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Short Communication

Language production is facilitated by semantic richness but inhibited by semantic density: Evidence from picture naming

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ABSTRACT

Communicating meaningful messages is the ultimate goal of language production. Yet, verbal messages can differ widely in the complexity and richness of their semantic content, and such differences should strongly modulate conceptual and lexical encoding processes during speech planning. However, despite the crucial role of semantic content in language production, the influence of this variability is currently unclear. Here, we investigate influences of the number of associated semantic features and intercorrelational feature density on language production during picture naming. While the number of semantic features facilitated naming, intercorrelational feature density inhibited naming. Both effects follow naturally from the assumption of conceptual facilitation and simultaneous lexical competition. They are difficult to accommodate with language production theories dismissing lexical competition.

1. Introduction

Language production ultimately aims to convey meaning. However, even at the level of single words verbal messages differ widely in the richness of their semantic representations and in the density of the regions they inhabit in semantic space. For instance, verbal concepts can transport a relatively high or low number of semantic features associated with them, and they can co-activate a relatively big or small number of related meaning alternatives. Given the key role of meaning in language production, such differences in the semantic richness or density of verbal messages should strongly modulate conceptual and lexical encoding processes. The aim of the present study was to describe how speech planning is shaped by the richness and density of the planned message.

In language comprehension research semantic richness has often been quantified by the number of semantic features (NOF; e.g. mouse – *is small*, *has four legs*, etc.) associated with a concept based on empirical semantic feature production norms (McRae, Cree, Seidenberg, & McNorgan, 2005), yielding facilitatory effects in different comprehension tasks such as lexical decisions, semantic categorizations, and self-paced reading (e.g., Pexman, Holyk, & Monfils, 2003; Pexman, Lupker, & Hino, 2002; Rabovsky, Sommer, & Abdel Rahman, 2012a, 2012b). In contrast, semantic factors in language production research are often investigated by manipulating the contexts in which identical messages are produced, rather than contrasting item-inherent attributes of different utterances (but see Bormann, 2011). For instance, the simultaneous presentation of a semantically related distractor word accompanying a to-be named picture in the picture–word interference (PWI) paradigm (e.g., Glaser & Glaser, 1989; La Heij, 1988; Lupker, 1979; Schriefers, Meyer, & Levelt, 1990), a semantically homogeneous composition of objects in the semantic blocking paradigm (Belke, Meyer, & Damian, 2005; Damian, Vigliocco, & Levelt, 2001; Kroll & Stewart, 1994), or the previous experience of naming objects from the same semantic category (Howard, Nickels, Coltheart, & Cole-Virtue, 2006) slows down naming times compared to unrelated distractor and block conditions. Facilitative influences of semantic context have also been observed (e.g., Abdel Rahman & Melinger, 2007; Alario, Segui, & Ferrand, 2000; Costa, Alario, & Caramazza, 2005; La Heij, Dirkx, & Kramer, 1990). Most production theories share the assumption that semantic contexts can induce facilitative priming of the target at the conceptual (Abdel Rahman & Melinger, 2009b; Costa et al., 2005) or lexical level (Mahon, Costa, Peterson, Vargas, & Caramazza, 2007), resulting in faster activation of the target concept and its lexical

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representation. However, they are at variance concerning why interference overrides facilitation in some situations but not in others. Specifically, there is an active debate as to whether lexical selection is competitive, as traditionally assumed (Abdel Rahman & Melinger, 2009a, 2009b; Hantsch & Maedebach, 2013; Jescheniak, Matushanskaya, Mädebach, & Müller, 2014; Jescheniak, Schriefers, & Lemhöfer, 2014; Levelt, Roelofs, & Meyer, 1999; Roelofs, Piai, & Schriefers, 2013a, 2013b; Starreveld, La Heij, & Verdonschot, 2013) or whether interference effects are due to alternative mechanisms (Costa et al., 2005; Finkbeiner & Caramazza, 2006; Janssen, 2013; Mahon & Caramazza, 2009; Mahon et al., 2007; Navarrete & Mahon, 2013).

The swinging lexical network proposal as a variant of competitive models assumes that semantic contexts cause conceptual priming and lexical competition simultaneously, and that the trade-off between conceptual facilitation and lexical competition crucially depends on whether an interrelated lexical cohort of sufficient size is activated (Abdel Rahman & Melinger, 2009b; Melinger & Abdel Rahman, 2012). This account was formulated to explain semantic context effects of opposite polarity, as observed, e.g., for categorically vs. associatively related distractors (Alario et al., 2000; La Heij et al., 1990). When target and distractor are members of the same category (e.g. dog, cat), they spread converging activation to further category members through shared semantic features so that a cohort of interrelated lexical nodes is co-activated and competes for selection, resulting in one-to-many competition, and therefore inducing substantial interference effects that outweigh semantic priming. On the other hand, when target and distractor are associatively related (e.g. bee, honey), their activation does not converge on semantic features that are shared by additional concepts so that they do not jointly activate other related concepts. Instead, both the target and the distractor separately activate other mutually unrelated concepts so that their activation diverges and eventually dissipates. Thus, only the target and distractor are highly activated, resulting in one-to-one competition which does not override conceptual priming.

Concerning semantic richness effects, an increasing NOF associated with the message should induce facilitatory effects similar to conceptual priming, with higher activation levels of concepts associated with many as compared to few semantic features (see Rabovsky & McRae, 2014; simulation 3). Stronger semantic activation specifically related to the to-be-named concept should result in enhanced activation flow to the corresponding lexical representation, inducing faster lexical selection and naming. This may be accompanied by the simultaneous activation of a bigger number of co-activated lexical competitors – those that share the semantic features with the target. However, while lexical co-activation should not be strong enough to outweigh direct conceptual facilitation due to semantic feature activation, a related variable, the density of semantic space, should reflect lexical cohort activation and competition more directly. This variable, the intercorrelational feature density, also provided in the feature norms by McRae et al. (2005), indicates the degree to which a concept's features are intercorrelated. Specifically, McRae et al. constructed a matrix where each element corresponds to the production frequency of a specific feature for a specific concept, and then calculated pairwise correlations between the resulting feature vectors for features that appeared in at least three concepts. Then the percentage of shared variance between each pair of a concept's features (for pairs sharing at least 6.5% of their variance) was summed. Concepts with high intercorrelational density inhabit denser regions of semantic space, and their activation results in stronger partial co-activation of other concepts through the intercorrelated features.

There is currently no evidence concerning influences of neither NOF nor intercorrelational density in language production. Here we assume that concepts with high intercorrelational density should co-activate cohorts of interrelated lexical competitors because highly correlated feature clusters often characterize groups of closely interrelated concepts (e.g. *has wings*, *can fly*, *has a beak*, etc. or *has four legs*, *has fur*, *has a tail*, etc.). As noted above, within the swinging lexical network, the activation of lexical cohorts should result in enhanced lexical competition, which should be reflected in sizeable interference effects that outweigh any possible facilitation induced by conceptual co-activation.

To summarize, in the present study we investigate how language production is shaped by message-inherent semantic attributes that have thus far gained little attention. We focused on the semantic richness and density of verbal messages. An increasing NOF associated with a concept should facilitate the formulation of the message at the conceptual level, and the density of the message in semantic space should cause the activation of an interrelated competitive cohort at the lexical level, resulting in semantic interference.

Please note that here, in contrast to most studies on semantic context effects, the target utterances necessarily differ between conditions, posing potential problems in terms of confounding variables. One common strategy to avoid these problems is to compare groups of stimuli that differ in the variables of interest (e.g., high vs. low NOF) but are closely matched on potentially confounding variables. However, dichotomizing continuous variables can result in a substantial loss of statistical power due to reducing the amount of experimental variance. Furthermore, the excessive matching of other variables required by this dichotomization strategy can result in the selection of unusual materials (Hauk, Davis, Ford, Pulvermuller, & Marslen-Wilson, 2006). Therefore, we used all the 541 object concepts from McRae et al.'s (2005) norms with richness and density continuously varying in the stimulus set, and analyzed naming responses with linear mixed models (Baayen, Davidson, & Bates, 2008) which allow for statistical control of potential confounds.

2. Material and methods

2.1. Participants

16 native German speakers (13 women) with mean age of 25 (range = 19–38) took part in our study. They reported normal or corrected-to-normal visual acuity, gave written informed consent prior to participation and received either course credit or monetary compensation (7 €/h) for participation.

2.2. Materials and procedure

Stimuli were grayscale photographs of the 541 concrete object concepts from the feature production norms by McRae et al. (2005) which were scaled to 3.5 × 3.5 cm and presented on a light blue background. To increase the number of correct responses for response time analyses, half of the participants (n = 8) were shown the object pictures and their correct German names (translated from the feature norms by McRae et al., 2005) in a familiarization block prior to the experiment proper where each picture/name pair was shown for 2 s. To control for potential influences of this procedure on the experimental effects, the other participant group (n = 8) was not familiarized with the pictures. For the main experiment, participants were instructed to name the pictures as correct (familiarization group) or as intuitive and specific (group without familiarization) as possible. Each trial began with a fixation cross displayed for 0.5 s. Then a picture was presented until a response was given or for maximally 4 s. The 541 pictures were presented in different random order for each participant. Naming latencies were registered with a voice key and response accuracy was