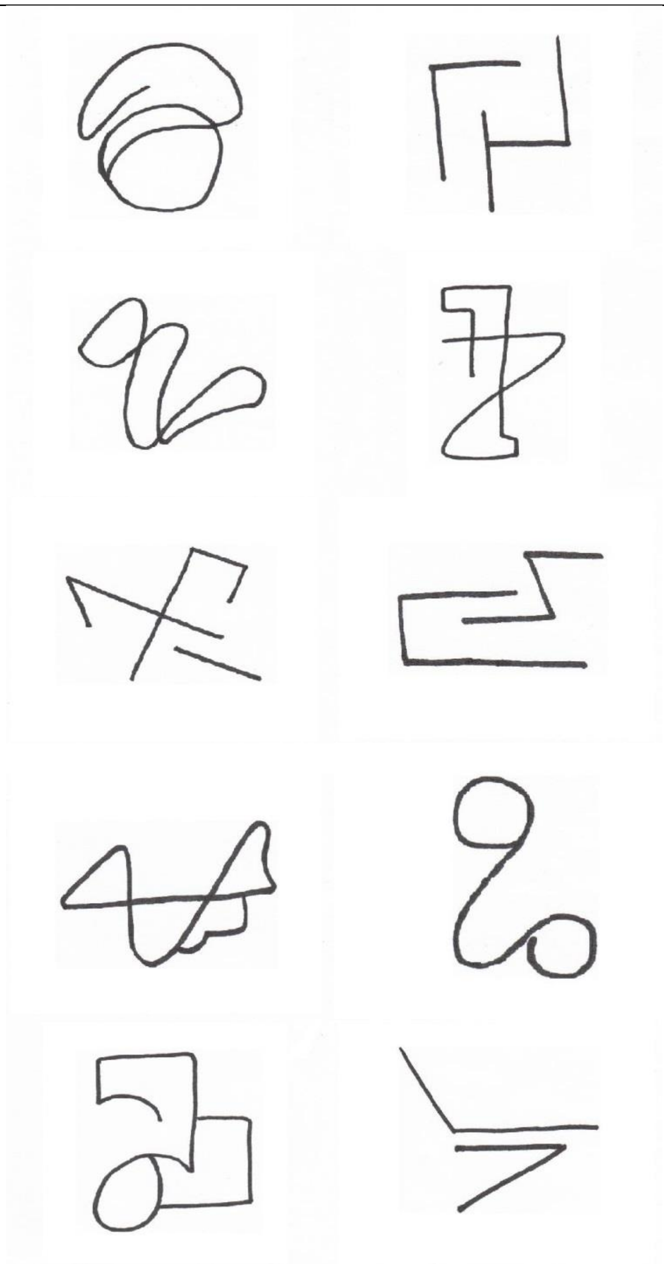
stimuli type	stimuli
	
nonsense line-drawings	

Table B.2. Auditory stimuli used in in the learning tasks, excluding animal sounds (audio files only).

real words	non-words
belief	Bolen
region	Daruke
domain	Gapet
perceive	Kovete
debate	Penak
margin	Tusen
colleague	Bekefe
defeat	Gisek
tonic	Punel
format	Tefob

Appendix C. Material massed vs. spaced learning task (see chapter five).

Table C.1. word-pairs and their correspondents in one of the three cued-retrieval trials.

to-be-learnt pairs		words involved in cued-retrieval	
cue	***target***	***distractor***	***filler***
artist	brush	drawing	feather
ball	chain	score	kitchen
basin	bath	tap	candidate
castle	tower	hill	cleaner
cotton	mill	thread	clue
disk	soup	flat	empire
drug	medicine	pill	journalist
engine	machine	driver	pool
fence	paint	barrier	fat
forest	mountain	dark	postman
gate	path	lock	tea
handle	pot	mug	murder
hook	coat	nail	butterfly
ice	cake	fridge	bridge
iron	metal	steam	horse
judge	trial	judgement	plot
kit	drum	bicycle	present
ladder	rope	stair	grass
meat	cow	flesh	brass
nation	flag	league	echo
pan	flash	bowl	cash
rabbit	ear	pie	motor
ruler	wood	plastic	crown
seat	bus	leather	beef
tape	deck	race	dragonfly
tent	pole	green	cling
victim	criminal	prey	wheel
weapon	arrow	rifle	disk
wind	storm	weather	sky
wife	marriage	daughter	ladder

Table C.2. Examples of picture-pairs of the four category and their correspondents in one of the three cued-retrieval trials.

	to-be-learnt pairs		words involved in cued-retrieval	
	cue	***target***	***distractor***	***filler***
scenery				
object				

	to-be-learnt pairs		**words involved in cued-retrieval**	
	cue	***target***	***distractor***	***filler***
water				
portrait/ animal				

Appendix D. Outcomes of Pearson's correlation coefficient of PWA with high and low language production scores as two separate groups.

Table D.1 Outcomes of Pearson's correlation coefficient between the cognitive abilities and the learning abilities – PWA with above-zero language production scores.

	Executive function	Semantic memory	Non-verbal STM	Language Production	Verbal STM	Recognition memory	Visual attention	Auditory attention	Pair-associative learning	Implicit learning	Massed learning	Spaced learning	Recognition of massed items	Recognition of spaced items
Executive function	1	.382	-.703	-.522	-.534	.564	-.626	.323	.476	.396	-.317	-.626	-.623	-.868
Semantic memory		1	-.602	.527	.490	.586	.116	-.550	-.664	.671	-.761	-.547	.447	-.451
Non-verbal STM			1	-.030	-.056	-.611	.270	-.033	.162	-.748	.577	.741	.243	.945
Language Production				1	.919**	.040	.666	-.829*	-.750	.481	-.603	-.297	.639	-.130
Verbal STM					1	-.051	.467	-.814*	-.969*	.590	-.602	-.317	.646	-.190
Recognition memory						1	.172	-.049	-.266	.014	-.046	-.034	.557	-.333
Visual attention							1	-.297	-.104	-.103	-.265	-.007	.857	-.030
Auditory attention								1	.852	-.170	.231	-.136	-.831	-.332
Pair-associative learning									1	-.619	.923	.152	-.975	.026
Implicit learning										1	-.969*	-.976*	-.301	-.880
Massed learning											1	.929	.220	.737
Spaced learning												1	.502	.906
Recognition of massed items													1	.473
Recognition of spaced items														1

Note 1) **. $p < 0.01$. *. $p < 0.05$.

2) Correlation value(s) highlighted in green was significant correlation before Holm correction was conducted.

Correlation value(s) highlighted in yellow was correlation that remained significant after Holm correction.

Table D.2 Outcomes of Pearson's correlation coefficient – between the cognitive abilities and the learning abilities PWA with below-zero language production scores.

	Executive function	Language production	Verbal STM	Recognition memory	Visual attention	Auditory attention	Non-verbal STM	Semantic memory	Pair-associative learning	Implicit learning	Massed learning	Spaced learning	Recognition of massed items	Recognition of spaced items
Executive function	1	.066	-.146	-.025	.063	.869**	.194	.046	.257	-.486	-.221	-.021	.361	.491
Language production		1	.352	.948**	.422	.398	-.537	.522	.106	.231	-.429	-.656	.385	.144
Verbal STM			1	.093	.845*	.016	.048	-.224	.398	.398	-.351	-.180	.072	.210
Recognition memory				1	.229	.278	.352	.884**	-.219	-.076	-.151	-.574	.829	.718
Visual attention					1	.339	-.722	-.181	.382	.675	-.028	.055	.927	.653
Auditory attention						1	-.100	.298	.017	-.281	-.520	-.324	.936	.612
Non-verbal STM							1	-.100	.099	-.316	.292	-.132	.383	.535
Semantic memory								1	.128	.053	.051	-.208	.890**	.755*
Pair-associative learning									1	.424	.766	.663	.041	-.060
Implicit learning										1	-.405	-.182	-.474	-.724
Massed learning											1	.770*	.196	.132
Spaced learning												1	-.118	-.010
Recognition of massed items													1	.880**
Recognition of massed items														1

Note 1) **. $p < 0.01$. *. $p < 0.05$.

2) Correlation value(s) highlighted in green was significant correlation before Holm correction was conducted. Correlation value(s) highlighted in yellow was correlation that remained significant after Holm correction.

References

Abel, S., Schultz, A., Radermacher, I., Willmes, K., & Huber, W. (2005). Decreasing and increasing cues in naming therapy for aphasia. *Aphasiology, 19*(9), 831-848.

Avons, S. E., Wright, K. L., & Pammer, K. (1994). The word-length effect in probed and serial-recall. *Quarterly Journal of Experimental Psychology Section a-Human Experimental Psychology, 47*(1), 207-231.

Baddeley, A. (2003). Working memory: Looking back and looking forward. *Nature Reviews Neuroscience, 4*(10), 829-839.

Baddeley, A., Lewis, V., Eldridge, M., & Thomson, N. (1984). Attention and retrieval from long-term-memory. *Journal of Experimental Psychology-General, 113*(4), 518-540.

Balota, D. A., Duchek, J. M., Sergent-Marshall, S. D., & Roediger, H. L. (2006). Does expanded retrieval produce benefits over equal-interval spacing? Explorations of spacing effects in healthy aging and early stage Alzheimer's Disease. *Psychology and Aging, 21*(1), 19-31.

Baron, R., Richard Hanley, J., Dell, G. S., & Kay, J. (2008). Testing single- and dual-route computational models of auditory repetition with new data from six aphasic patients. *Aphasiology, 22*(1), 62-76.

Basso, A., Marangolo, P., Piras, F., & Galluzzi, C. (2001). Acquisition of new "words" in normal subjects: A suggestion for the treatment of anemia. *Brain and Language, 77*(1), 45-59.

Basso, A., Spinnler, H., Vallar, G., & Zanobio, M. E. (1982). Left Hemisphere damage and selective impairment of auditory verbal short-term memory. A case study. *Neuropsychologia, 20*(3), 263-274.

Best, W., Herbert, R., Hickin, J., Osborne, F., & Howard, D. (2002). Phonological and orthographic facilitation of word-retrieval in aphasia: Immediate and delayed effects. *Aphasiology, 16*(1-2), 151-168.

Bhatarah, P., Ward, G., Smith, J., & Hayes, L. (2009). Examining the relationship between free recall and immediate serial recall: Similar patterns of rehearsal and similar effects of word length, presentation rate, and articulatory suppression. *Memory & Cognition, 37*(5), 689-713.

Bjork, R. A. (1994). Memory and metamemory considerations in the training of human beings. In J. Metcalfe & A. Shimamura (Eds.), *Metacognition: Knowing about knowing* (pp. 185-205). Cambridge, MA: MIT Press.

Bjork, R. A. (1999). Assessing our own competence: Heuristics and illusions. In D. Gopher & A. Koriat (Eds.), *Attention and Performance Xvii: Cognitive Regulation of Performance: Interaction of Theory and Application* (Vol. 17, pp. 435-459).

Brookshire, R. H. (1967). Speech pathology and the experimental analysis of behavior. *Speech and hearing Dis., 32*, 215-227.

Brookshire, R. H. (1969). Probability learning by aphasic subjects. *Journal of speech and hearing research, 12*(4), 857-864.

Brown, A. A., & Bodner, G. E. (2011). Re-examining dissociations between remembering and knowing: Binary judgments vs. independent ratings. *Journal of Memory and Language, 65*(2), 98-108.

Burgio, F., & Basso, A. (1997). Memory and aphasia. *Neuropsychologia, 35*(6), 759-766.

Carpenter, S. K., & DeLosh, E. L. (2005). Application of the testing and spacing effects to name learning. *Applied Cognitive Psychology, 19*, 619-636.

Caspari, I., Parkinson, S. R., LaPointe, L. L., & Katz, R. C. (1998). Working memory and aphasia. *Brain and Cognition, 37*(2), 205-223.

Cepeda, N. J., Pashler, H., Vul, E., Wixted, T., & Rohrer, D. (2006). Distributed practice in verbal recall tasks: A review and quantitative synthesis. *Psychological Bulletin, 132*(3), 354-380.

Challis, B. H. (1993). Spacing effects on cued-memory tests depend on level of processing. *Journal of Experimental Psychology-Learning Memory and Cognition, 19*(2), 389-396.

Christensen, S. C., & Wright, H. H. (2010). Verbal and non-verbal working memory in aphasia: What three n-back tasks reveal. *Aphasiology, 24*(6-8), 752-762.

Cohen, R., Woll, G., & Ehrenstein, W. H. (1981). Recognition deficits resulting from focussed attention in aphasia. *Psychol Res, 43*, 391-405.

Connor, L. T., Albert, M. L., Helm-Estabrooks, N., & Obler, L. K. (2000). Attentional modulation of language performance. *Brain and Language, 71*(1), 52-55.

Conrad, R. (1960). Serial order intrusions in immediate memory. *British Journal of Psychology, 51*, 45-48.

Conroy, P., & Ralph, M. A. L. (2012). Errorless learning and rehabilitation of language and memory impairments Introduction. *Neuropsychological Rehabilitation, 22*(2), 137-137.

Conroy, P., Sage, K., & Ralph, M. A. L. (2009). Errorless and errorful therapy for verb and noun naming in aphasia. *Aphasiology, 23*(11), 1311-1337.

Craik, F. I. M. (1970). The fate of primary memory items in free recall. *Journal of Verbal Learning and Verbal Behavior, 9*, 143-148.

Craik, F. I. M. (2002). Levels of processing: Past, present...and future? *Memory, 10*(5/6), 305-318.

Craik, F. I. M., & Tulving, E. (1975). Depth of processing and the retention of words in episodic memory. *Journal of Experimental Psychology: General, 104*(3), 268-294.

Craik, F. I. M., & Watkins, M. J. (1973). The role of rehearsal in short-term memory. *Journal of Verbal Learning and Verbal Behavior, 12*, 699-607.

Crawford, J. R., & Howell, D. C. (1998). Regression equations in clinical neuropsychology: An evaluation of statistical methods for comparing predicted and obtained scores. *Journal of Clinical and Experimental Neuropsychology, 20*(5), 755-762.

Crowder, R. G. (1976). *Principles of learning and memory.* Hillsdale, NJ: Erlbaum.

Cull, W. L. (2000). Untangling the benefits of multiple study opportunities and repeated testing for cued recall. *Applied Cognitive Psychology, 14*, 215-235.

Dell, G. S., Schwartz, M. F., Martin, N., Saffran, E. M., & Gagnon, D. A. (1997). Lexical access in aphasic and nonaphasic speakers. *Psychological Review, 104*(4), 801-838.

Drew, R. L., & Thompson, C. K. (1999). Model-based semantic treatment for naming deficits in aphasia. *Journal of Speech Language and Hearing Research, 42*(4), 972-989.

Ebbinghaus, H. (1964). *A contribution to experimental psychology.* (H. A. Ruger, C. E. Bussenius & E. R. Hilgard, Trans.). New York, NY: Dover Publications.

Erickson, R. J., Goldinger, S. D., & LaPointe, L. L. (1996). Auditory vigilance in aphasic individuals: Detecting nonlinguistic stimuli with full or divided attention. *Brain and Cognition, 30*, 244-253.

Evans, G. A. L., Ralph, M. A. L., & Woollams, A. M. (2012). What's in a word? A parametric study of semantic influences on visual word recognition. *Psychonomic Bulletin & Review, 19*(2), 325-331.

Evans, J. J., Wilson, B. A., Schuri, U., Andrade, J., Baddeley, A., Bruna, O., & Taussik, I. (2000). A comparison of "errorless" and "trial-and-error" learning methods for teaching individuals with acquired memory deficits. *Neuropsychological Rehabilitation, 10*(1), 67-101.

Fillingham, J. K., Hodgson, C., Sage, K., & Ralph, M. A. L. (2003). The application of errorless learning to aphasic disorders: A review of theory and practice. *Neuropsychological Rehabilitation, 13*(3), 337-363.

Fillingham, J. K., Sage, K., & Ralph, M. A. L. (2005a). Further explorations and an overview of errorless and errorful therapy for aphasic word-finding difficulties: The number of naming attempts during therapy affects outcome. *Aphasiology, 19*(7), 597-614.

Fillingham, J. K., Sage, K., & Ralph, M. A. L. (2005b). Treatment of anomia using errorless versus errorful learning: are frontal executive skills and feedback important? *International Journal of Language & Communication Disorders, 40*(4), 505-523.

Fillingham, J. K., Sage, K., & Ralph, M. A. L. (2006). The treatment of anomia using errorless learning. *Neuropsychological Rehabilitation, 16*(2), 129-154.

Filoteo, J. V., Friedrich, F. J., Rabbel, C., & Stricker, J. L. (2002). Visual perception without awareness in a patient with posterior cortical atrophy: Impaired explicit but not implicit processing of global information. *Journal of the International Neuropsychological Society, 8*, 461-472.

Flowers, C. R. (1975). Proactive interference in short-term recall by aphasic, brain-damaged nonaphasic and normal subjects. *Neuropsychologia, 13*(1), 59-68.

Forster, K. I., & Forster, J. C. (2003). A Windows display program with millisecond accuracy. *Behavior Research Methods Instruments & Computers, 35*(1), 116-124.

Francis, D. R., Clark, N., & Humphreys, G. W. (2003). The treatment of an auditory working memory deficit and the implications for sentence comprehension abilities in mild "receptive" aphasia. *Aphasiology, 17*(8), 723-750.

Freed, D. B., Marshall, R. C., & Phillips, D. S. (1998). Comparison of semantically and phonemically based training procedures in an overlearned naming task. *Perceptual and motor skills, 87*, 795-800.

Fridriksson, J., Nettles, C., Davis, M., Morrow, L., & Montgomery, A. (2006). Functional communication and executive function in aphasia. *Clinical Linguistics & Phonetics, 20*(6), 401-410.

Friedmann, N., & Gvion, A. (2003). Sentence comprehension and working memory limitation in aphasia: A dissociation between semantic-syntactic and phonological reactivation. *Brain and Language, 86*(1), 23-39.

Gathercole, S. E. (2006). Nonword repetition and word learning: The nature of the relationship. *Applied Psycholinguistics, 27*(4), 513-543.

Graf, P., & Schacter, D. L. (1985). Implicit and explicit memory for new associations in normal and amnesic subjects. *Journal of Experimental Psychology-Learning Memory and Cognition, 11*(3), 501-518.

Gupta, P. (2003). Examining the relationship between word learning, nonword repetition, and immediate serial recall in adults. *Quarterly Journal of Experimental Psychology Section a-Human Experimental Psychology, 56*(7), 1213-1236.

Gupta, P., Lipinski, J., Abbs, B., Lin, P. H., Aktunc, E., Ludden, D., & Newman, R. (2004). Space aliens and nonwords: Stimuli for investigating the learning of no vel word-meaning pairs. *Behavior Research Methods Instruments & Computers, 36*(4), 599-603.

Gupta, P., & Tisdale, J. (2009). Does phonological short-term memory causally determine vocabulary learning? Toward a computational resolution of the debate. *Journal of Memory and Language, 61*, 481-502.

Hamilton, A. C., & Martin, R. C. (2005). Dissociations among tasks involving inhibition: A single-case study. *Cognitive Affective & Behavioral Neuroscience, 5*(1), 1-13.

Hamilton, A. C., & Martin, R. C. (2007). Proactive interference in a semantic short-term memory deficit: Role of semantic and phonological relatedness. *Cortex, 43*(1), 112-123.

Hanley, J. R., Dell, G. S., Kay, J., & Baron, R. (2004). Evidence for the involvement of a nonlexical route in the repetition of familiar words: A comparison of single and dual route models of auditory repetition. *Cognitive Neuropsychology, 21*(2-4), 147-158.

Hanley, J. R., Kay, J., & Edwards, M. (2002). Imageability effects, phonological errors, and the relationship between auditory repetition and picture naming: Implications for models of auditory repetition. *Cognitive Neuropsychology, 19*(3), 193-206.

Haslam, C., Hodder, K. I., & Yates, P. J. (2011). Errorless learning and spaced retrieval: How do these method fare in healthy and clinical populations? *Journal of Clinical and Experimental Neuropsychology, 33*(4), 432-447.

Helm-Estabrooks, N. (2002). Cognition and aphasia: a discussion and a study. *Journal of Communication Disorders, 35*, 171-186.

Helm-Estabrooks, N., Connor, L. T., & Albert, M. L. (2000). Treating attention to improve auditory comprehension in aphasia. *Brain and Language, 74*(3), 469-472.

Hockley, W. E. (2008). The picture superiority effect in associative recognition. *Memory & Cognition, 36*(7), 1351-1359.

Howard, D., & Nickels, L. (2005). Separating input and output phnology: semantic, phonological, and orthographic effects in short-term memory impairment. *Cognitive Neuropsychology, 22*(1), 42-77.

Howard, D., & Patterson, K. (1992). *Pyramids and Palm Trees: A test of semantic access from pictures and words.* UK: Thames Valley publishing.

Howard, D., Patterson, K., Franklin, S., Orchardlisle, V., & Morton, J. (1985). Treatment of word retrieval deficits in aphasia - a comparison of 2 therapy methods. *Brain, 108*(4), 817-829.

Hulme, C., Maughan, S., & Brown, G. D. A. (1991). Memory for familiar and unfamiliar words - evidence for a long-term-memory contribution to short-term-memory span. *Journal of Memory and Language, 30*(6), 685-701.

Humphreys, G. W., Bickerton, W. L., Samson, D., & Riddoch, M. J. (2011). *The Birmingham Cognitive Screen (BCoS)*. London: Psychology press.

Hunting-Pompon, R., Kendall, D., & Moore, A. B. (2011). Examing attention and cognitive processing in participants with self-reported mild anomia. *Aphasiology, 25*(607), 800-812.

Jackson, C. E., Maruff, P. T., & Snyder, P. J. (2013). Massed versus spaced visuospatial memory in cognitively healthy young and older adults. *Alzheimer's & Dementia, 9*, S32-S38.

Kahana, M. J., & Howard, M. W. (2005). Spacing and lag effects in free recall of pure lists. *Psychological Bulletin & Reviews, 12*(1), 159-164.

Kalinyak-Fliszar, M., Kohen, F., & Martin, N. (2011). Remediation of language processing in aphasia: Improving activation and maintenance of linguistic representations in (verbal) short-term memory. *Aphasiology, 25*(10), 1095-1131.

Karpicke, J. D., & Blunt, J. R. (2011). Retrieval Practice Produces More Learning than Elaborative Studying with Concept Mapping. *Science, 331*(6018), 772-775.

Karpicke, J. D., & Roediger, H. L., III. (2007a). Expanding retrieval practice promotes short-term retention, but equally spaced retrieval enhances long-term retention. *Journal of Experimental Psychology-Learning Memory and Cognition, 33*(4), 704-719.

Karpicke, J. D., & Roediger, H. L., III. (2007b). Repeated retrieval during learning is the key to long-term retention. *Journal of Memory and Language, 57*(2), 151-162.

Karpicke, J. D., & Roediger, H. L., III. (2008). The critical importance of retrieval for learning. *Science, 319*(5865), 966-968.

Kelly, H., & Armstrong, L. (2009). New word learning in people with aphasia. *Aphasiology, 23*(12), 1398-1417.

Kessels, R. P. C., & de Haan, E. H. F. (2003). Implicit learning in memory rehabilitation: A meta-analysis on errorless learning and vanishing cues methods. *Journal of Clinical and Experimental Neuropsychology, 25*(6), 805-814.

Koenig-Bruhin, M., & Studer-Eichenberger, F. (2007). Therapy of short-term memory disorders in fluent aphasia: A single case study. *Aphasiology, 21*(5), 448-458.

Kole, J. A., & Healy, A. F. (2013). Is retrieval mediated after repeated testing? *Journal of Experimental Psychology: Learning, Memory, and Cognition, 39*(2), 426-427.

Kornell, N., & Bjork, R. A. (2008). Learning concepts and categories: Is spacing the "enemy of induction"? *Psychological Science, 19*(6), 585-592.

Kornell, N., Castel, A. D., Eich, T. S., & Bjork, R. A. (2010). Spacing as the friend of both memory and induction in young and older adults. *Psychology and Aging, 25*(2), 498-503.

Kroll, J. F., & Potter, M. C. (1984). Recognizing words, pictures, and concepts - a comparison of lexical, object, and reality decisions. *Journal of Verbal Learning and Verbal Behavior, 23*(1), 39-66.

Lambon Ralph, M. A., Snell, C., Fillingham, J. K., Conroy, P., & Sage, K. (2010). Predicting the outcome of anomia therapy for people with aphasia post CVA: Both language and cognitive status are key predictors. *Neuropsychological Rehabilitation, 20*(2), 289-305.

Leech, G., Rayson, P., and Wilson, A. (2001). *Word frequencies in written and spoken English based on the British National Corpus*. London: Longman.

Levelt, W. J. M. (1983). Monitoring and self-repair in speech. *Cognition, 14*(1), 41-104.

Locke, J. L., & Deck, J. W. (1978). Retrieval failure, rehearsal deficiency, and short-term memory loss in the aphasic adult. *Brain and Language, 5*, 227-235.

Logan, J. M., Castel, A. D., Haber, S., & Viehman, E. J. (2012). Metacognition and the spacing effect: The role of repetition feedback, and instruction on judgments of learning for massed and spaced rehearsal. *Metacognition Learning, 7*, 175-195.

Majerus, S., Perez, T. M., & Oberauer, K. (2012). Two distinct origins of long-term learning effects in verbal short-term memory. *Journal of Memory and Language, 66*(1), 38-51.

Marshall, R. C., Freed, D. B., & Karow, C. M. (2001). Learning of subordinate category names by aphasic subjects: A comparison of deep and surface-level training methods. *Aphasiology, 15*(6), 585-598.

Marshall, R. C., Freed, D. B., & Phillips, D. S. (1994). Labeling of novel stimuli by aphasic subjects - effects of phonological and self-cueing procedures. *Clinical Aphasiology*, *22*, 335-343.

Martin, E. (1968). Stimulus meaningfulness and paired-associate transfer: an encoding variability hypothesis. *Psychological Review, 75*(5), 421-441.

Martin, N., & Ayala, J. (2004). Measurements of auditory-verbal STM span in aphasia: Effects of item, task, and lexical impairment. *Brain and Language, 89*, 464-483.

Martin, N., Fink, R. B., Renvall, K., & Laine, M. (2006). Effectiveness of contextual repetition priming treatments for anomia depends on intact access to semantics. *Journal of the International Neuropsychological Society, 12*(6), 853-866.

Martin, N., Kohen, F., Kalinyak-Fliszar, M., Soveri, A., & Laine, M. (2012). Effects of working memory load on processing of sounds and meanings of words in aphasia. *Aphasiology, 26*(3-4), 462-493.

Martin, N., Lesch, M. F., & Bartha, M. C. (1999). Independence of input and output phonology in word processing and short-term memory. *Journal of Memory and Language, 41*, 3-29.

Martin, N., & Saffran, E. M. (1997). Language and auditory-verbal short-term memory impairments: Evidence for common underlying processes. *Cognitive Neuropsychology, 14*(5), 641-682.

Martin, N., & Saffran, E. M. (1999). Effects of word processing and short-term memory deficits on verbal learning: Evidence from aphasia. *International Journal of Psychology, 34*(5/6), 339-346.

Martin, N., Schwartz, M. F., & Kohen, F. P. (2006). Assessment of the ability to process semantic and phonological aspects of words in aphasia: A multi-measurement approach. *Aphasiology, 20*(2/3/4), 154-166.

Martin, R. C., & Allen, C. M. (2008). A disorder of executive function and its role in language processing. *Seminars in Speech and Language, 29*(3), 201-210.

Martin, R. C., Lesch, M. F., & Bartha, M. C. (1999). Independence of input and output phonology in word processing and short-term memory. *Journal of Memory and Language, 41*(1), 3-29.

Martini, P., & Maljkovic, V. (2009). Short-term memory for pictures seen once or twice. *Vision Research, 49*(13), 1657-1667.

McKone, E., & Trynes, K. (1999). Acquisition of novel traces in short-term implicit memory: priming for nonwords and new associations. *Memory & Cognition, 27*(4), 619-632.

Melton, A. W. (1970). The situation with respect to the spacing of repetitions and memory. *Journal of verbal learning and verbal behaviour*, *9*, 596-606.

Middleton, E. L., & Schwartz, M. F. (2012). Errorless learning in cognitive rehabilitation: A critical review. *Neuropsychological Rehabilitation, 22*(2), 138-168.

Morton, J. (1969). Interaction of information in word recognition. *Psychological Review, 76*(2), 165-178.

Moss, H., & Older, L. (1996). *Birkbeck word association norms*. Hove: Psychology Press.

Murray, L. L. (1999). Attention and aphasia: theory, research and clinical implications. *Aphasiology, 13*(2), 91-111.

Murray, L. L. (2000). The effects of varying attentional demands on the word retrieval skills of adults with aphasia, right hemisphere brain damage, or no brain damage. *Brain and Language, 72*(1), 40-72.

Murray, L. L. (2004). Cognitive treatments for aphasia: Should we and can we help attention and working memory problems? *Journal of Medical Speech-Language Pathology, 12*(3), XXV-XL.

Murray, L. L. (2012). Attention and Other Cognitive Deficits in Aphasia: Presence and Relation to Language and Communication Measures. *American Journal of Speech-Language Pathology, 21*(2), S51-S64.

Murray, L. L., Keeton, R. J., & Karcher, L. (2006). Treating attention in mild aphasia: Evaluation of attention process training-II. *Journal of Communication Disorders, 39*(1), 37-61.

Nickels, L. (2002). Improving word finding: Practice makes (closer to) perfect? *Aphasiology, 16*(10-11), 1047-1060.

Nozari, N., Kittredge, A. K., Dell, G. S., & Schwartz, M. F. (2010). Naming and repetition in aphasia: Steps, routes, and frequency effects. *Journal of Memory and Language, 63*, 541-559.

Pashler, H., Zarow, G., & Triplett, B. (2003). Is temporal spacing of tests helpful even when it inflates error rates? *Journal of Experimental Psychology: Learning, Memory, and Cognition, 29*(6), 1051-1057.

Patterson, K., & Shewell, C. (1987). Speak and spell: Dissociations and word-class effects. In M. Coltheart, G. Sartori & R. Job (Eds.), *The cognitive neuropsychology of language* (pp. 273-294). London: Lawrence Erlbaum Association.

Perruchet, P. (1989). The effect of spaced practice on explicit and implicit memory. *British Journal of Psychology, 80*, 113-130.

Potagas, C., Kasselimis, D., & Evdokimidis, I. (2011). Short-term and working memory impairments in aphasia. *Neuropsychologia, 49*, 2874-2878.

Purdy, M. (2002). Executive function ability in persons with aphasia. *Aphasiology, 16*(4/5/6), 549-557.

Ramsberger, G. (2005). Achieving conversational success in aphasia by focusing on non-linguistic cognitive WIN: A potentially promising new approach. *Aphasiology, 19*(10-11), 1066-1073.

Robertson, I. H., Ward, T., Ridgeway, V., & Nimmo-Smith, I. (1994). *The test of everyday attention.* Bury St. Edmunds, UK: Thames Valley Test Company.

Rodd, J. M., Gaskell, M. G., & Marslen-Wilson, W. D. (2004). Modelling the effects of semantic ambiguity in word recognition. *Cognitive Science, 28*(1), 89-104.

Roediger, H. L. (1990). Implicit memory - retention without remembering. *American Psychologist, 45*(9), 1043-1056.

Roediger, H. L., Gallo, D. A., & Geraci, L. (2002). Processing approaches to cognition: The impetus from the levels-of-processing framework. *Memory, 10*(5-6), 319-332.

Roediger, H. L., & Karpicke, J. D. (2006). Test-enhanced learning: Taking memory tests improves long-term retention. *Psychological Science, 17*(3), 249-255.

Roelofs, A. (1997). The WEAVER model of word-form encoding in speech production. *Cognition, 64*(3), 249-284.

Rogers, T. T., Ralph, M. A. L., Hodges, J. R., & Patterson, K. (2004). Natural selection: The impact of semantic impairment on lexical and object decision. *Cognitive Neuropsychology, 21*(2-4), 331-352.

Russo, R., Mammarella, N., & Avons, S. E. (2002). Toward a unified account of spacing effects in explicit cued-memory tasks. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 28*(5), 819-829.

Sage, K., Snell, C., & Ralph, M. A. L. (2011). How intensive does anomia therapy for people with aphasia need to be? *Neuropsychological Rehabilitation, 21*(1), 26-41.

Salis, C. (2012). Short-term memory treatment: Patterns of learning and generalisation to sentence comprehension in a person with aphasia. *Neuropsychological Rehabilitation, 22*(3), 428-448.

Schacter, D. L. (1994). Priming and multiple systems: perceptual mechanism of implicit memory. In D. L. Schacter & E. Tulving (Eds.), *Memory systems* (pp. 233-268). Cambridge, MA: MIT Press.

Schretlen, D. J. (2010). *Modified Wisconsin card sorting test (M-WCST).* Lutz, FL: Psychological Assessment Resources.

Seniow, J., Litwin, M., & Lesniak, M. (2009). The relationship between non-linguistic cognitive deficits and language recovery in patients with aphasia. *Journal of the Neurological Sciences, 283*(1-2), 91-94.

Silverberg, N., & Buchanan, L. (2005). Verbal mediation and memory for novel figural designs: a dual interference study. *Brain and Cognition, 57*(2), 198-209.

Skinner, B. F. (1968). *The technology of teaching.* Englewood Cliffs, NJ: Prentice Hall.

Sobel, H. S., Cepeda, N. J., & Kapler, I. V. (2011). Spacing Effects in Real-World Classroom Vocabulary Learning. *Applied Cognitive Psychology, 25*(5), 763-767.

Son, L. K. (2004). Spacing one's study: Evidence for a metacognitive control strategy. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 30*(3), 601-604.

Standing, L. (1973). Learning 10.000 pictures. *Quarterly Journal of Experimental Psychology, 25*, 207-222.

Stenberg, G., Radeborg, K., & Hedman, L. R. (1995). The picture superiority effect in a cross-modality recognition task. *Memory & Cognition, 23*(4), 425-441.

Sumowski, J. F., Wood, H. G., Chiaravalloti, N., Wylie, G. R., Lengenfelder, J., & Deluca, J. (2010). Retrieval practice: A simple strategy for improving memory after traumatic brain injury. *Journal of the International Neuropsychological Society, 16*, 1147-1150.

Swinburn, K., Porter, G., & Howard, D. (2004). *The Comprehensive Aphasia Test*. Hove, UK: Psychology Press.

Tailby, R., & Haslam, C. (2003). An investigation of errorless learning in memory-impaired patients: improving the technique and clarifying theory. *Neuropsychologia, 41*(9), 1230-1240.

Tikofsky, R. S., & Reynolds, G. L. (1962). Preliminary study: nonverbal learning and aphasia. *Journal of speech and hearing research, 5*, 133-143.

Tikofsky, R. S., & Reynolds, G. L. (1963). Further studies of nonverbal learning and aphasia. *Journal of speech and hearing research, 13*, 329-337.

Tseng, C. H., McNeil, M. R., & Milenkovic, P. (1993). An investigation of attention allocation deficits in aphasia. *Brain and Language, 45*(2), 276-296.

Tulving, E. (1985). How many memory-systems are there. *American Psychologist, 40*(4), 385-398.

Tuomiranta, L., Gronholm-Nyman, P., Kohen, F., Rautakoski, P., Laine, M., & Martin, N. (2011). Learning and maintaining new vocabulary in persons with aphasia: Two controlled case studies. *Aphasiology, 25*(9), 1030-1052.

Vallila-Rohter, S., & Kiran, S. (2013). Non-linguistic learning and aphasia: Evidence from a paired associate and feedback-based task. *Neuropsychologia, 51*(1), 79-90.

Viggiano, M. P., Galli, G., Righi, S., Brancati, C., Gori, G., & Cincotta, M. (2008). Visual recognition memory in Alzheimer's disease: Repetition-lag effects. *Experimental Aging Research, 34*(3), 267-281.

Wahlheim, C. N., & Dunlosky, J. J., L. L. (2011). Spacing enhances the learning of natural concepts: an investigating of mechanisms, metacognition, and aging. *Memory & Cognition, 39*, 750-763.

Warrington, E. K. (1996). *The Camden memory tests: short recognition memory test for faces*: Psychology press.

Watkins, M. J. (1977). Intricacy of memory span. *Memory & Cognition, 5*(5), 529-534.

Wechsler, D. (1987). *WMS-R: Wechsler Memory Scale-Revised*: Psychological Corporation.

Wegesin, D. J., & Nelson, C. A. (2000). Effects of inter-item lag on recognition memory in seizure patients preceding temporal lobe resection: evidence from event-related potentials. *International Journal of Psychophysiology, 37*, 243-255.

Wheeler, M., Ewers, M., & Buonanno, J. (2003). Different rates of forgetting following study versus test trials. *Memory, 11*(6), 571-580.

Whitworth, A., Webster, J., & Howard, D. (2005). *A cognitive neuropsychological approach to assessment and intervention in aphasia*. UK: Psychology Press.

Whitworth, A., Webster, J., & Howard, D. (2012). Clinical aphasiology and CNP: A pragmatic alliance. Commentary on Laine and Martin, "Cognitive neuropsychology has been, is, and will be significant to aphasiology". *Aphasiology, 26*(11), 1386-1390.

Wright, H. H., & Shisler, R. J. (2005). Working memory in aphasia: Theory, measures, and clinical implications. *American Journal of Speech-Language Pathology, 14*(2), 107-118.

Yonelinas, A. P. (2002). The nature of recollection and familiarity: A review of 30 years of research. *Journal of Memory and Language, 46*, 441-517.

Yu, Z.-z., Jiang, S.-j., Bi, S., Li, J., Lei, D., & Sun, L.-l. (2013). Relationship between linguistic functions and cognitive functions in a clinical study of Chinese patients with post-stroke aphasia. *Chinese Medical Journal, 126*(7), 1252-1256.