



Visually perceived spatial distance affects the interpretation of linguistically mediated social meaning during online language comprehension: An eye tracking reading study [☆]



Ernesto Guerra ^{a,*}, Pia Knoeferle ^b

^a Experimental Psycholinguistics Lab & Center for Intercultural and Indigenous Research (CIIR), Pontificia Universidad Católica de Chile, Villarrica, Chile

^b Department of German Studies and Linguistics, Humboldt-Universität zu Berlin, Berlin, Germany

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ABSTRACT

Recent experimental evidence suggests that spatial distance between two depicted objects in a non-referential visual context (i.e., when neither spatial distance nor the objects were mentioned) can rapidly and incrementally modulate the processing of semantic similarity between and-coordinated subject noun phrases in a sentence. The present research examines in three eye-tracking reading experiments whether these spatial distance effects extend to another abstract domain (social relations). More importantly, we assessed how precisely cognitive mechanisms link spatial information to sentence interpretation. To this end we varied between experiments the (order of the) constituents conveying information about social relations. We examined to what extent object distance effects on sentence interpretation depend upon a one-to-one mapping (relating objects to nouns). The eye-tracking record showed that spatial distance effects extended to abstract language other than semantic similarity and that these effects occurred as soon as the readers encountered linguistic information about social relations – independent of whether that information was conveyed by the (coordinated) nouns or by other constituents. Finally, the direction of the spatial distance effects seemed to depend on the activation level of the spatial distance representations, as determined by the constituent order. We discuss the contribution of these results to accounts of situated sentence comprehension.

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Introduction

Most research on visually situated language processing has examined language comprehension when sentences referred to objects and events in the immediate visual context (e.g., Altmann & Kamide, 2007; Knoeferle & Crocker, 2007; Tanenhaus, Magnuson, Dahan, & Chambers, 2000). Recent experimental results, however, suggest that a visual

context can modulate online sentence processing even when it is not referentially related to the sentence (Guerra & Knoeferle, 2014). In the latter situation, comprehenders seemed to be able to rapidly exploit non-referential links between object distance and semantic similarity of nouns. In an experiment by Guerra and Knoeferle (2014) participants observed two objects (playing cards) moving either farther apart or closer together and then read abstract sentences in German, such as *Frieden und Krieg sind bestimmt verschieden...* ('Peace and war are certainly different...') or *Kampf und Krieg sind freilich entsprechend...* ('Battle and war are certainly similar...'). The assumption was that spatial distance (as gleaned from the card distance prior to sentence reading)

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* Corresponding author at: Bernardo O'Higgins 501, Villarrica, Chile.
E-mail address: erguerrag@uc.cl (E. Guerra).

maps onto semantic similarity (as conveyed by compositional interpretation of the sentence) and the key question was whether such effects of spatial distance would occur in real time. Participants' eye-gaze times for sentences expressing similarity between the two coordinated nouns were shorter when the cards had moved closer together (compared to farther apart) in the visual context. For sentences expressing dissimilarity, the opposite pattern emerged, with shorter gaze times when cards moved farther apart (vs. closer together). These effects emerged incrementally and closely time-locked to the relevant linguistic input (e.g., during 'similar/different'). They suggest that participants rapidly related the spatial distance between the two cards to the semantic similarity (or dissimilarity) of the sentential nouns.

From a theoretical vantage point, these findings suggest that information from the non-linguistic context can interact with language processing without an overt referential (e.g., *man* referring to a man) or a lexically associative link (e.g., *eat* cueing a cake). Current accounts have, by contrast, focused on accommodating interactions of language processing and visual context precisely when language was related to the visual context via referential relations or lexico-semantic associations (Coordinated Interplay Account (CIA): Knoeferle & Crocker, 2007; Knoeferle, Urbach, & Kutas, 2014; see also Glenberg & Robertson, 1999). In the absence of referential links for their stimuli, Guerra and Knoeferle (2014) accommodated the effects of spatial distance on semantic interpretation by means of a non-referential mechanism that relates corresponding elements from the sentence and the visual context by co-indexing them in real-time at the conceptual level.

The results reported by Guerra and Knoeferle (2014) thus revealed the effects of a non-referential visual context on the real-time interpretation of abstract sentences. However, the scope of that study was limited to a specific semantic domain (i.e., semantic similarity) and constituent order (i.e., and-coordination of abstract nouns). Moreover, we need a more thorough examination of how precisely abstract language co-indexes with contextual spatial information to advance theoretical accounts of situated language processing. Referential visual information affects sentence interpretation time-locked to when language refers to an object (e.g., inspecting a man when hearing *man*, see Knoeferle & Guerra, 2016, for a recent review). By contrast, the mechanism(s) implicated in relating spatial distance between objects to abstract language are less clear. Below we first discuss the notion of co-indexing in accounts of situated language processing followed by insights into how social relations might relate to spatial relations. The goal of this discussion is to motivate our examination of both the generality of spatial distance effects (for another abstract domain, i.e., social relations) and the implicated co-indexing mechanisms.

The notion of co-indexing in situated language processing accounts

Previous research has used the notion of co-indexing for relating language to representations derived from experi-

ence with the manipulation of objects (see Glenberg & Robertson, 1999) or visually-based representations (see Knoeferle & Crocker, 2007). Glenberg and Robertson (1999), for instance, proposed the 'indexical hypothesis', according to which language-based representations index to objects or corresponding (internal or external) representations. In this process the affordances (actions that can be performed with an object, e.g., we can eat an apple but not a rock) of these objects become available. Object affordances then allow the language users to make sensible conceptual combinations (e.g., the girl eats an apple) and comprehend language. Experiential components (such as action representations) are thus critical for language comprehension in this approach.

The notion of co-indexing referential expressions with their referents also plays a prominent role in the processing account by Knoeferle and Crocker (2007). In their account, the interaction between language and non-linguistic visual information occurs in three stages. In a first stage, the linguistic input is incrementally processed, yielding a partial interpretation and associated expectations based on linguistic and world knowledge. In the second stage, the current sentence interpretation directs (visual) attention to relevant aspects of the visual scene (or its mental representation). The model assumes that representations are maintained in a working memory buffer and that they are subject to decay. In a third stage, linguistic interpretation and the active visual context representations are co-indexed and the interpretation is grounded in the visual scene (stage three is not identical with, but related to the indexation proposed by Glenberg & Robertson). This tightly time-locked coordinated interplay continues as further linguistic information becomes available.

In these two models, co-indexing thus draws on referential language-world relations (e.g., sentential nouns refer to objects, verbs to actions, and sentences to concrete events) and implicates lexico-semantic associations as well as mechanisms for compositional interpretation. However, these accounts are not well equipped to accommodate effects when sentences do not refer to the visual context as is the case for abstract language. Abstract words (e.g., *similarity*, *friendliness*) do not have an unequivocal referent or visual correlate (although they can be visually represented). Recent results (Guerra & Knoeferle, 2014) suggested that for visual context effects on abstract language processing, co-indexing might depend on subtler (non-referential) associations such as that between similarity and spatial distance. Yet, the precise conditions under which co-indexing between abstract language and non-referential visual information can occur are unclear. In light of this recent evidence, it is critical to assess in more detail how precisely visually-derived spatial distance cues and abstract semantic meaning are co-indexed in order to refine theoretical accounts of visually situated language comprehension. To this end, we must more closely consider the stimulus properties.

Recall that in Guerra and Knoeferle (2014), the cards presented before the sentence moved in a coordinated manner either farther apart or closer together. In the ensuing sentence, the two noun phrases described as either

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