



Development of implicit processing of thematic and functional similarity relations during manipulable artifact object identification: Evidence from eye-tracking in the Visual World Paradigm



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ABSTRACT

This study assessed the implicit processing development of three types of semantic relations during manipulable artifact identification. Thirteen adults and thirty-nine children (age 6, 8, and 10 years) participated. Fixation temporal dynamics were used to assess competition effects from thematic (e.g., wood), specific function (e.g., axe), and general function (e.g., knife) distractors during target identification (e.g., saw). Competition effects were analyzed depending on distractor type and age group. Developmental results demonstrate emergence of competition effects with general function distractors with age, whereas competition effects with thematic and specific function distractors were stable from 6. Findings highlight fine-grained development of similarity-based semantic mechanism implicit use during object processing from 6 to adulthood. They further suggest that complementarity-based mechanism is efficiently used during object semantic processing starting from 6 and likely involved in processing both thematic and specific function relations.

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1. Introduction

In the domain of conceptual development, much attention has been drawn to natural object category formation. Less is known about everyday object categories, which may have a more complex and flexible structure. Nonetheless, two types of semantic relations have been shown to be critical for manipulable artifact object categorization: thematic and functional similarity relations. The present study aims at evaluating how implicit processing of these relations during object visual identification develops with age.

Thematic relations bind objects that “perform complementary roles in the same scenario or event” (Estes, Golonka, & Jones, 2011). Thematically-related objects may belong to the same superordinate category (e.g., hammer–nail) or not (e.g., spoon–yogurt). For manipulable artifact objects, thematic relations often refer to objects that are directly used together. Interestingly, thematic relations are identified faster for manipulable artifacts than for non-manipulable artifacts from the age of 7 (Kalénine & Bonthoux, 2008; Kalénine et al., 2009) suggesting that in adults, like in young children, thematic knowledge is particularly relevant for manipulable artifact concepts. Functional similarity relations (e.g., hammer–screwdriver, both

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used to fix things) have also been highlighted for manipulable artifact semantic categorization. Functional attributes are more important for artifact than for natural object categories in both adults (Cree & McRae, 2003) and young children (Hughes, Woodcock, & Funnell, 2005). Furthermore, many studies have stressed the importance of function similarity in young children's categorization of artifacts (Booth, Schuler, & Zajicek, 2010; Kemler Nelson, Russell, Duke, & Jones, 2000; Träuble & Pauen, 2007). Thus, both semantic relations based on thematic knowledge and common functional attributes are likely to play a crucial role in conceptual development of manipulable artifacts.

Thematic and functional similarity relations may rely on distinct semantic processes. Specifically, processing complementarity between objects may be more relevant for detecting thematic relations, while processing similarity between objects may underlie functional similarity relations. Note that processing similarity must be understood in the broad sense here as the ability to process various types of commonalities between objects, including common perceptual and non-perceptual features (other authors have also used the term “comparison”, see Wisniewski & Bassok, 1999). Wisniewski and Bassok (1999) argued for a distinction between complementarity-based and similarity-based processing based on subjective ratings of object pairs. More recently, neuroimaging and patient studies have shown that different anatomical substrates underlie complementarity-based and similarity-based semantic processes (Kaléline et al., 2009; Lewis, Poeppel, & Murphy, 2015; Mirman & Graziano, 2012; Schwartz et al., 2011), hence supporting the existence of functionally and anatomically distinct semantic mechanisms. Moreover, recent evidence suggests that the weighting of complementarity-based and similarity-based mechanisms during adult semantic processing may be continuous rather than dichotomous (Crutch & Warrington, 2005; Kaléline, Mirman, & Buxbaum, 2012; Pluciennicka, Coello, & Kaléline, 2014). While functional similarity relations at the general level (e.g., saw-knife, can both be used to cut things) would rely mostly on similarity processing, functional similarity relations at a more specific level (e.g., saw-axe, can both be used to cut wood) would involve both similarity-based and complementarity-based mechanisms (Kaléline, Mirman, & Buxbaum, 2012; Kaléline, Mirman, Middleton, & Buxbaum, 2012; Pluciennicka et al., 2014). In a nutshell, recent data suggest that a combination of complementarity-based and similarity-based semantic mechanisms contributes to both thematic and functional similarity relations between manipulable artifacts.

Classic developmental models have posited for the existence of a developmental shift from complementarity-based to similarity-based semantic processing between 4–5 and 7–8 year-olds (Nelson, 1983a, 1983b, 1985; Piaget & Inhelder, 1959; Vygotsky, 1962). For instance, Nelson (1983a, 1983b, 1985), proposed that superordinate categories (e.g., drinks) develops from event knowledge (e.g., breakfast) via an intermediate stage when children understand that objects that occupy the same slot in a given event belong to the same category (e.g., breakfast drinks). Interestingly, thematic, specific function similarity, and general function similarity relations between manipulable artifacts may relate to the event-based, slot-filler, and superordinate categorization stages described by Nelson. The existence of a developmental shift has been largely challenged (see Estes et al., 2011). Thematic knowledge remains highly relevant in adulthood (Lin & Murphy, 2001), and young children categorization behavior appears more dependent on instructions and task than on putative developmental levels (Blaye, Bernard-Peyron, & Bonthoux, 2000; Hashimoto, McGregor, & Graham, 2007; Waxman and Namy, 1997). In a forced-choice categorization task, Berger and Aguerre (2010) recently showed that predominant thematic (e.g., sled-snow man) or superordinate (e.g., sled-rollers) categorical choices could be induced by the prior presentation of an object from the same thematic (e.g., glove) or superordinate (e.g., bike) category in both 4- and 6-year-olds, indicating that children as young as 4 could flexibly adjust their categorization behavior depending on task demands. However, prior presentation of an object from the same “slot-filler” category (e.g., skis), which may be processed using complementarity or similarity-based mechanisms, biased 4-year-old children toward thematic choices, while it facilitated in the same way the thematic and superordinate categorical choices of 6-year-old children. Such result suggests that from the age of 4, both complementarity-based and similarity-based processing can drive explicit categorization choices, but younger children still prefer to rely on complementarity when matching objects. Thus, a gap may exist between the age of acquisition of a given semantic mechanism (i.e., when it is *possibly used*) and the age when this mechanism is *actually used* when processing objects.

Considering thematic and functional similarity relation processing in the light of developmental categorization studies, we can imagine that children as young as 4 are able to categorize objects according to the three types of semantic relations, which would support the hypothesis that both complementary and similarity-based mechanisms are acquired from that age. However, young children may not actually use them during processing of visually presented objects when explicit identification of semantic relations between objects is not required by the task. In a priming study conducted in elementary school children and adults, Perraudin and Mounoud (2009) showed that thematic primes (knife-bread), but not superordinate primes (cake-bread), facilitated object naming in 5-year-olds. In contrast, the two types of primes had similar effects in older children and adults. This suggests that the involvement of the two semantic mechanisms – especially that of similarity – in object processing continues to evolve during elementary school. Thus, we may expect that implicit processing of thematic, specific function similarity and general function similarity relations will follow different developmental trajectories. To our knowledge, development of implicit processing of these semantic relations during object identification has never been assessed before.

1.1. Eye movements and implicit semantic processing

Many studies have used eye-tracking in the Visual World Paradigm (VWP) to study the time course of implicit semantic activation during object processing (e.g., Huettig & Altmann, 2005; Mirman & Magnuson, 2009; Yee & Sedivy, 2006). In the

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