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On the influence of typicality and age of acquisition on semantic processing: Diverging evidence from behavioural and ERP responses

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ABSTRACT

Various behavioural studies show that semantic typicality (TYP) and age of acquisition (AOA) of a specific word influence processing time and accuracy during the performance of lexical-semantic tasks. This study examines the influence of TYP and AOA on semantic processing at behavioural (response times and accuracy data) and electrophysiological levels using an auditory category-member-verification task. Reaction time data reveal independent TYP and AOA effects, while in the accuracy data and the event-related potentials predominantly effects of TYP can be found. The present study thus confirms previous findings and extends evidence found in the visual modality to the auditory modality. A modality-independent influence on semantic word processing is manifested. However, with regard to the influence of AOA, the diverging results raise questions on the origin of AOA effects as well as on the interpretation of offline and online data. Hence, results will be discussed against the background of recent theories on N400 correlates in semantic processing. In addition, an argument in favour of a complementary use of research techniques will be made.

1. Introduction

Numerous studies provide evidence that psycholinguistic variables influence speed and accuracy during language comprehension and production. Semantic typicality and age of acquisition are two word characteristics which seem to affect lexical-semantic processing in particular.

Semantic typicality (TYP) is defined as the rated degree to which a semantic concept represents a semantic category. The originally called "Theory of Prototypicality" assumes that certain members constitute better examples ("goodness-of-example") and are thus more typical than other members of a category (Osherson and Smith, 1981; Rosch, 1975). For instance, for the semantic category BIRD a *sparrow* would be more typical than a *penguin*. The notion of prototypes was first described by Posner and Keele (1968) in a perceptual learning experiment. Rosch and colleagues (e.g., Merviset al., 1976; Rosch, 1973a, 1973b) used various experimental tasks to investigate the inner structure of semantic concepts and revealed that TYP could also be found in natural categories. They demonstrated that members of a semantic category are not equally ranked and that the borderlines between categories are fuzzy rather than clearly defined (Hampton, 1995; Rosch, 1978).

Differences between typical and atypical members of a category do not only appear in typicality ratings (e.g., Rips et al., 1973; Schröder et al., 2012), but also in response latencies obtained from visual semantic categorisation tasks (Holmes and Ellis, 2006; McCloskey and Glucksberg, 1979; Rips et al., 1973), with faster reaction times for typical vs. atypical members. This so called *typicality effect* has repeatedly been demonstrated in written category-member-verification tasks where a semantic relation, including a superordinate and a subordinate item, is visually presented in form of a sentence (e.g., "A SPARROW is a BIRD"; Mervis and Rosch, 1981; Smith et al., 1974) or as a word pair (e.g., "BIRD – SPARROW"; Hampton, 1997; Kiran et al., 2007; Larochelle and Pineau, 1994). In addition, TYP effects have been found in semantic tasks involving category-based induction and deduction (e.g., Lei et al., 2010; Rein et al., 2010), visual living/non-living-decisions (Morrison and Gibbons, 2006), category naming (Casey, 1992; Hampton, 1995), and in tasks involving both lexical and semantic processes like picture naming (Dell'Acqua et al., 2000; Holmes and Ellis, 2006), reading (Garrod and Sanford, 1977), sentence production (Kelly et al., 1986) or category-member-generation (e.g., Hernández-Muñoz et al., 2006). Concerning different forms of categories, TYP effects are not restricted to perceptual (e.g., GEOMETRIC FIGURES or COLOURS; Posner and Keele, 1968; Rosch, 1973a) or natural taxonomic categories (e.g., biological: FRUITS, ANIMALS or artefacts: FURNITURE, VEHICLES; Larochelle et al., 2000), but also exist in ad-hoc categories (e.g., "things to buy at the bakery"; Barsalou, 1983; Sandberg et al., 2012) and well-

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defined categories (e.g. ODD NUMBERS or MALE; Armstrong et al., 1983; Larochelle et al., 2000; Sandberg et al., 2012).

Several semantic representation models seek to implement the underlying mechanisms of the TYP effect. In the framework of the theory of prototypes (Osherson and Smith, 1981; Rosch, 1973b), the prototype of a semantic category has been depicted as a mental idealised image, which is created by a list of the most typical features of a category and the greatest family resemblance to other category members (Rosch and Mervis, 1975). Within this theory a member of a category is considered to be more typical the more features or attributes it has in common with the prototype (Rosch, 1975, 1978). Thus, the more typical an item is, the more features it shares with other category members, which speeds-up the access to typical items, resulting in faster reaction times.

Feature-comparison models do not assume prototypical representatives, but instead describe TYP effects in categorization tasks based on individual features which comprise semantic categories (McCloskey and Glucksberg, 1979; Smith et al., 1974). TYP effects have also been explained in network models, where categories are displayed as separate nodes within the semantic network and TYP effects result from different strengths of the links between members and categories (Collins and Loftus, 1975; Glass and Holyoak, 1974). Recent accounts of TYP effects combine core characteristics of the above mentioned models, including feature comparisons as well as spreading activation from network models, in computational connectionist models (e.g., McClelland and Rogers, 2003; Rogers et al., 2004). In a connectionist framework, McRae et al. (1999) argue against concept typicality and assume rather a typicality of features. Thus, typicality is determined by the intercorrelation of semantic features. Typical items therefore possess features which are highly intercorrelated with other typical members of the category (e.g., sweet and seeds as typical intercorrelated semantic features for FRUITS), while atypical items are represented by less intercorrelated features.

Age of acquisition (AOA) is defined as the age at which the concept of a certain word has been learned and produced for the first time (e.g., Ellis, 2011). In their pioneering work, Carroll and White (1973) first described AOA as a critical variable which influences word production regardless of the words' frequency, in that objects with early acquired names are named faster than objects with late acquired names.

Subsequent behavioural studies in different languages and populations replicated this benefit in language processing of words with an early vs. late AOA for numerous lexical and/or semantic tasks (see Ellis, 2011; Johnston and Barry, 2006; Juhasz, 2005 for reviews). AOA effects have been found in visual and auditory lexical decision tasks (e.g., Menenti and Burani, 2007; Smith et al., 2006), thus pointing to a potential lexical origin of AOA in language recognition. The influence of AOA on semantic processing is less clear: AOA effects have been found in various visual semantic tasks (e.g., semantic association, categorization, or living-/non-living-classification tasks; e.g., Brysbaert et al., 2000; Johnston and Barry, 2006) and provide evidence for an influence of AOA on semantic word processing. However, some studies failed to find comparable results in semantic tasks (Holmes and Ellis, 2006; Morrison et al., 1992). Moreover, increased effect sizes for AOA have been reported as soon as semantic and additional lexical output processes were involved (e.g., for word naming and picture naming: Belke et al., 2005; Chalard and Bonin, 2006; for word reading and written word production tasks: Bonin et al., 2006). Based on these contradictory results, numerous proposals on the locus of AOA effects have been discussed (Juhasz, 2005). In sum, single locus theories localise AOA effects on either phonological/lexical processing levels (Brown and Watson, 1987; Laganaro and Perret, 2011; Perret et al., 2014) or semantic processing levels (Brysbaert et al., 2000; Steyvers and Tenenbaum, 2005). In contrast, AOA effects were recently explained within multiple processing level accounts that are mainly based on production data (e.g., Brysbaert and Ghyselinck, 2006; Moore et al., 2004). As an example, Catling and Johnston (2009) claim that the AOA effect is additive and increases with the number of involved processing stages. In particular, additional involvement of phonological processes, as is the case in word reading or word production, will enhance the expected effect size (Catling and Johnston, 2006, 2009). Thus, Catling and Johnston postulate two parallel origins for AOA effects: a first one at early phonological levels and a second one at the link between semantic and phonological representations. As a further example of multiple level theories, recent computational accounts aim at modelling the underlying mechanisms of AOA effects within connectionist models (Ellis and Lambon Ralph, 2000). Within these models the focus is not on specific processing levels, such as phonological or semantic levels, but on the strength of connections between representations affecting the entire cognitive system. Ellis and Lambon Ralph (2000) demonstrated a crucial benefit of early acquired concepts over late acquired concepts in their network model, which is due to the continuing loss of the network's plasticity over life (Mermillod et al., 2012; Zevin and Seidenberg, 2002).

Considering the studies on TYP and AOA separately, in sum, the majority of the above mentioned studies provide evidence for an influence of both variables on visual semantic processing at a behavioural level. Only a few studies have investigated the effects of AOA and TYP within the same experiment, although rating studies have shown that TYP and AOA are substantially correlated (Holmes and Ellis, 2006; Schröder et al., 2012), with early acquired concepts being the more typical members of a category (e.g., bed – FURNITURE) (Holmes and Ellis, 2006; Mervis and Rosch, 1981). To our knowledge, Holmes and Ellis (2006) were the first to directly compare the effect of TYP and AOA in semantic processing. They showed that in a visual category-member-verification task, AOA effects disappeared as soon as the items are controlled for TYP. Hence it is important to control for TYP and AOA in order to clarify how the two variables influence word processing, whether effects occur in dependence of each other (as indicated by a possible interaction), and if both arise from the same semantic processing level.

A crucial ERP component that is predominantly assigned to semantic processing and context integration[1] is the N400. The N400 is characterized by a negative amplitude peaking around 400 ms post stimulus onset and is distributed over centro-parietal areas with a slight asymmetry to the right hemisphere for visual stimuli (Federmeier and Laszlo, 2009; Kutas and Federmeier, 2011). Kutas and Hillyard (1980) first reported the N400 component in an anomalous-sentence-paradigm. They discovered a larger negativity for sentence final words which are semantically unrelated (incongruent targets) to the preceding sentence context, in contrast to semantically related words (congruent targets). Subsequent studies revealed that the N400 is not only influenced by semantic violations but also by the cloze probability, or rather expectancy, of words given in a sentential context (Kutas and Federmeier, 2000). In priming studies, semantically related but rather unexpected words evoke a larger N400 than semantically related but fully expected ones (Federmeier and Kutas, 1999; Kutas and Hillyard, 1984). These so called N400-priming effects have been shown both at sentence level processing and at the word level using word lists (e.g., Bentin et al., 1995; Nobre and McCarthy, 1994) or word pairs (Chwilla et al., 1995; Holcomb and Neville,

[1] Notably, in addition to the wealth of literature on semantic manipulations modulating the N400, it has also been found to be sensitive to rhyme priming (Praamstra et al., 1994; Rugg, 1984).