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The role of nondeclarative memory in the skill for language: Evidence from syntactic priming in patients with amnesia

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ABSTRACT

Syntactic priming, the phenomenon in which participants adopt the linguistic behaviour of their partner, is widely used in psycholinguistics to investigate syntactic operations. Although the phenomenon of syntactic priming is well documented, the memory system that supports the retention of this syntactic information long enough to influence future utterances, is not as widely investigated. We aim to shed light on this issue by assessing patients with Korsakoff's amnesia on an active-passive syntactic priming task and compare their performance to controls matched in age, education, and premorbid intelligence. Patients with Korsakoff's syndrome display deficits in all subdomains of declarative memory, yet their nondeclarative memory remains intact, making them an ideal patient group to determine which memory system supports syntactic priming. In line with the hypothesis that syntactic priming relies on nondeclarative memory, the patient group shows strong priming tendencies (12.6% passive structure repetition). Our healthy control group did not show a priming tendency, presumably due to cognitive interference between declarative and nondeclarative memory. We discuss the results in relation to amnesia, aging, and compensatory mechanisms.

1. Introduction

The human language system is often characterized by a tripartite architecture (Jackendoff, 2002) that enables us to map sound onto meaning (in listening) or meaning onto sound (in speaking). Next to sound and meaning, there is syntax, which enables the well-formed grouping of words into longer utterances. At a very general level, for all three information types (sound, syntax, meaning), one can make a distinction between two crucial components. The one relates to the common assumption that the basic building blocks of linguistic knowledge get encoded and consolidated in the course of language acquisition. This is what we refer to as the *Memory* component of the human language system, and is more usually called the mental lexicon in the field of psycholinguistics. Crucially, however, language processing is more than the retrieval of lexical knowledge and goes beyond the simple concatenation of retrieved lexical items. The expressive power of human language derives from the possibility to combine elements from memory in often novel ways. This creative aspect led Wilhelm Von Humboldt (1829) to characterize language as a system which *"makes infinite use of finite means"*. This process of deriving new and complex meaning from the lexical building blocks is referred to by some as *Unification* (Hagoort, 2005, 2013, 2016). This process supports the on-line assembly of lexical building blocks into larger structures, with contributions from context and general world knowledge. It instantiates what in linguistic theories is often called the compositionality of language. Although the mental lexicon is part of semantic memory, and hence a component of declarative memory (Hagoort, 2005; Ullman, 2001), it is less clear which memory structure supports the on-line assembly of utterances that are not prestored in the mental lexicon. It has been argued (Ullman, 2001) that the on-line composition (speaking) or decomposition (listening/reading) of sound, morphological, and syntactic structures is subserved by procedural memory (Gupta and Cohen, 2002). Here we investigate a group of patients with severe amnesia that might provide relevant information on the contribution of procedural memory to human language skills, more in particular to the Unification component of the language system.

A core process in language production and comprehension is the production and comprehension of the syntactic relations between the

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lexical items in an utterance; i.e., the processing of the relationships between words in a sentence. The same words can be combined, but in different syntactic roles (e.g., subject, object), to produce different meanings (*the man kisses the woman/the woman kisses the man*) or different words fulfilling the same syntactic roles can be combined to produce the same meaning (*the man kisses the woman/the woman is kissed by the man*). Without a functioning syntactic processing system, the ability to understand language as well as to produce it is severely impaired. As language production and comprehension are so tightly linked, interlocutors are prone to repeat the syntactic structure in which their partner formulates her utterance. Indeed, corpus studies have shown that interlocutors adapt their syntactic language behaviour to match that of their partner (Giles and Powesland, 1975).

In 1982, Levelt and Kelter were the first to experimentally reproduce this repetition of syntax; they showed that the question "*On which instrument does Paul play?*" was more commonly answered (89%) with "*On the piano*" as opposed to "*The piano*" by the 36 participants they tested. The language adaptation behaviour, referred to in this article as syntactic *priming,* but also known as *accommodation* or *alignment,* has been used in a wide-range of applications. Syntactic priming studies have shown that abstract linguistic structures have a basis in psychological reality (Bock, 1986), how these are acquired during language development (Kidd, 2012), and which role syntactic priming plays in social cueing (Balcetis and Dale, 2005). However, the memory system that is needed to retain this linguistic information long enough to be used in producing utterances has not been seriously investigated.

Most studies that have examined the retention of linguistic information over time did not distinguish between different memory types. However, studies that investigated the effect of intervening irrelevant linguistic information or just time itself (Branigan et al., 2000), using either spoken (Bock and Griffin, 2000) or written modalities (Bernolet et al., 2016; Hartsuiker et al., 2008), did not observe a significant decrease in priming ability. Although the primed structures may remain active over some intervening trials, the length of the decay (sometimes even a week; Kaschak et al., 2011b) does not rule out that the participant may have consciously learnt the relevant linguistic structures. This points towards the involvement of declarative memory, the memory that underlies the acquisition, representation, and use of knowledge about facts and events.

At the same time, other studies have suggested that priming might be a form of statistical learning, a subcomponent of nondeclarative memory: participants automatically and unconsciously pick up on the frequency of event occurrences, which could explain why they produce these events with increasing probability over the length of the experimental session (Bock and Griffin, 2000; Jaeger and Snider, 2013; Kaschak et al., 2011a). Indeed a detailed computational model has been developed which supports these claims (Chang, 2002; Chang et al., 2006, 2000). One critical note is that empirial demonstrations of priming studies suffer from the problem of possible declarative contamination (Light, 1991). That is, in healthy participants it is difficult to rule out the possibility that priming effects may be mediated by declarative memory processes as well.

The most direct method to ensure that there is no influence of the declarative memory system is to measure participants that have amnesia. Until now, only one study has used this approach: Ferreira et al. (2008) had patients with declarative memory deficits complete a syntactic priming task (a task that focuses only on grammatical adaptation in language behaviour) and compared their performance to age- and IQ-matched controls. Their results showed that patients' ability to repeat syntactic structures did not differ significantly from the control group, even though their declarative memory performance was significantly worse compared to the controls. This led the authors to conclude that syntactic priming does not require declarative memory. However, this is only a single study, which examined only four patients with a mixed aetiology. The mixed aetiology could potentially be a confound, as both the declarative and nondeclarative memory systems have extensive neural networks, and thus lesions in different areas may not effect the four patients to the same extent.

The declarative memory system is mainly based in the diencephalon and the medial temporal lobe (MTL) structures. These include the hippocampus proper, the entorhinal cortex, the perirhinal cortex and the parahippocampal cortex (Squire and Dede, 2015; Squire and Knowlton, 2000; Suzuki and Eichenbaum, 2000). The hippocampus projects to the midline diencephalic nuclei, including the mammillary bodies and portions of the thalamus (Kopelman, 2014), although there is increasing evidence that the involvement of the hippocampus is not limited to the declarative memory system (Hannula and Greene, 2012; Schapiro et al., 2016). This diencephalic-MTL circuitry is involved in several memory related functions, including encoding, consolidation, and retrieval of new memories (Eichenbaum and Cohen, 2001; Squire and Knowlton, 2000), although memories eventually become mostly independent of the medial temporal lobe structures and dependent upon neocortical regions, particularly the temporal lobes (Hodges and Patterson, 1997; Squire et al., 2001). For language, memory for items stored in the mental lexicon has usually been related to inferior, middle, and superior temporal lobe regions (Hagoort, 2013, 2014; Hagoort and Indefrey, 2014; Ullman, 2001).

The nondeclarative (procedural) memory system is composed of an extensive neural network with the root in the frontal-striatal circuits and branching out to include portions of the parietal cortex, superior temporal cortex, and the cerebellum (De Renzi, 1989; Schacter and Tulving, 1994; Squire and Dede, 2015). The input to the basal ganglia (including the striatum) depend upon the type of information involved; for example motor learning might be projected from the supplementary motor area (SMA) and pre-supplementary motor area (Middleton and Strick, 2000), whereas syntax-related combinatorial operations (i.e., syntactic unification) could be projected from areas such as Broca's region (Conway and Christiansen, 2001). The information is then processed in the basal ganglia and projected back to prefrontal cortex, closing the loop. As the network is so extensive, it is imperative to ensure that whatever the cause of the patient's declarative memory deficit, their nondeclarative memory is not affected.

Korsakoff's syndrome is a neurological disorder caused by a chronic deficiency of thiamine (vitamin B_1) due to severe malnutrition usually associated with chronic alcoholism. Patients display profound amnesia due to bilateral lesions to the thalamus and mammillary bodies (Pitel et al., 2014) which, as mentioned above, are structures relevant for the encoding and consolidation of new memories via the declarative memory system. Patients therefore display deficits in all subdomains of declarative memory, but nondeclarative memory remains intact (Cermak et al., 1991; Oudman et al., 2011), making them an ideal patient group to include in this study.

In this study we aim to shed light on which memory system underlies syntactic priming. To control for any influence of the declarative memory system, we will be comparing the performance of amnesia patients with age-, education-, and premorbid intelligence-matched controls in a syntactic priming task. Overall, if syntactic priming is supported by nondeclarative memory, the amnesia patients should show robust priming effects.

2. Materials and methods

2.1. Participants

2.1.1. Patients with amnesia

Eighteen patients with Korsakoff's syndrome (13 men) were recruited from the Centre of Excellence for Korsakoff and Alcohol-Related Cognitive Disorders of Vincent van Gogh Institute of Psychiatry in Venray, The Netherlands. For all patients, the current intelligence level of each participant had to be in concordance with the estimation of premorbid functioning based on occupational and educational history, to exclude possible alcohol-related dementia (Oslin et al., 1998). All