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Not so secret agents: Event-related potentials to semantic roles in visual event comprehension

Neil Cohn[a,b,*], Martin Paczynski[c], Marta Kutas[a]

[a] Department of Cognitive Science, University of California, San Diego, La Jolla, CA, USA
[b] Tilburg Center for Cognition and Communication, Tilburg University, Tilburg, The Netherlands
[c] Wright State Research Institute, Wright State University, Dayton, OH, USA

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ABSTRACT

Research across domains has suggested that agents, the doers of actions, have a processing advantage over patients, the receivers of actions. We hypothesized that agents as "event builders" for discrete actions (e.g., throwing a ball, punching) build on cues embedded in their preparatory postures (e.g., reaching back an arm to throw or punch) that lead to (predictable) culminating actions, and that these cues afford frontloading of event structure processing. To test this hypothesis, we compared event-related brain potentials (ERPs) to averbal comic panels depicting preparatory agents (ex. reaching back an arm to punch) that cued specific actions with those to non-preparatory agents (ex. arm to the side) and patients that did not cue any specific actions. We also compared subsequent completed action panels (ex. agent punching patient) across conditions, where we expected an inverse pattern of ERPs indexing the differential costs of processing completed actions as a function of preparatory cues. Preparatory agents evoked a greater frontal positivity (600–900 ms) relative to non-preparatory agents and patients, while subsequent completed actions panels following non-preparatory agents elicited a smaller frontal positivity (600–900 ms). These results suggest that preparatory (vs. non-) postures may differentially impact the processing of agents and subsequent actions in real time.

1. Introduction

Within the structure of transitive two-participant events (e.g., *X punches Y* or *X grasps Y*), agents, the doers of actions (*punchers*), typically hold an advantage over patients (*punchees*), the receivers of actions (Dowty, 1991; Gruber, 1965). Arguably, this leads to an "agent advantage" across all human communication and comprehension (Strickland, 2016). Agents typically precede patients in the canonical sentence structures of most (89%) human languages (Dryer, 2011; Greenberg, 1966; Kemmerer, 2012). This ordering also persists in the signs of deaf children who have not learned a sign language (Goldin-Meadow, 2003; Goldin-Meadow & Feldman, 1977) and the gestures of non-signing adults asked to communicate without speaking (Gershoff-Stowe & Goldin-Meadow, 2002), independent of their native spoken language (Goldin-Meadow, So, Özyürek, & Mylander, 2008). In addition, agents are typically recognized faster than patients in pictures and films of events (Robertson & Suci, 1980; Segalowitz, 1982; Webb, Knott, & Macaskill, 2010), even when these agents are represented by geometric shapes (Verfaillie & Daems, 1996).

Based on a series of behavioral experiments with events depicted in comic strips, we have argued that agents provide more information about event structure than do patients, and thereby facilitate event processing (Cohn & Paczynski, 2013). For example, we observed longer self-paced viewing times to preparatory agents (like a figure reaching back an arm to punch) than to patients, regardless of their relative position within a sequence (i.e., in agent-patient vs. patient-agent orders), at panels prior to those wherein semantic roles would be assigned (i.e., at the completed punch). Moreover, completed actions following agent-patient orderings or agents alone are viewed for shorter durations than those following patient-agent orderings or just patients. This is consistent with the possibility that preparatory agents may afford frontloading of event processing and thereby facilitate processing of action events when they occur. Though examined in the context of visual narrative sequences, we have argued that this "event builder" role may motivate the preference for agents over patients across many domains.

These sorts of findings raise the question of what visual features comprehenders might use to interpret characters' semantic roles (agent, patient) *prior* to their appearance in completed actions, when those roles become actualized. Not only does body posture cue action pre-

* Corresponding author at: Tilburg University, Tilburg center for Cognition and Communication (TiCC), P.O. Box 90153, 5000 LE Tilburg, The Netherlands.
E-mail address: neilcohn@visuallanguagelab.com (N. Cohn).

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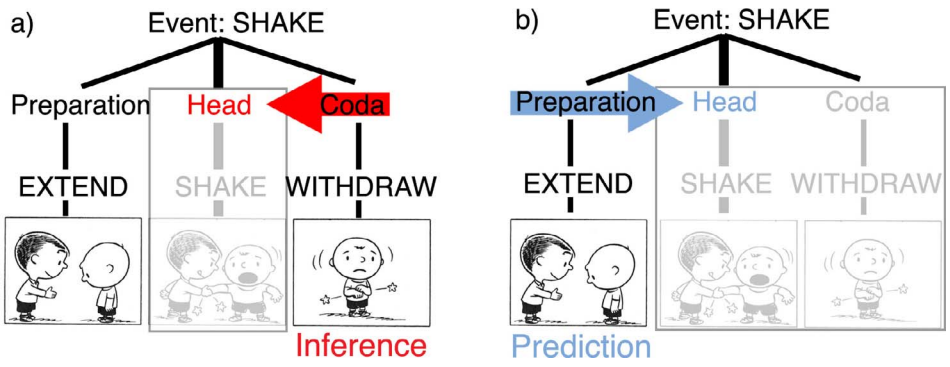

Fig. 1. Inference and prediction of event states from a tripartite event schema. *Peanuts* is © Peanuts Worldwide LLC.

processing, e.g., sports or dancing, particularly for viewers with greater expertise with those actions (Aglioti, Cesari, Romani, & Urgesi, 2008; Smith, 2016; Urgesi, Savonitto, Fabbro, & Aglioti, 2011; Urgesi et al., 2010), but even 5 month old infants seem able to distinguish action-based cues from static postures (Shirai & Imura, 2016). Moreover, postural cues allow comprehenders to discern agent and patient roles (Wilson, Papafragou, Bunger, & Trueswell, 2011), even in rapidly presented (37 ms, 73 ms) action photographs (Hafri, Papafragou, & Trueswell, 2012).

Given that postural cues can serve to distinguish semantic roles during an event, we hypothesize that similar cues can signal *upcoming* agents for *preparatory* actions (i.e., reaching back an arm *in order to* punch), which might then afford predictions about upcoming actions (Urgesi et al., 2010). Indeed, static figure postures implying specific upcoming movements activate motor brain areas (Kourtzi & Kanwisher, 2000; Senior et al., 2000) similarly active during viewing of those actual movements (Dupont, Orban, De Bruyn, Verbruggen, & Mortelmans, 1994; Zeki et al., 1991).

Such observations align with mounting evidence of neural prediction during event comprehension. For example, fMRI activation has been observed prior to event boundaries during event segmentation (Zacks, Braver, et al., 2001), and participants have been found to generate more accurate subjective predictions about subsequent events from within a segment than after a segment boundary (Zacks, Kurby, Eisenberg, & Haroutunian, 2011). Centrally-distributed ERP negativities have been observed in anticipation of incongruous dance motions, prior to their full manifestation, an effect that is larger for experienced dancers than novices (Amoruso et al., 2014). In addition, an increase in motor-evoked potentials has been observed when participants view people shoot basketballs, even before the ball leaves a shooter's hands (Aglioti et al., 2008).

Despite indications that comprehenders preactive event information, little work has examined what motivates these expectancies. Postural kinematic cues do motivate anticipation of actions, particularly for expert observers (Aglioti et al., 2008; Smith, 2016; Urgesi et al., 2010, 2011). However, research on event predictions has not directly *manipulated* these potential cues. Extant work has focused on specific actions (basketball, dancing) rather than generalizing across different actions, and the frequent use of video stimuli has made it difficult to distinguish precisely which cues are critical given that events unfurl over an extended time period (although, see Webb et al., 2010). We hypothesize that the postural cues of expected agents may provide one source for frontloading of event processing.

Preparatory visual cues are recognized as such to the extent they are linked to a completed action, constituting an "event schema" entrenched in semantic memory (Lasher, 1981; Strickland & Keil, 2011). Jackendoff (2007) argues that an abstract schema generalizes across specific events; a completed "head" is preceded by a "preparation" and followed by a "coda" (see also Moens & Steedman, 1988). For example, shaking hands involves a preparation (extending a hand), a head (grasping and shaking another hand), and a coda (releasing and withdrawing). This process can be recursive, with whole structures serving as preparations or codas (ex. walking up to a person may be a preparation for shaking hands). Such hierarchies have been well established in psychological research (Zacks & Tversky, 2001; Zacks, Tversky, & Iyer, 2001). An event "script" (Schank & Abelson, 1977) reflects a concatenation of numerous event schemas for specific situations and scenarios (e.g., the event schemas comprising restaurant behavior). While psychological theories of event comprehension include such schemas, they generally leave both representations and their contributions to processing unspecified (e.g., Zacks, Speer, Swallow, Braver, & Reynolds, 2007).

Because of the tripartite preparation-head-coda structure of this schema, viewing parts of an event should frame inferences of other parts of events. For example, viewing both the preparation and coda provide enough information to infer an unseen completed head of an event (Strickland & Keil, 2011), as schematized in Fig. 1a. Preparations also seem to afford some forward predictions of subsequent actions (Aglioti et al., 2008; Smith, 2016; Urgesi et al., 2010, 2011). Thus, as in Fig. 1b, extension of a hand would be recognized as a preparation, thereby activating the generalized event schema for a subsequent head of hand-shaking. We here ask whether the specific preparatory cues offered by an agent-to-be motivate such predictions.

We used event-related brain potentials (ERPs) to explore the contribution of semantic roles and/or visual preparatory cues to the processing of visual events. We drew upon visual narratives (comics) that depict events statically in their prototypical states, as in prior work (Cohn & Paczynski, 2013). These stimuli enabled us to isolate and manipulate the preparatory actions of characters across various different types of actions.

We followed up on prior behavioral work (Cohn & Paczynski, 2013) by recording ERPs to visual narrative sequences with completed action panels preceded by either a preparatory agent or a patient for the event. We expanded this design by manipulating the postural cues that signaled the preparatory actions taken by the agent, and adding a condition with "non-preparatory agents" in passive postures as well (see Fig. 2). Because we hypothesized that these cues motivate the building of event structures, we expected their absence (vs. presence) to affect action-related (event) processing.

We hypothesized that, on the basis of these cues, preparatory agents would initiate the building of an event structure more than patients would. Event processing would thus be frontloaded to the processing of the preparatory action panel, which in turn would facilitate processing downstream at the completed action. Based on our behavioral results showing longer viewing times to agents than patients (Cohn & Paczynski, 2013), we expected ERP activity to preparatory agents to reflect greater processing effort. Without the cues indicating a preparatory action, the semantic role of this "agent-to-be" would not be recognized, and thus should render these non-preparatory-agents as indistinguishable from patients in their accessing event structures *prior* to the completed action. We thus expected similar ERP effects for patients and non-preparatory-agents compared to preparatory agents.

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