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The cumulative semantic interference effect in normal and pathological ageing

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ABSTRACT

People affected by mild cognitive impairment (MCI), a precursor of Alzheimer's Disease, present with impairments in picture naming, a lexical/semantic task which rests on the activation of perceptual, semantic, and phonological representations. The poor performance of MCI individuals in picture naming has been accounted for in terms of deficits of either the perceptual, semantic, or phonological stages. To disentangle the source of this deficit we compared the cumulative semantic interference effect (Howard et al., 2006. Cognition. 100, 464–482.) and the repetition priming effect of a group of people with MCI to that of a group of healthy elderly participants and with a group of healthy young participants. The cumulative semantic interference effect defines a linear increase in the picture naming reaction times which is function of the already named pictures belonging to the same semantic category to which the named picture belongs. The repetition priming effect refers to an increase in performance for repeated items compared to unrepeated items. Results showed that whereas the cumulative semantic interference effect was present in the healthy elderly and young samples, it was absent in the MCI sample; instead, all groups showed comparable repetition priming effects. This pattern of results suggests that the impairment in picture naming exhibited by MCI individuals is due to an inefficient semantic access.

1. Introduction

In this study, we determined which component of the lexical-semantic system used for word production (that is, semantic processing, lexical processing, or item-specific connections between the semantic system and the lexical system) is responsible for the deficit in picture naming that is observed in people fitting the criteria for a diagnosis of mild cognitive impairment (MCI) (Duong et al., 2006) a precursor of Alzheimer's Disease (AD) (Petersen, 2004). To this aim, we compared the cumulative semantic interference effect (Howard et al., 2006) and the repetition priming effect in picture naming in three groups of participants: MCI, healthy elderly, and healthy young adults.

A cumulative semantic interference effect upon word production was first reported by Howard et al. (2006). They presented participants with pictures to be named. Pictures were drawn from several semantic categories (e.g., animals, fruit, vehicles). Picture naming reaction times (RTs; i.e., the interval between the onset of the target stimulus and the onset of the verbal response) increased linearly as a function of the number of previously named pictures in that category. This is a cumulative semantic interference effect (see also, Mulatti et al., 2012). Noteworthy, the number of items intervening between two exemplars of the same category does not modulate the effect. For example, given the sequence of pictures SHEEP, CAR, HOUSE, PIG, the RTs for PIG would be slower than those for SHEEP, independently of the number of unrelated interspersed items. That is, the sequence SHEEP, CAR, HOUSE, BOOK, PIG shows the same slowing effect on the RTs for PIG as SHEEP, CAR, PIG.

Howard et al. (2006) and Oppenheim et al. (2010) suggested that the cumulative interference effect could arise as a consequence of the presence of three properties of the cognitive system employed in picture naming, namely, shared activation, priming, and competition.

The property of 'shared activation' refers to the idea that when the semantic representation of a given word – say, SHEEP – is activated, the semantic representations of words that are related to it – such as PIG – will also be activated. If the elements of the semantic system represent simple semantic features ("decompositional semantics"), then the property of shared activation would emerge because the set of semantic features involved in the processing of a particular picture would partially overlap with the set of semantic features composing the meaning of semantically related pictures. If instead the elements of the semantic system represent individual concepts as a whole

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("compositional semantic"), then the property of shared activation could be implemented by an associative network linking related units, so that the activation of a given unit would also co-activate semantic units of related (linked) concepts. Both views posit that the activation of any semantic representation results in the co-activation of semantic representations of semantically similar concepts. This is 'shared activation'.

'Priming' refers to the idea that any activation/retrieval of a representation in the phonological lexicon facilitates following activation(s)/retrieval(s) of that particular representation. The authors conceptualized 'priming' as a strengthening of the links (specific for each item) from the semantic system to the phonological lexicon.

The property of 'competition' reflects the need for a mechanism that selects one response among several concurrently activated possible responses. That is: given that there are item-specific connections from semantics to phonology, and given that a picture will activate the semantic not only of itself but also of concepts semantically similar to it (shared activation), it follows that when a picture is presented, multiple competing representations in the phonological lexicon will be activated. It is therefore necessary to make sure that the correct phonological representation amongst the concurrently activated phonological representations is selected for production. Howard et al. (2006) propose that this selection might occur through lateral-inhibition, i.e., representations in the phonological lexicon mutually inhibit each other. Although Oppenheim et al. (2010) offer a different account of the specific mechanism by which competition is resolved, they agree that the system used for picture naming possesses the property of competition (along with the other two properties discussed above, priming and shared activation). They spell out this concept clearly: "Lexical retrieval leads to lexical learning. The light side of learning is well known. Retrieving the same word again becomes faster and more accurate. But learning also has a dark, competitive, side that hinders the subsequent retrieval of semantically related words." (Oppenheim et al., 2010, p. 247).

The three properties just discussed are supposed to work conjointly to determine the cumulative semantic interference effect: when a representation is activated in the lexicon upon the presentation of a picture, the lexical representations of semantically related items are also activated (i.e., the activation is shared); and the activated non-target lexical representations compete with the target lexical representation in a mutually inhibitory way, thus slowing down processing (i.e., selection is accomplished through competition). Any retrieval of a lexical representation facilitates its subsequent retrieval(s) (i.e., there is priming), which makes it a stronger competitor when, in the following trials, related lexical representations have to be retrieved, therefore causing those following target lexical representations to be retrieved more slowly.

If, as argued, the cumulative semantic interference effect rests on three properties of the system subtending picture naming, then we can take advantage of the effect itself to determine the locus of a malfunctioning of the word production system in populations with particular characteristics, as a diagnosis of MCI. Suppose that the cumulative interference effect in picture naming is stronger in a particular population with respect to a control population. In this case, the malfunctioning mechanism must be that implementing 'competition', i.e., – in the model presented so far – the malfunctioning regards the process of lateral inhibition within the phonological lexicon: primed competitors are not properly inhibited and thus interfere more strongly with the selection of the target lexical representation. Suppose, instead, that a particular population fails to show cumulative interference effects in picture naming. The malfunction would then interest either shared activation or priming. In fact, if the target picture does not co-activate the semantic representations of semantically similar entities (i.e., there is not shared activation), then those entities will not interfere with target processing. Alternatively, if the processing of a given target picture does not result in the strengthening of the target-specific connection between its semantic and the phonological representations (i.e., if there is not priming), there will not be a cumulatively increasing interference. Thus, a lack of cumulative interference is compatible with two, rather distinct, theoretical alternatives. To discriminate between the two, we can look at how the population that shows no cumulative semantic interference effects behaves in a task aimed at directly testing for item repetition priming effects. If this group does show repetition priming effect, then the lack of cumulative semantic interference has to be ascribed to a malfunction of the system implementing shared activation, i.e., the semantic system. If it does not show repetition priming, then the lack of cumulative semantic interference has to be ascribed to a malfunction of the mechanism implementing priming, i.e., strengthening of the item-specific connections between semantics and phonology.

In the current experiment, we compared the cumulative semantic interference effect and the repetition effect of a group of healthy young adults with those of a group of healthy elderly and with those of a group of MCI patients. Healthy young adults constitute the control group: these participants should show both a clear cumulative semantic interference effect and a clear repetition priming effect. Picture naming RTs get slower as the age of the participants increases (Mitchell, 1989), hence mean RTs of the healthy elderly participants should be slower than mean RTs of the healthy young participants. It has been argued that inhibitory mechanism becomes less efficient with aging (e.g., Hasher and Zacks, 1988; Hasher et al., 1991). If this were the case, we should predict a stronger cumulative semantic interference effect in the elderly than in the young group, due to the inefficient inhibitory mechanisms resulting in an inefficient lexical selection process. However, the sort of inhibition involved in lexical selection (i.e., lateral inhibition) is an automatic, reflexive inhibitory mechanism, and there is evidence that automatic inhibitory mechanism are preserved: the deteriorating inhibitory mechanisms are those inhibitory mechanisms that are controlled (e.g., see Amieva et al., 2004). Healthy elderly participants, thus, should show a cumulative semantic interference effect and a repetition priming effect comparable to those of the healthy young adults. Automatic, reflexive inhibitory mechanisms are preserved also in individuals with AD (Amieva et al., 2004) which suggests that they should also be preserved in the less impaired MCI patients. Thus, there are no reasons to predict a stronger cumulative semantic interference effect for the MCI group. Semantic processing (i.e., access to semantic information), however, is impaired in MCI (Curiel et al., 2013; Crocco et al., 2014; Joubert et al., 2010), and thus co-activation of representations of entities semantically similar to the target picture might be absent or limited. If so, MCI should (a) not show cumulative semantic interference effect and (b) show a regular repetition priming effect.

2. Experiment

2.1. Method

2.1.1. Participants

A total of 40 Italian right-handed, elderly participants entered the study. Twenty were diagnosed as affected by mild cognitive impairment (MCI) (mean age: 72.5, SD = 7.4, range: 60 to 80; years of formal education: 9.4, SD = 9.4; 9 males) whereas twenty acted as healthy elderly controls (mean age: 66.4, SD = 5.3, range: 60 to 80; years of formal education: 11.2, SD = 4.9; 6 males). All participants were assessed with a neuropsychological battery (see Supplementary materials, Table 1). Specifically, people with MCI were diagnosed according to formal criteria (Petersen, 2004; Winblad et al., 2004) requiring: (1) change in cognition recognized by the affected