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Vocabulary relearning in semantic dementia: Positive and negative consequences of increasing variability in the learning experience

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ABSTRACT

Anomia therapy typically aims to improve patients' communication ability through targeted practice in naming a set of particular items. For such interventions to be of maximum benefit, the use of trained (or relearned) vocabulary must generalise from the therapy setting into novel situations. We investigated relearning in three patients with semantic dementia, a condition that has been associated with poor generalisation of relearned vocabulary. We tested two manipulations designed to improve generalisation of relearned words by introducing greater variation into the learning experience. In the first study, we found that trained items were retained more successfully when they were presented in a variety of different sequences during learning. In the second study, we found that training items using a range of different pictured exemplars improved the patients' ability to generalise words to novel instances of the same object. However, in one patient this came at the cost of inappropriate over-generalisations, in which trained words were incorrectly used to name semantically or visually similar objects. We propose that more variable learning experiences benefit patients because they shift responsibility for learning away from the inflexible hippocampal learning system and towards the semantic system. The success of this approach therefore depends critically on the integrity of the semantic representations of the items being trained. Patients with naming impairments in the context of relatively mild comprehension deficits are most likely to benefit from this approach, while avoiding the negative consequences of over-generalisation.

1. Introduction

Word-finding difficulty (anomia) is a key presenting symptom in almost all forms of aphasia and is the most commonly addressed ability in impairment-based aphasia therapies (Nickels, 2002). The goal of anomia therapies is always the same: to improve the patient's word retrieval ability, thereby increasing the expressive vocabulary available to them in everyday situations. The success of this approach therefore depends critically on the patient's ability to generalise gains made in the training setting to novel situations. Many studies have assessed the degree to which training on a particular set of words results in improvement for other words that were not included in the therapeutic intervention. The evidence suggests that this form of generalisation is typically very limited (Croot et al., 2009; Nickels, 2002). In this study, we use the term generalisation in a slightly different way. We were interested in how successfully patients are able to generalise knowledge for the items treated in therapy when they encounter those same items in novel settings. This could include apparently trivial changes to the setting, such as presenting the stimuli used in therapy in a different order to the one the patient experienced during therapy sessions, or it might include more major changes to the therapy stimuli themselves.

Generalisation of this form has received much less attention but is critical for ensuring that interventions have maximum benefit for patients in everyday situations and not only within the narrow confines of the therapy setting (Croot et al., 2009; Herbert et al., 2003). Anomia therapies often use a single picture as a naming cue for a particular word and assume that naming of this one stimulus will generalise to the diverse, and often visually dissimilar, range of other examples of the same object that could be encountered in the world (see Fig. 6 for examples). In addition, most anomia therapies feature highly specific tasks (repetition, cued naming and so on) which are focused around a limited pool of items and administered in a relatively rigid or fixed order. The

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goal of the present study was to explore whether increasing variability within the learning experience would improve the success of anomia therapy by promoting generalisation. We investigated this using a series of interventions in three patients with semantic dementia (SD). Although SD is a relatively rare disorder and is not typical of all forms of aphasia, the advantage of using this population is that generalisation is known to be a particular weakness in this group and has received some attention in the rehabilitation literature (Graham et al., 1999; Heredia et al., 2009; Mayberry et al., 2011a; Snowden and Neary, 2002).

SD (also known as the semantic variant of primary progressive aphasia) is a neurodegenerative condition whose primary presenting symptom is a progressive loss of semantic knowledge (Gorno-Tempini et al., 2011; Hodges and Patterson, 2007). The degradation of semantic knowledge, which is associated with atrophy to anterior temporal cortex (Butler et al., 2009; Nestor et al., 2006), is multi-modal, affecting comprehension of words as well as object use and recognition of objects from vision, sound, taste and smell (Bozeat et al., 2000, 2002; Luzzi et al., 2007; Piwnica-Worms et al., 2010). In most patients, however, the most prominent symptom is a pronounced anomia. Patients experience a progressive reduction in expressive vocabulary, with general, superordinate terms like “thing” and “place” and “do” increasingly replacing more specific terms in speech (Bird et al., 2000; Hoffman et al., 2014). It is important to note, however, that anomia in SD is less a word-finding difficulty and more a word-*knowing* difficulty. In other words, the patients' anomia appears to be a direct consequence of the degradation of the underlying semantic knowledge store, as evidenced by the increasingly non-specific responses given in picture naming (e.g., swan → duck → bird → animal; Hodges et al., 1995) and the strong relationship between naming ability and the familiarity and typicality of the concepts being probed (Hoffman et al., 2012; Woollams et al., 2008).

A number of studies have used naming therapies to treat anomia in SD patients (e.g., Bier et al., 2009; Henry et al., 2013; Heredia et al., 2009; Jokel et al., 2006, 2010; Mayberry et al., 2011a; Savage et al., 2013; Snowden and Neary, 2002). Given that anomia in these patients is related to loss of knowledge of word meaning, this process is often referred to as “word relearning”. Most studies have found that repeated practice in naming pictures can lead to substantial improvements in naming for those items, albeit with a number of important caveats. The first is that the success of relearning is dependent on the degree of residual semantic knowledge for the trained items, with therapy gains most likely for items that patients still recognise and demonstrate understanding of Jokel et al. (2006, 2010) and Snowden and Neary (2002). The second is that trained knowledge often fades quickly once regular practice stops (Croot et al., 2009; Graham et al., 1999; Savage et al., 2013). The third is that generalisation of the trained words to novel situations is limited. Snowden and Neary (2002), for example, conducted a study in which a patient with SD learned to name 20 pictures through repeated practice over a period of three weeks. Following this training, the patient was able to name all of the pictures correctly. However, her performance deteriorated substantially when the pictures were presented in a different context to that used during training (on different sheets of paper and in a different sequence). Another well-known case is that of patient DM (Graham et al., 1999), who spent long periods practicing recall of lists of words from different categories. He typically recalled items in exactly the same order as they appeared in the training materials, suggesting that he relied mainly on “rote learning” to memorise the items. Other studies have found that patients show limited generalisation to novel exemplars of the objects used during training, particularly if these are visually dissimilar (Heredia et al., 2009; Mayberry et al., 2011a).

A number of researchers have interpreted these findings within the complementary learning systems theory of knowledge acquisition (Graham et al., 1999; Heredia et al., 2009; Mayberry et al., 2011a; McClelland et al., 1995). This theory posits a neural division of labour between hippocampal and medial temporal lobe structures that are critically involved in initial coding of new memories and neocortical sites that are involved in representing knowledge over the longer term (see also Alvarez and Squire, 1994). This view holds that the hippocampal system is able to rapidly encode the specific details of individual learning episodes. To achieve this goal, it employs a sparse coding system in which individual experiences are clearly differentiated from one another. Over time, the details of these individual episodes are transferred to the neocortex through a process of gradual consolidation. Importantly, the consolidation process extracts statistical regularities that are true across a whole series of experiences, while discarding the idiosyncratic aspects of each individual episode. This process results in the acquisition of semantic knowledge that reflects the typical characteristics of objects and events in the world, rather than the details of individual experiences. Because knowledge in the neocortical system is no longer tied to specific experiences, it can readily be generalised to novel situations. How does this theory explain the poor generalisation demonstrated by SD patients in relearning studies? It has been claimed that, due to damage to the neocortical semantic system, patients are particularly reliant on the hippocampal system for representing information learnt during therapy. This allows the patients to learn the association between a particular picture they are exposed to during training and the word used for this picture, but the specific nature of the hippocampal trace means that they have difficulty generalising the name to new instances of the same type of object. In the same vein, when patients attempt to recall trained information they do so by recalling the specific details of the learning experience, which results in apparent “rote learning” effects in which they tend to rigidly recall items in the same order that they were encountered during training.

Over-reliance on hippocampal learning is at one level a reasonable strategy for patients with SD, in that it allows them to reliably associate pictures with names within the narrow confines of the training setting. However, it is problematic in the long term because it hampers their ability to generalise their learning to novel situations. In the present study, we tested two manipulations aimed at improving the usefulness and generalisability of names acquired during a relearning therapy programme. Classical learning theory holds that greater variability of experience during learning leads to more successful recall, particularly when learned information must be recalled in a novel context (Anderson and Bower, 1972; Smith et al., 1978). With this in mind, we designed two manipulations that increased the variability of the training experience. In the first study, we manipulated a low-level factor: the order in which items were presented during relearning. Patients practiced producing names in response to pictures of objects over a period of three weeks. In one condition, the pictures were presented in the same order each day, as is typically the case in interventions of this kind. In the other condition, they were presented in a different order each day. We found that the variation in order had a beneficial effect on learning, allowing the patients to better generalise their knowledge to a novel order at follow-up. In the second study, we investigated a factor that has a more direct bearing on the semantic deficits experienced by SD patients: generalisation of word learning to novel exemplars. We varied the learning experience by training patients to name three different exemplars of each object and contrasted this with an equivalent amount of training with only one exemplar. We found that training with multiple exemplars of the same object improved generalisation to new examples of the object. However, in one patient, this came at the cost of incorrect generalisations to other objects that were visually similar.

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