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ERP correlates of script chronology violations

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ABSTRACT

Research indicates a distinction between the processing of script content (which events, behaviors, scenes... are part of it) and script chronology (what is their usual order of occurrence). Using sequences of two line drawings depicting everyday social script events, we examined the event related potential (ERP) correlates of script chronology violations (i.e., wrong order). An increased left anterior negativity (LAN) following chronology violations suggests similarities between the processing of script chronology in visually observed human behavior and verbal syntax. Consequently, this study extends previous findings suggesting that the LAN is sensitive to structure violation across domains (e.g., verbal syntax, abstract structure), including that of meaningful human actions.

1. Introduction

Scripts are defined as stereotyped action plans (Read, 1987) which help us to interpret, predict and understand the behavior of others in our complex social world. As the most classical example, the restaurant script entails the sequence of "taking a seat", "waiting for the menu", "ordering what to eat" and so on. Scripts are composed of events and actions with an overarching individual or collective goal (Read, 1987). The comprising events or actions each have a subgoal that contributes to the overall finality of the script. Although scripts and actions share similarities, there are important differences. The goals that define scripts are of a more abstract, conceptual nature than action goals, which are more grounded in concrete motor representations (Vallacher & Wegner, 1987; see also Spunt, Satpute, & Lieberman, 2011).

Abelson (1981) proposed that scripts can contain at least two distinct types of information. On the one hand, they consist of knowledge about which behaviors, events, actors and roles occur in a given context (script content). On the other hand, scripts delineate a more or less fixed chronological order in which these events and behaviors normally proceed (script chronology).

Behavioral evidence supports the notion that both types of script information enable anticipation of upcoming behaviors in a given context. Regarding the representation of script content in the verbal domain, words denoting script events facilitate the processing of other events belonging to the same script both in relatedness judgment tasks and lexical decision paradigms. This occurs even when excluding normatively associated words (e.g., honey – bee), or words belonging to a mutual category (e.g., honey – sugar). Chwilla and Kolk (2005) demonstrated this using script triplets without associative or obvious semantic relation among individual elements, e.g. director – dismissal – bribe, while an earlier study by Moss, Ostrin, Tyler, and Marslen-Wilson (1995) used normatively unassociated word pairs, e.g., restaurant – wine. The influence of script knowledge can transcend that of simple associative relations between individual events or concepts: a recent study demonstrated that lexical decisions regarding a target event are facilitated when the preceding prime events were presented together, but the same prime events had no facilitating effect when presented on their own (e.g., "marinate" and "grill" as primes for "chew", Khalkhali, Wammes, & McRae, 2012). More fine-grained investigations have disentangled the role of different kinds of script information, demonstrating that *event nouns* prime *actors* and *objects* commonly involved in them; *locations* prime *actors* and *objects* commonly found at those locations and *instrument nouns* prime *objects* on which those instruments are commonly used, but not the *people* who typically use them (Hare, Jones, Thomson, Kelly, & McRae, 2009). Such findings are difficult to reconcile with spreading activation accounts of semantic memory in their simplest form, apparently implying the existence of qualitatively differentiated types of association.

Behavioral research has documented the encoding of script *chronology* in semantic memory as well. As an early indication, even after memorizing an incorrectly ordered list, participants tended to reproduce script events in their canonical order (Bower, Black, & Turner, 1979). More recently, several reaction

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time studies have documented effects of temporal directionality in general event knowledge (Khalkhali et al., 2012; Nuthmann & van der Meer, 2005; Van der Meer, Beyer, Heinze, & Badel, 2002). For example, relatedness judgments regarding script word triplets are faster when the triplets are presented in the correct rather than reversed order (e.g., wake up – shower – brush versus shower – wake up – brush; Khalkhali et al., 2012). In the action domain, evidence for great sensitivity to temporal order comes from a study in which participants judged which phase a photographed athletic action belonged to (approach versus flight of a high jumper; Güldenpenning, Koester, Kunde, Weigelt, & Schack, 2011). The target pictures were subliminally preceded by a picture depicting an earlier or later phase of the same action. Athletes (experts) were significantly faster in classifying the targets when the prime-target pairs constituted a chronologically correct rather than reversed sequence, even within movement phases (i.e., approach/flight). A similar effect occurred in novices only when prime and target were taken from a different phase of the jump (approach versus flight), supposedly as a consequence of their less fine-grained temporal knowledge about these actions.

Although an extensive event related potential (ERP) literature documents how script *content* knowledge shapes our understanding of the world (for a review, see Sitnikova, Perrone, Goff, & Kuperberg, 2010), research on script *chronology* information is rather scarce. In fact, to the best of our knowledge, there is no study to date on the ERP correlates of script chronology violations. Such an investigation could be of importance in addressing at least two questions. One key issue is whether or not scripts are unitary knowledge structures, storing information about both content and chronology. More central for the present study is the question to which extent the processing of chronological script information concerning actions is similar to the processing of other types of sequential information, language in particular, or rather appeals to a separate, specialized network. Before turning to the hypotheses of the present study, we will briefly review the existing ERP literature on script information processing.

1.1. ERPs and script content: contextual mismatch and the N400

Previous ERP studies have addressed the impact of script content violations. A recurrent finding is that elements or behaviors that do not belong to a previously primed script elicit larger N400 amplitudes than elements or behaviors that do fit the script. The N400 is a negative-going deflection peaking at about 400 ms after stimulus onset. There are at least two functional interpretations of the N400 effect (Lau, Almeida, Hines, & Poeppel, 2009; Lau, Phillips, & Poeppel, 2008). According to the lexical view, the N400 indexes the very process of lexical access (Kutas & Federmeier, 2000), that is, the activation of features of the long-term memory representation associated with a single lexical item. The integration view, on the other hand, proposes that the N400 reflects a combinatorial process of semantic integration of lexical items with the local and global linguistic working context (Hagoort, 2008). Hybrid hypotheses have also been formulated, suggesting that the N400 reflects a conglomeration of several distinct sub-processes (Pylkkänen & Marantz, 2003).

Increased N400 amplitudes in response to script content anomalies have been documented in studies using verbal descriptions of behavior (Chwilla & Kolk, 2005) as well as studies using graphic stimulus material (using picture sequences, e.g. showing a man taking a cutting board – a man taking a loaf of bread – a man cutting versus ironing the bread, Sitnikova, Holcomb, Kiyonaga, & Kuperberg, 2008; within pictures, e.g., woman cutting bread with a saw, Proverbio & Riva, 2009; for a review, see Sitnikova et al., 2010). Apparently, the activation of script content information is a broad and rapid process: even information that is anomalous with the local linguistic context is activated (Metusalem et al., 2012). Consider the following passage: "A huge blizzard ripped through town last night. My kids ended up getting the day off from school. They spent the whole day outside building a big snowman/jacket/towel." While both "jacket" and "towel" are semantically anomalous sentence endings, relatively smaller N400 amplitudes were observed in response to "jacket", supposedly reflecting the activation of script content.

1.2. ERPs and structure violations: the LAN

Violations of structure in sequences of meaningful stimuli have classically been associated with left anterior negativities (LANs) in the ERP. As such, the LAN has been observed in response to a wide range of violations of syntactic structure (e.g., word order, for a review, see Friederici, 2002). However, the LAN is not only sensitive to the structure of verbal sequences. Cohn et al. (2012) recently demonstrated sensitivity of the LAN to a syntax-like structure in sequences of meaningful non-verbal stimuli (sequential cartoon images). According to these authors, this syntax-like structure entails a narrative architecture, which typically begins by establishing or introducing the characters and context. Next, an event is initiated and then culminates in a peak or climax. Finally, the event is wrapped up at the end of the sequence. Cohn et al. (2012) found increased LANs to image sequences lacking such narrative structure, even when the pictures were thematically unrelated. This is somewhat analogous to increased LANs in response to grammatical errors in nonsense sentences (Hahne & Jescheniak, 2001).

While script content provides the basic building blocks of a script, script chronology structures them into a meaningful whole. As such, script chronology violations may elicit increased LANs. However, ERP research involving sequences of meaningful behaviors (as opposed to abstract, e.g., geometric stimuli) is quite scarce (Koester & Prinz, 2007). Nevertheless, some support for this hypothesis can be found in existing neurolinguistic studies on chronological inconsistencies. Baggio (2008) presented sentences containing chronology violations entailing a (mis)match between the tense of the verb and a temporal anchoring expression (e.g., "Last Sunday, Vincent painted/paints his house"). He observed increased LANs in response to such anachronisms, setting in between 200 and 300 ms after the onset of the critical word. Similarly, increased LAN amplitudes have been observed when participants were confronted with linguistic bypasses of the "default" order implied by the *iconicity assumption* (the assumption that the order in which events are presented in language or stories is the order in which they occurred; Hopper, 1979). For example, whereas a sentence of the form "After she X, she Y" is congruent with the iconicity assumption, the reverse implied order "Before she X, she Y" is incongruent with the iconic X–Y order. Münte et al. (1998) found that otherwise identical sentences beginning with the non-iconic "before" elicited an increased LAN compared to sentences beginning with the iconic "after". Importantly, this effect emerged as early as 300 ms after the onset of the first word of the sentence – that is, before all relevant temporal information in the sentence had been processed. This suggests that the retrieval of temporal-conceptual knowledge is part of word comprehension almost immediately. In line with previous work (Kluender & Kutas, 1993), the authors proposed that this LAN effect reflects working memory processes, supported by the finding that its magnitude correlated with individual differences in working memory span. In abstract sequences, structural information symbols, enabling prediction of upcoming events when combined with previous elements, elicit a similar LAN (Hoen & Dominey, 2000). This suggests the LAN may be associated with a general neurocomputational function engaged by both linguistic and non-linguistic sequential structures.