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Developmental changes in hemispheric processing of ambiguous words during adolescence

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ABSTRACT

Previous research has provided evidence of a hemispheric asymmetry in processing dominant and subordinate associations of ambiguous words. However, developmental changes of this hemispheric asymmetry have been little studied. We used the divided visual field paradigm to examine the pattern of hemispheric involvement in ambiguity resolution in 31 Hebrew-speaking adolescents and 41 young adults. Participants performed a semantic judgement task on word pairs, where the first word was an ambiguous word (presented centrally) and the second word was related to either its dominant or subordinate meaning (presented laterally after a 750 ms stimulus onset asynchrony). In both groups, no difference was found between the visual fields performance in the dominant meaning condition. However, in the subordinate meaning condition, adolescents (but not adults) responded slower in the left visual field/right hemisphere. These results suggest that the role of RH in the broader semantic search of distant meanings become refined over adolescence, which might be related to the significant development of figurative language during this period. This study may extend the scope of the Fine-Coarse Semantic Coding Theory by including a developmental perspective.

1. Introduction

During the adolescent years, considerable growth occurs in language as the brain undergoes substantial changes in its structure and functioning (Blakemore & Choudhury, 2006; Giorgio et al., 2010; Nippold, 1998, 2002). By this time, adolescents already have a wide repertoire of semantic abilities and can perform at adult-like levels on a number of tasks (Chan & Marinellie, 2008; Duthie, Nippold, Billow, & Mansfield, 2008; Nippold, 2000; Winner, 1997). Yet, figurative language, such as humor, puns, and metaphors, continue to develop rapidly during adolescence. These skills depend on the comprehension of lexical ambiguity, which also develops during this time (Kave, Kukulansky-Segal, Avraham, Herzberg, & Landa, 2010; Simpson, Krueger, Kang, & Elofson, 1994). Thus, identifying the mechanisms underlying the processing of lexical ambiguity is essential for understanding the underpinnings of later language development. Several linguistic and cognitive factors were suggested to account for the late development of lexical ambiguity and figurative language, including mastering of literacy skills (Nippold, 2002; Ravid & Tolchinsky, 2002), a better ability to integrate conceptual relations (Thibaut, French, & Vezneva, 2010), advanced metalinguistic knowledge (Levorato & Cacciari, 1992; Nippold, 2004), expanding semantic knowledge (Gentner, 1988), pragmatic abilities (Levorato & Cacciari, 2002) and socialization (de Silveira & Habermas, 2011). However, these factors may not be sufficient. It is likely that this later language development is also

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associated with neurological changes that occur during adolescence. The aim of the present study was to examine changes in hemispheric processing of ambiguous words during adolescence using a divided visual field (DVF) paradigm.

Much previous research conducted with adult participants suggests that the comprehension of figurative language and lexical ambiguity involves unique semantic processing mechanisms of the right cerebral hemisphere (RH) (e.g., Faust & Mashal, 2007; Faust, 2012; Jung-Beeman, 2005; Mirous & Beeman, 2012; Whitman, Holcomb, & Zanes, 2010). Thus, although traditionally the left cerebral hemisphere (LH) has been shown to be dominant for language processing, it has been suggested that unique semantic processing in the RH enables processing of specific types of language that require the activation and/or maintenance of multiple meanings, including more distant and unusual meanings (Jung-Beeman, 2005). This RH involvement in figurative language, particularly in lexical ambiguity, has been supported by studies with patients with left or right brain lesions (e.g., Copland, Chenery, & Murdoch, 2002; Hagroot, 1993; E.; Klepousniotou & Baum, 2005a, 2005b; Milberg, Blumstein, & Dworetzky, 1987; Tompkins, Fassbinder, Scharp, & Meigh, 2008), DVF studies (e.g., Burgess & Simpson, 1988; Faust & Lavidor, 2003) and neuroimaging studies (Copland, Zubicaray, McMahon, & Eastburn, 2007; Copland et al., 2003; Harpaz, Levkovitz, & Lavidor, 2009). These studies demonstrated that, whereas both hemispheres are involved in processing ambiguous words, each hemisphere plays a unique role in this process.

The Fine-Coarse Theory (FCT) postulates that each of the two hemispheres have qualitatively different semantic processing representations (Jung-Beeman, 2005; Mirous & Beeman, 2012) as reflected by processing of lexical ambiguity (Atchley, Keeney, & Burgess, 1999; Burgess & Simpson, 1988; Chiarello, Maxfield, & Kahan, 1995; Peleg & Eviatar, 2008). The LH's fine semantic coding, which has a clear advantage for core semantic processes, initially activates both meanings of ambiguous words and maintains only the core meaning. By contrast, the RH's coarse semantic coding, which processes a wide range of word meanings, initially activates the dominant meaning, but then suppresses it just as the subordinate meaning becomes activated (Jung-Beeman, 2005). This hypothesis has been supported by studies using Divided Visual Field (DVF) paradigm. Under automatic processing condition, at a short time interval between prime and target presentation (namely, Stimulus Onset Asynchrony, SOA < 200 ms), the two meanings showed similar facilitation in the LH, but only the dominant meaning was activated in the RH. Conversely, at a long SOA (750 ms), the subordinate meaning was suppressed in the LH, but showed equivalent or greater facilitation relative to the dominant meaning in the RH (Atchley et al., 1999; Burgess & Simpson, 1988; Chiarello et al., 1995). These differences in semantic processing are assumed to be related to the asymmetries in cortical microcircuitry (Jung-Beeman, 2005) and/or to the hemispheric differences in the links between phonological, orthographic and semantic representations (Peleg & Eviatar, 2008, 2009). Interestingly, when more controlled and strategic processing was elicited by tasks (e.g., semantic judgment) that directed the attention to either the dominant or subordinate meanings of ambiguous words, an involvement of the two hemispheres was observed. (Atchley, Story, & Buchanan, 2001; Ekaterini; Klepousniotou, Gracco, & Pike, 2014; Peleg & Eviatar, 2017). The involvement of the LH during controlled conditions might be linked to the role of the left inferior frontal gyrus in the selection among competing semantic alternatives (Jung-Beeman, 2005; Ekaterini; Klepousniotou et al., 2014; Thompson-Schill, D'Esposito, Aguirre, & Farah, 1997).

Although the FCT has been studied in the mature brain for decades, to our knowledge there has been no research into the developmental aspects of hemispheric engagement in fine and coarse processing. Particularly, little is known about the development of hemispheric processing of lexical ambiguity. There is, however, a handful of studies on the development of lexical ambiguity processing using centrally presented words. Simpson and Foster (1986) examined children's lexical ambiguity resolutions in the absence of context. Children ages 8, 10 and 12 named target words that were primed by ambiguous words, using various SOAs. Targets were either related or unrelated to the dominant or subordinate meaning of the ambiguous word. All groups showed automatic retrieval of both meanings of the ambiguous word at a shorter SOA (300 ms). However, for the older group, this automatic retrieval was followed by a second stage, in which more controlled processes were facilitated by a longer SOA (750 ms) and the dominant meaning was maintained while the subordinate meaning was inhibited. These results suggest that, in the absence of context, the 12-year-olds initially conducted an exhaustive access of all meanings of the ambiguous words and then used frequency information that allocated attention to the most frequent meaning of the ambiguous word, suppressing the subordinate meaning (Simpson & Foster, 1986). This finding, that late development of control processes is a limiting factor in lexical ambiguity resolution, is also supported by studies investigating context effects on ambiguity resolution (e.g., Bar-On, Dattner, & Ravid, 2017; Booth, Harasaki, & Burman, 2006; Khanna & Boland, 2011; Simpson et al., 1994) and ambiguity retrieval (Kave et al., 2010). Taken together, the findings indicate that lexical ambiguity resolution changes with age as more controlled processes develop.

Taken together, figurative language and distant meanings of words, such as lexical ambiguity, which are known to be supported by the RH (Jung-Beeman, 2005), are still in development during adolescence. Given evidence from both functional and structural imaging studies that the maturation of the RH is prominent during adolescence (Bava et al., 2010; Giorgio et al., 2010; Lebel, Treit, & Beaulieu, ; Uda et al., 2015), it is possible that changes in the RH may be related to processing of distant meanings of ambiguous words. For example, a fMRI study using a semantic judgment task with children 9–15 years old showed that age-related changes in processing distantly semantic related pairs were related to recruitment of the right inferior frontal gyrus (Chou et al., 2006). Additional support to our hypothesis might derive from studies on adults with lower language skills. Atchley and her colleagues examined hemispheric processing of ambiguous words and found an absence of a priming effect in the RH for subordinate meaning in adults with a history of developmental language disorders compared to those with typical development (Atchley et al., 2001).

The present study aimed to explore the development of the fine and coarse semantic coding between adolescence and early adulthood by examining the processing of ambiguous words in the context of an explicit semantic judgment task combined with the DVF paradigm. Adolescents and young adults were presented with ambiguous words preceding words that were related to either the dominant or the subordinate meaning of the ambiguous words, as well as presented to the right or the left visual field. We employed a semantic judgment task with a relatively long SOA (750 ms), as it enhances controlled selection and integration processes, which is

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