Journal of Neurolinguistics 45 (2018) 36–44

Contents lists available at ScienceDirect

Journal of Neurolinguistics

journal homepage: www.elsevier.com/locate/jneuroling

Perceptual simulations during sentence comprehension: A comparison between typical adolescents and adolescents with autism spectrum disorder

Orna Peleg [a, b, *], Rotem Ozer [c], Tal Norman [a], Osnat Segal [c]

[a] The Program of Cognitive Studies of Language and its Uses, Israel
[b] Sagol School of Neuroscience, Tel-Aviv University, Israel
[c] Department of Communication Disorders, Sackler Faculty of Medicine, Tel-Aviv University, Israel

ARTICLE INFO

Article history:
Received 26 December 2016
Received in revised form 22 August 2017
Accepted 30 August 2017

ABSTRACT

Consistent with embodied theories of language comprehension, several studies have shown that comprehenders automatically activate perceptual (visual) information of verbally described objects, even when this information in neither explicitly mentioned nor necessary to perform the task. To clarify the role of perceptual activations in meaning construal; and to identify a potential cause of comprehension difficulties in autism spectrum disorder (ASD), the present study examined the extent to which individuals with ASD activate perceptual representations during sentence comprehension. 16 adolescents with ASD and 16 typically developing (TD) controls were asked to decide whether an object depicted in a line drawing had been mentioned in a preceding sentence. In the *match condition*, the shape or the orientation of the object matched the one implied by the preceding sentence. In the *mismatched condition*, the shape or the orientation of the object did not match the one implied by the sentence. TD adolescents responded faster in the match than in the mismatch condition. In contrast, adolescents with ASD did not distinguish between the two conditions. Thus, compared to controls, ASD adolescents were less able to spontaneously activate perceptual information as a function of sentence context. The implications of these results are discussed.

1. Introduction

Embodied theories of language processing hold that sentences are understood by mentally simulating the state-of-affairs described by the sentence. That is, the same mental representations that are activated when we perceive real events are also activated in response to verbally described events. Language comprehension therefore involves not only the activation of linguistic representations and structures, but also the activation of sensorimotor representations associated with the described objects and events (e.g., Barsalou, 2008; Zwaan et al., 2004). In line with this proposal, several studies have shown that comprehenders automatically activate perceptual (visual) information of verbally described objects even when this information is not explicitly stated, but merely implied by the described situation (e.g., Stanfield & Zwaan, 2001; Zwaan, Stanfield, & Yaxley, 2002; Engelen, Bouwmeester, de Bruin, & Zwaan, 2011).

* Corresponding author. The Program of Cognitive Studies of Language and its Uses, Tel Aviv University, Tel Aviv 69978, Israel.
E-mail address: pelegor@post.tau.ac.il (O. Peleg).

http://dx.doi.org/10.1016/j.jneuroling.2017.08.003
0911-6044/

In these studies, participants are asked to read (or listen to) sentences describing objects in particular locations. Importantly, the object's visual shape (or orientation) changes as a function of its location. For example, the sentence "Ron saw the balloon in the air" implies an inflated balloon, whereas the sentence "Ron saw the balloon in the pack" implies a deflated balloon. Similarly, the sentence "Dan saw the toothbrush in the cup" implies a vertical toothbrush, while "Dan saw the toothbrush in the sink" implies a horizontal toothbrush.

To investigate whether comprehenders spontaneously activate such subtle perceptual details, a sentence-picture verification task is typically used, in which participants are asked to decide whether a depicted object (e.g., balloon) was mentioned in the preceding sentence (e.g., "Ron saw the balloon in the air"). The critical trials are always positive (i.e., the object was indeed mentioned), however, the object's shape (or orientation) may be consistent (e.g., an inflated balloon) or inconsistent (e.g., a deflated balloon) with the one implied by the sentence. In all these studies, responses were faster in the match than in the mismatch condition, suggesting that the mental representation resulting from sentence comprehension incorporates perceptual (visual) information associated with the described scene, even when this information in neither explicitly mentioned, nor necessary to perform the task.

These visual effects (i.e., faster responses in the match than in the mismatch condition) were obtained regardless of the specific task that was used (e.g., Madden & Zwaan, 2006), or the participants' age (e.g., Dijkstra, Yaxley, Madden, & Zwaan, 2004; Engelen et al., 2011). For example, using the same sentence-picture verification task, Engelen et al. (2011) demonstrated that even children as young as seven are able to activate and integrate perceptual information, as a function of sentence context. In that study, similar perceptual effects were found among children aged 7–13 years, both after listening to sentences and after reading them aloud. Importantly, the effect size did not increase as a function of age, suggesting that both younger and older children construct a perceptual simulation of the described object's shape and orientation during sentence comprehension. Such early visual effects are consistent with the idea that perceptual simulation of verbally described situations is obligatory and relatively effortless.

Nevertheless, although the interaction between linguistic and perceptual representations, is now well established, exactly what role these representations play in language comprehension is still under investigation (e.g., Mahon & Caramazza, 2008). In an attempt to establish a causal relationship between perceptual simulations and language comprehension, Madden and Zwaan (2006), examined the ability of low- and high-span comprehenders to activate implied perceptual representations of verbally describe objects. High-span comprehenders activated implied perceptual information faster than low-span comprehenders, suggesting that the strength of the links between linguistic and perceptual representations may influence the process of meaning construal. In particular, Madden and Zwaan (2006) have suggested that perceptual representations may act as a mechanism for construing the contextually appropriate sense of a word during language processing.

To further test the relationship between perceptual simulations and language comprehension, the present study focused on individuals with autism spectrum disorder (ASD). As detailed below, constructing contextually appropriate meanings can be a source of particular difficulty for individuals with ASD. If perceptual simulations are necessary for meaning construal, then comprehension difficulties in individuals with ASD may be associated with weaker connections between linguistic and perceptual representations. Thus, to clarify the role of perceptual simulations in language processing; and to identify a potential cause of comprehension difficulties in ASD, the goal of the current study was to investigate the extent to which individuals with ASD spontaneously activate perceptual information as a function of sentence context.

ASD is a neurodevelopmental condition characterized by impaired social interaction and communication; and restricted, repetitive patterns of behavior (DSM-V). Although both language and perceptual (visual) deficits are not part of the diagnostic criteria, individuals with ASD often exhibit impairments (or atypical behavior) in both domains. In particular, it has been claimed that individuals with ASD have a cognitive bias towards local rather than global processing (e.g., Frith, 1989; Happé & Frith, 2006). That is, they tend to focus on the 'trees' (i.e., the details, parts) rather than the 'forest' (i.e., the whole). In the visual domain, this cognitive bias is demonstrated by superior performance in tasks requiring local processing (e.g., O'Riordan, Plaisted, Driver, & Baron-Cohen, 2001; Plaisted, O'Riordan, & Baron-Cohen, 1998), together with impairments in tasks requiring global processing (e.g., Brosnan, Scott, Fox & Pye, 2004; Happe, 1996).

In the linguistic domain, support for reduced global processing comes from studies demonstrating impaired ability to use context in order to generate inferences (e.g., Norbury & Bishop, 2002) or in order to resolve ambiguous words (e.g.,Frith & Snowling, 1983; Happe, 1997; Jolliffe & Baron-Cohen, 1999). For example, Frith and Snowling (1983) asked children with and without ASD to read aloud sentences that contained homographs (words with the same spelling, but different pronunciation and meaning, such as *tear*). The sentences were biased towards the homograph's dominant ("In her eyes there was a *tear*") or subordinate ("In her dress there was a *tear*") meaning. In contrast to typically developing (TD) children who tended to read the contextually appropriate word, children with ASD, tended to choose the dominant pronunciation, irrespective of the sentential context. However, supporting the idea of a local bias rather than a global processing impairment (e.g., Happé & Frith, 2006), there is also evidence that individuals with ASD have the ability to process information globally if they are explicitly instructed to do so (e.g., Hadad & Ziv, 2015; Snowling & Frith, 1986). Thus, evidence from studies in both the visual and the linguistic domains suggest that in situations where TD individuals spontaneously process incoming information globally and in context, individuals with ASD tend to process information "piece by piece" (but see, Giora, Gazal, Goldstein, Fein, & Stringaris, 2012; Hahn, Snedeker, & Rabagliati, 2015, for different results with high functioning autistic individuals).

At the neurological level, this cognitive bias towards local rather than global processing in individuals with ASD, was recently explained in terms of "disrupted cortical connectivity" (e.g., Brock, Brown, Boucher, & Rippon, 2002; Just, Cherkassky, Keller, & Minshew, 2004; Just, Keller, Malave, Kana, & Varma, 2012; Kana, Keller, Cherkassky, Minshew, & Just, 2006). In