Brain & Language 142 (2015) 76–85

Contents lists available at ScienceDirect

Brain & Language

journal homepage: www.elsevier.com/locate/b&l

Verbal declarative memory impairments in specific language impairment are related to working memory deficits

Jarrad A.G. Lum [a,*], Michael T. Ullman [b], Gina Conti-Ramsden [c]

[a] Cognitive Neuroscience Unit, School of Psychology, Deakin University, Australia
[b] Department of Neuroscience, Georgetown University, United States
[c] School of Psychological Sciences, The University of Manchester, United Kingdom

ARTICLE INFO

Article history:
Accepted 10 January 2015

Keywords:
Specific language impairment
List learning
Declarative memory
Verbal learning
Memory
Working memory

ABSTRACT

This study examined verbal declarative memory functioning in SLI and its relationship to working memory. Encoding, recall, and recognition of verbal information was examined in children with SLI who had below average working memory ($SLI_{Low\ WM}$), children with SLI who had average working memory ($SLI_{Avg.\ WM}$) and, a group of non-language impaired children with average working memory ($TD_{Avg.\ WM}$). The $SLI_{Low\ WM}$ group was significantly worse than both the $SLI_{Avg.\ WM}$ and $TD_{Avg.\ WM}$ groups at encoding verbal information and at retrieving verbal information following a delay. In contrast, the $SLI_{Avg.\ WM}$ group showed no verbal declarative memory deficits. The study demonstrates that verbal declarative memory deficits in SLI only occur when verbal working memory is impaired. Thus SLI declarative memory is largely intact and deficits are likely to be related to working memory impairments.

1. Introduction

Children with specific language impairment (SLI) have deficits in the production and comprehension of language that occur in the absence of sensory problems and intellectual impairments (American Psychiatric Association, 2013; Bishop, 1997; Leonard, 2000; World Health Organization, 1993). Different memory systems may play a role in the aetiology of SLI. Evidence has been presented showing poor working memory and procedural memory functioning is related to the language deficits in SLI (Estes, Evans, & Else-Quest, 2007; Gathercole & Baddeley, 1990; Lum, Conti-Ramsden, Morgan, & Ullman, 2013; Montgomery, 2003; Ullman & Pierpont, 2005). However, not all memory systems have been proposed to be impaired in this group. One suggestion is that declarative memory, unlike working and procedural memory, remains relatively normal in SLI, and moreover plays an important compensatory role (Lum & Conti-Ramsden, 2013; Ullman & Pierpont, 2005; Ullman & Pullman, 2015). In this investigation we examine declarative memory in SLI, and its relationship to working memory.

1.1. The declarative memory system

The declarative memory system encodes (or learns), stores, consolidates as well as retrieves knowledge for personal experiences (episodic memory), general knowledge about the world (semantic memory), and knowledge of words (Cabeza & Moscovitch, 2013; Eichenbaum, Sauvage, Fortin, Komorowski, & Lipton, 2012; Henke, 2010; Squire & Wixted, 2011; Ullman, 2004). Encoding knowledge or information into the system can be fast (Gluck, Meeter, & Myers, 2003). In some cases a single exposure to information or an event is sufficient for a memory to be created, stored and then retrieved after an extended period of time (Rutishauser, Mamelak, & Schuman, 2006). However, stored information is less likely to be forgotten if it can be repeatedly re-encoded from the environment and/or re-activated within the declarative memory system via consolidation processes (Alvarez & Squire, 1994; Inostroza & Born, 2013).

Much is known about the neural substrates of the declarative memory system (Squire, Stark, & Clark, 2004). During encoding the hippocampus binds different pieces of information to create a single memory trace (Eichenbaum, 2004; Mayes, Montaldi, & Migo, 2007; Squire, 1992). Evidence from clinical populations and neuroimaging of neurologically intact adults has shown structures within the medial temporal lobe are also necessary for recall and recognition of information (Gleissner, Helmstaedter, Schramm, & Elger, 2002; Haist, Shimamura, & Squire, 1992; Jones-Gotman

* Corresponding author at: School of Psychology, Deakin University, 221 Burwood Highway, Melbourne 3125, Australia.
E-mail address: jarrad.lum@deakin.edu.au (J.A.G. Lum).

http://dx.doi.org/10.1016/j.bandl.2015.01.008
0093-934X/

et al., 1997; Knowlton & Squire, 1995; Lepage, Habib, & Tulving, 1998; Moser & Moser, 1998; Spaniol et al., 2009; Squire, 1992).

Regions within the prefrontal cortex also play a role in encoding and retrieving information from declarative memory (Blumenfeld & Ranganath, 2007; Dolan & Fletcher, 1997; Fletcher, Shallice, & Dolan, 1998; Fletcher, Shallice, Frith, Frackowiak, & Dolan, 1998; Nyberg, Cabeza, & Tulving, 1996; Sandrini, Censor, Mishoe, & Cohen, 2013; Simons & Spiers, 2003). The dorsolateral prefrontal cortex (DLPFC) has been found to be active when multiple items are to be encoded into declarative memory. Under these conditions the DLPFC re-organises items together on the basis of similar semantic or perceptual features (Blumenfeld, Parks, Yonelinas, & Ranganath, 2011; Blumenfeld & Ranganath, 2006; Long, Öztekin, & Badre, 2010). Presumably, this permits more information to be encoded because fewer neural resources are required to represent the incoming information. The ventrolateral prefrontal cortex (VLPFC) aids encoding by directing attention to salient features of information and disengaging attention from irrelevant information (Badre & Wagner, 2007; Raye, Johnson, Mitchell, Reeder, & Greene, 2002). With respect to retrieval, the DLPFC plays a role in monitoring information retrieved from declarative memory (Badre & Wagner, 2007; Henson, Shallice, & Dolan, 1999; McLaughlin, Moore, Fulwiler, Bhadelia, & Gansler, 2009; Rugg, Fletcher, Chua, & Dolan, 1999). Evidence has been presented suggesting that VLPFC is involved in selecting cues that are used to retrieve information from declarative memory (Badre, Poldrack, Paré-Blagoev, Insler, & Wagner, 2005; Dobbins, Foley, Schacter, & Wagner, 2002).

The prefrontal regions that support the encoding and retrieval of information from declarative memory also support processes associated with working memory (WM; Blumenfeld & Ranganath, 2006, 2007; Fletcher & Henson, 2001; Haxby, Petit, Ungerleider, & Courtney, 2000; Ranganath, Johnson, & D'Esposito, 2003). Working memory is involved in the short-term storage and manipulation or processing of information (Baddeley, 2003; Cowan, 1999). Prefrontal regions have been shown to subserve the working memory functions that involve the manipulation or processing of information (D'Esposito et al., 1995). For instance, the DLPFC is active when information in working memory is manipulated (D'Esposito, Postle, Ballard, & Lease, 1999). The VLPFC directs attention to information processed in working memory and/or away from distracting information (Wolf, Vasic, & Walter, 2006).

The processing and manipulation operations undertaken by working memory appear to play a role in declarative memory (Becker & Lim, 2003; Simons & Spiers, 2003; Stebbins, Gabrieli, Masciari, Monti, & Goetz, 1999; Wagner, 1999). One source of evidence to support this claim has been forwarded from fMRI studies with healthy adults. In one study Blumenfeld and Ranganath (2006) asked participants to re-order a list of words on the basis of their physical characteristics (e.g., weight). Participants completed this task whilst in an MRI scanner. After scanning was completed participants were given a surprise recognition task. Their goal was to recognise words they had re-ordered in the scanner from distractor items. A key result to emerge was that the DLPFC activation associated with re-ordering the words, predicted success on the recognition task. In interpreting these results it was suggested that working memory supports encoding of information into declarative memory by re-organising or chunking information prior to being encoded into the hippocampus. In another study Cabeza, Dolcos, Graham, and Nyberg (2002) found DLPFC was activated when participants engaged in a recognition task and whilst temporarily storing a word. These data might suggest that working memory serves as a temporary hold to monitor information retrieved from declarative memory.

There is behavioural data consistent with the proposal that common processes may support working memory and declarative memory. Research into the latent structure of the Wechsler Memory Scale-III (Wechsler, 1997), which is a standardised memory test for adolescents and adults, indicates the working memory construct correlates with the declarative memory construct. Millis, Malina, Bowers, and Ricker (1999) found the correlation between working memory and declarative memory for verbal information (which includes the encoding and retrieval of information) to be .65. The correlation between working memory and declarative memory for visual information was found to be .49. Using Cohen's (1988) convention the magnitude of the correlation between working memory and declarative memory can be considered to be 'large'.

During childhood there also appears to be an association between working memory and the encoding and retrieval of information from declarative memory. The association between these two memory system has been examined to investigate the validity of the Children's Memory Scale (Cohen, 1997a). The CMS is a standardised test for assessing memory functioning in children and adolescents. The subtests that comprise this instrument are similar to the WMS-III (Wechsler, 1997). Using data from the standardisation sample, the correlation between a composite scale that measures verbal working memory and a scale that measures encoding and retrieval of verbal information from declarative memory, is reported to be .41 (Cohen, 1997b). Thus at the behavioural level the association between working memory and declarative memory appears to be present from childhood to adulthood.

1.2. Declarative memory in specific language impairment

The ability to encode and retrieve information via declarative memory in SLI has been examined for verbal and non-verbal information. Evidence suggests that declarative memory for non-verbal information such as for unknown faces or abstract visual stimulus remains largely normal in SLI, as tested with a variety of paradigms probing encoding, recall, and recognition (e.g., Baird, Dworzynski, Slonims, & Simonoff, 2010; Bavin, Wilson, Maruff, & Sleeman, 2005; Lum, Gelgec, & Conti-Ramsden, 2010; for a review see Lum & Conti-Ramsden, 2013; Riccio, Cash, & Cohen, 2007). The status of verbal declarative memory in SLI is less clear, with some studies report impairments as compared to typically developing individuals (Dewey & Wall, 1997; McGregor et al., 2013; Nichols et al., 2004), and others finding no evidence of such deficits (Baird et al., 2010; Records, Tomblin, & Buckwalter, 1995; Shear, Tallal, & Delis, 1992).

Verbal declarative memory in SLI and other disorders has been commonly assessed using word list-learning tasks (Baron, 2004; Lezak, 2004). These tasks typically consist of encoding (learning) and retrieval (recall, recognition) phases. During the encoding phase participants are auditorily presented with a list of words. The list is presented three, four or five times, depending on the task. After each trial (i.e., after each presentation of the list), the participant is asked to recall all the words. Performance on this part of the task is taken to index encoding abilities.

The performance of children with SLI on list learning tasks has been widely investigated (for a review see Lum & Conti-Ramsden, 2013). A well-replicated finding is that participants with SLI perform worse than age-matched peers during the encoding phase (Baird et al., 2010; Dewey & Wall, 1997; Duinmeijer, de Jong, & Scheper, 2012; Lum & Bleses, 2012; Lum, Conti-Ramsden, Page, & Ullman, 2012; Nichols et al., 2004; Records et al., 1995; Riccio et al., 2007; Shear et al., 1992). That is, even after repeated exposures to a word list, individuals with SLI recall fewer words from the list when compared to typically developing (TD) peers.

It is not clear whether SLI is associated with a retrieval deficit from declarative memory. With respect to immediate recall, although some studies have found deficits (Lum & Bleses, 2012; Lum, Conti-Ramsden, Page, et al., 2012; Nichols et al., 2004), others