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Memory for action sequences in semantic dementia


 Anna-Lynne R. Adlam^{a,b,*}, Michelle de Haan^e, John R. Hodges^{b,d}, Karalyn Patterson^{b,c}
^a Centre for Clinical Neuropsychology Research, University of Exeter, UK^b Cognition and Brain Sciences Unit, Medical Research Council, Cambridge CB2 7EF, UK^c Department of Clinical Neurosciences, University of Cambridge, Cambridge CB2 0PY, UK^d Neuroscience Research Australia, Barkers Road, Randwick, NSW 2031, Australia^e Developmental Cognitive Neuroscience Unit, Institute of Child Health, London WC1N 1EH, UK

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ABSTRACT

Semantic dementia (SD) is associated with a progressive, relatively selective, degeneration of semantic memory (both verbal and nonverbal facts and knowledge). Episodic memory, however, is thought to be relatively preserved. This study aimed to further assess the nonverbal, incidental, episodic memory profile associated with SD using deferred imitation, which measures recall by the nonverbal imitation of novel action sequences after a 24-h delay. The performance of six individuals with SD was compared to that of 10 healthy age- and education-matched controls. After a baseline phase, where sets of objects were presented for manipulation to measure the spontaneous production of relevant action sequences, participants were shown eight novel three-step action sequences with the sets of objects. The component actions of the sequences were causally related in four of the eight series and arbitrarily related in the remaining four, to investigate the influence of sequence structure on memory performance. All participants produced more target actions and pairs in the arbitrary sequences 24-h after demonstration compared to baseline, indicating memory for the sequences, but only the control group showed significant memory for the order of the causal sequences (pairs). Furthermore, and perhaps more strikingly, only the control participants showed a recall advantage for the causal relative to the arbitrary sequences, indicating that they, but not the patients, could take advantage of the semantic nature of these sequences. Together these findings suggest that individuals with SD show some nonverbal episodic memory, even after a 24-h delay, and that new anterograde memory can to some extent be established without significant support from semantic memory.

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1. Introduction

Everyday memory includes both episodic memories for contextually bound experiences that occur in a particular time and place – e.g., I remember climbing the Eiffel tower last spring – and semantic memories for context-free general knowledge – e.g., I know that the Eiffel tower is in Paris and that Paris is the capital of France (Tulving, 1972). Both of these types of memories are dependent on regions in the temporal lobes, as evidenced by their impairment in cases of brain damage or disease affecting these brain regions (e.g., Aggleton & Brown, 1999; Jeneson & Squire, 2011; Squire, 2009). The aim of this study was to investigate part of the memory profile associated with semantic dementia (SD), using an incidental nonverbal test of recall called deferred imitation (McDonough, Mandler, McKee, & Squire, 1995).

Patients with SD present with a progressive, relatively selective, degeneration of semantic memory (e.g., Hodges & Patterson, 1996; Hodges, Patterson, Oxbury, & Funnell, 1992; Neary et al., 1998; Snowden, Griffiths, & Neary, 1994). Semantic memory impairments manifest as difficulty in both production and comprehension of words and also on nonverbal tests such as identifying characteristic sounds and colours of familiar objects and animals (e.g., Adlam et al., 2006; Bozeat, Lambon Ralph, Patterson, Garrard, & Hodges, 2000a; Rogers, Patterson, & Graham, 2007). By some accounts, the verbal and non-verbal deficits represent two separate impairments resulting from discrete regions of brain atrophy (e.g., Hurley, Paller, Rogalski, & Mesulam, 2012; Mesulam et al., 2013). Other researchers conclude that the two domains of deficit are parallel manifestations of disruption to a single, amodal component of the semantic network (Adlam et al., 2006; Peelen & Caramazza, 2012). Although these are different interpretations of the observed pattern in SD, there is no real disagreement about the pattern itself. Quantitative MRI and FDG-PET studies show that the anterior fusiform, perirhinal and temporo-polar cortices are the

* Correspondence to: Centre for Clinical Neuropsychology Research, School of Psychology, College of Life and Environmental Sciences, University of Exeter, Exeter, EX4 4QG, UK. Tel: +44 1392 722209; fax: +44 1392 724623.

E-mail address: a.r.adlam@exeter.ac.uk (A.-L. Adlam).

most atrophic regions in SD, with bilateral though often asymmetric involvement in all cases (e.g., Acosta-Cabronero et al., 2011; Davies, Graham, Xuereb, Williams, & Hodges, 2004; Galton et al., 2001; Mion et al., 2010). A key role for these anterior, inferior temporal-lobe regions in semantic memory (or integrating information about objects across modalities: Lambon Ralph & Patterson, 2003; Simmons & Barsalou, 2003) accords with evidence from studies in non-human primates (e.g., Bussey, Saksida, & Murray, 2002), computational modelling approaches (e.g., Rogers et al., 2004), imaging studies (e.g., Moss, Rodd, Stamatakis, Bright, & Tyler, 2005; Warren, Crinion, Lambon Ralph, & Wise, 2009; Binney, Embleton, Jefferies, Parker, & Ralph, 2010; Visser, Jefferies, & Lambon Ralph, 2010; Visser & Lambon Ralph, 2011) and effects of repetitive transcranial magnetic stimulation (Holland & Lambon Ralph, 2010; Ishibashi, Lambon Ralph, Saito, & Pobric, 2011; Pobric, Lambon Ralph, & Jefferies, 2009).

In contrast, episodic memory is thought to be relatively preserved in SD (e.g., Graham, Simons, Pratt, Patterson, & Hodges, 2000), especially when tested using nonverbal measures (e.g., Adlam, Patterson, & Hodges, 2009; Graham, Patterson, Powis, Drake, & Hodges, 2002; Lee, Rahman, Hodges, Sahakian, & Graham, 2003) and topographical memory tasks (Pengas et al., 2010). Although a number of different verbal and nonverbal measures have been used to examine episodic memory in patients with SD, no study so far has employed the technique administered here: recall as measured by nonverbal imitation of action sequences. We propose that this technique might have several advantages. First, the fact that it is nonverbal is particularly relevant for patients with SD, because impairments on tests of verbal memory might reflect difficulties with word production and/or comprehension rather than with episodic memory per se (Moss, Cappelletti, de Mornay Davies, Jaldow, & Kopelman, 2000). Second, most nonverbal tasks used previously to assess episodic memory in SD have been tests of recognition rather than recall; evidence regarding the patients' ability to recognise previously experienced events is of course informative, but recall seems closer to the 'heart' of episodic memory (Jacoby, Toth, & Yonelinas, 1993; Wheeler, Stuss, & Tulving, 1997). Although the task used here does not enable the differentiation between recollective and non-recollective (familiarity-based) recall (e.g., Brainerd & Reyna, 2010), the deferred imitation of observed action sequences is definitely considered to rely on declarative recall (Meltzoff, 1990, 1995; McDonough et al., 1995). Third, most of the episodic memory studies in SD have employed lists of single unrelated events such as words or pictures of objects or faces; memory for a sequence of events or actions is probably more similar to what people normally remember in everyday life. Finally, most of the measures used to date have involved instructed recall (i.e., participants are informed, prior to the information being presented, that they will be tested on their memory for the information), which again is not typical of everyday life. Deferred imitation is an incidental memory task, and therefore, recall is unlikely to be contaminated by the participant engaging in encoding or rehearsal strategies.

In nonverbal imitation, the experimenter uses props to generate a sequence of actions that the participant is then invited to imitate, either immediately or after a delay (deferred). The nonverbal reproduction of the event, rather than a verbal description of it, serves as a measure of recall. Typically two measures of memory are obtained: the number of correct individual actions ('target actions') reproduced and the number of pairs of temporally adjacent actions that are reproduced in the correct order ('target pairs'). Prior to the experimenter's demonstration of the sequence, the participant is given the set of props and asked to "do something with these". Any spontaneous production

of the target actions and their order serves as a baseline measure, and differences between this baseline and performance after exposure to the sequences modelled by the experimenter are taken as evidence of memory for the event (Bauer, 1997; Meltzoff, 1988).

Memory for action sequences is influenced by a number of factors, including the structure of the event. When one action in the sequence must be carried out prior to another in order to achieve the desired end-state or goal, the pair of actions is said to be causally ordered. For example, if the desired end-state is to transfer water from one cup to another with a straw, the straw must first be placed in the cup containing water, a finger must then be placed over the top of the straw, and the finger must then be lifted for the water to be released into the empty cup. Alternative orders of the same actions would not achieve the goal. In contrast, action sequences that are not temporally constrained to reach a goal can be arbitrarily ordered. For example, to balance coins on a ruler resting on a block, the coins can be placed on each side of the ruler before or after the ruler is placed on the block.

Several studies suggest that the presence of causal structure in a sequence facilitates recall of the temporal order of the component actions (e.g., Barr & Hayne, 1996; Bauer & Mandler, 1992; Mandler & McDonough, 1995). This effect is maintained over a delay (e.g., Bauer & Hertsgaard, 1993; McDonough et al., 1995) and is obtained even when equivalent numbers of individual target actions are produced in both conditions (Bauer, 1996), indicating that the differences in ordered recall are not an artefact of differential opportunities for ordering. This effect is somewhat similar to the superior recall of category-ordered word-lists compared to unordered word-lists observed in healthy adults (e.g., Channon & Daum, 2000; Channon, Daum, & Polkey, 1989). Like category-ordered word-lists, the superior recall of causally-ordered sequences may be due to their increased meaningfulness. In this way, recall of the order of causally-ordered sequences might be considered more 'semantic' compared to arbitrarily-ordered sequences.

Patients with amnesia (both developmental amnesia (DA) and adult-onset amnesia) are impaired on nonverbal imitation. That is, individuals with amnesia did not differ significantly from their age-matched controls in spontaneous production of action sequences prior to modelling (baseline), but they recalled significantly fewer target actions and action pairs than the control group after a 24-h delay (DA: Adlam, Vargha-Khadem, Mishkin, & de Haan, 2005; adults: McDonough et al., 1995). Interestingly, despite this impairment, patients with amnesia, like controls, benefited from causal structure of the sequences, recalling more causal than arbitrary actions and pairs. Given the relative preservation of semantic memory in developmental amnesia (Gadian et al., 2000; Vargha-Khadem et al., 1997), these findings lend further support to the notion that causally-ordered sequences might be considered more 'semantic' in nature.

The current study aimed to investigate: (i) whether, relative to baseline, patients with SD would reveal significant memory for the nonverbal sequences after a 24-h delay (deferred imitation); and (ii) whether, due to their semantic impairments, patients with SD would fail to benefit from more 'semantic' elements of the task. The specific prediction was that, as shown in previous studies, healthy controls would recall more causal than arbitrarily ordered sequences, whereas no such benefit would be observed for the SD patients (i.e., a significant group by time by sequence structure interaction) to this end, the performance of six patients with SD was compared to the performance of 10 healthy age- and education-matched controls on the deferred imitation sequences utilised in studies by Adlam et al. (2005) and McDonough et al. (1995) briefly described in Table 1.

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