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Getting it: human event-related brain response to jokes in good and poor comprehenders

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Abstract

Joke comprehension has been decomposed into surprise registration followed by a coherence stage, involving frame-shifting (retrieving a new frame from long-term memory to reinterpret information in working memory). We examined this view by recording event-related brain potentials (ERPs) from adults reading one-line jokes or non-joke controls with equally unexpected endings. Joke and non-joke ERPs differed in several respects depending on participants' ability to get the joke and contextual constraint. In good joke comprehenders, all jokes elicited a left-lateralized sustained negativity (500–900 ms), indexing frame-shifting, low constraint jokes elicited a frontal positivity (500–900 ms), and high constraint jokes elicited an N400 and later posterior positivity. By contrast, poor joke comprehenders showed only a right frontal negativity (300–700 ms) to jokes. This pattern of effects does not map readily onto a two-stage model of joke comprehension. © 2001 Published by Elsevier Science Ireland Ltd.

Keywords: Event-related potentials; Comprehension; Jokes; Language; Humor

The ability to appreciate humor is an intriguing aspect of human behavior, considered by many to be a defining human attribute [11]. Though it recruits a number of cognitive processes, analysts have decomposed joke comprehension into two major components: registration of *surprise* followed by re-establishment of *coherence* [16]. For example, 'years' is surprising when it occurs in "I let my accountant do my taxes because it saves time: last spring it saved me 10 years". However, to really 'get' the joke, the listener must go beyond surprise and formulate a new, coherent interpretation in which the speaker is worried about going to jail, and pays an accountant to conceal illegal business practices. Coherence involves a process of *frame-shifting*, in which the listener activates a new frame from long-term memory to reinterpret information already active in working memory [4]. Here ,we use event-related brain potentials (ERPs) recorded from healthy adults to examine the two-stage model by assessing the psychological reality of frame-shifting, and differentiate it from the surprise component of joke comprehension.

Joke comprehension deficits have been observed in patients with right hemisphere brain damage (RHD), especially including the anterior portion of the right frontal lobe [3,14]. When asked to pick the punch-line of a joke from an array of choices, including straightforward endings, non-sequitur endings, and the correct punch-line, RHD patients erred by picking non-sequitur endings, indicating that they know surprise is necessary but are impaired on coherence [2]. Though these data suggest a dissociation between the surprise and coherence stages of joke comprehension, their implications for normal brain function are uncertain, as they may reflect compensatory strategies, and functional reorganization of the damaged brain. Further, lesion data do not address the time course of the two stages of joke comprehension. To these ends, we recorded ERPs as neurologically intact participants read sentences that ended either as jokes or with equally surprising non-joke endings that did not entail frame-shifting.

Participants were 28 right-handed, college-age, monolingual English speakers (ten men) with normal, or corrected-to-normal, vision. Participants' read sentences and answered true/false questions while their electroencephalogram was sampled at 250 Hz and recorded from 26 tin electrodes arranged in a geodesic pattern, referenced to the left mastoid.

Sixty sentences ended either as jokes (30), or as non-jokes (30); 100 were filler sentences. One-line jokes were chosen

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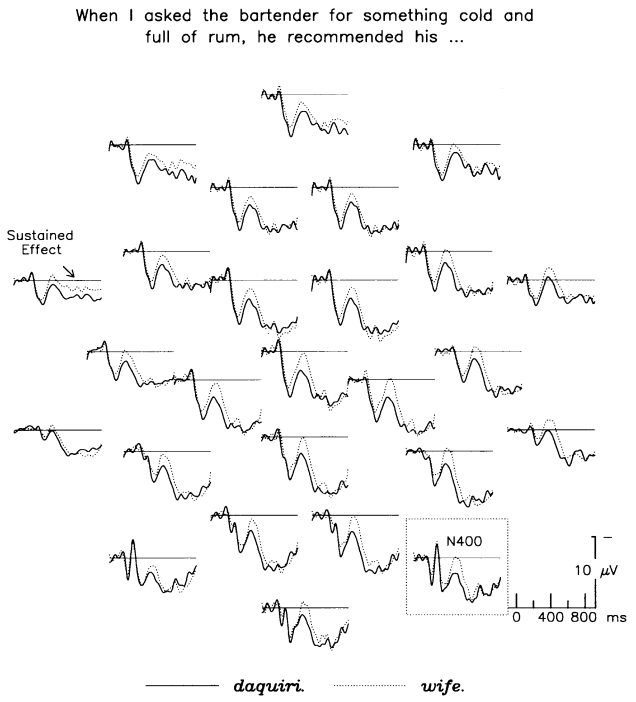

Fig. 1. Grand average ($n = 28$) ERPs to joke (dotted) and non-joke (solid) endings from all electrode ($n = 26$) sites. Negative voltage is plotted up in this and all subsequent figures.

from anthologies so that their comprehension required frame-shifting triggered by the sentence-final noun. Stimuli were normed on an off-line *cloze task* in which a separate group of 45 adults completed each joke fragment with the first word that came to mind. The *cloze probability* of the joke endings (percentage of subjects completing the sentence with the joke endings) was quite low (3%). Non-joke endings were constructed by replacing the last word of jokes with contextually congruent completions that matched the joke endings for length (6.5 characters; SD = 2), frequency (87/million; SD = 146), and cloze probability (3%; SD = 2.5).

Experimental sentences in joke and non-joke conditions were thus identical until the sentence-final word. Non-joke endings were consistent with the contextually evoked frame, while joke endings required frame-shifting. Experimental sentences were further divided according to sentence constraint, a factor thought to affect the specificity of semantic expectations [17], operationalized here as the cloze probability of the most popular response for each sentence. A median split yielded sentence constraints of <40% (e.g. "Statistics indicate that Americans spend 80 million a year on games of chance, mostly *weddings/dice*") and >40% (e.g. "She read so much about the bad effects of smoking she decided she'd have to give up *reading/habit*") for low and high constraint sentences, respectively.

Sentences were presented at a rate of two words/s (200 ms duration; final word = 500 ms) and followed by a true/false question that assessed comprehension, especially whether or not participants were getting the jokes. For example, for "I asked the bartender for something cold and full of rum, and he recommended his wife", the comprehension question was "The bartender's wife was a frigid lush" (true). For "We have a concrete swimming pool, but when you live near the beach, nobody wants to swim in the concrete", the question was "Their pool is filled with chlorinated water" (false).

ERPs to sentence-final words displayed the P1/N1/P2 complex typical of visually presented words, a negative-going wave from 300 to 700 ms (N400), and a late positivity (see Fig. 1). ERPs were quantified as the mean amplitude between 300–500, 500–700, and 700–900 ms post-word onset relative to 100 ms pre-stimulus baseline and subjected to repeated measures analysis of variance (ANOVA) with ending (joke/non-joke), constraint (low/high), and three factors indexing scalp topography: hemisphere (left/right); laterality (dorsal/lateral); and anterior/posterior (four levels). All P values were corrected using the Huhyn–Feldt correction; for clarity, we report original degrees of freedom.

Between 300 and 500 ms, there was a main effect of ending ($F_{(1,27)} = 7.98$, $P < 0.01$) and an ending by constraint interaction (Ending × Constraint, $F_{(1,27)} = 4.34$, $P < 0.05$; Ending × Constraint × Anteriority, $F_{(3,78)} = 4.68$, $P < 0.05$, $e = 0.42$; Ending × Constraint × Laterality, $F_{(1,26)} = 4.26$, $P < 0.05$; Ending × Constraint × Laterality × Hemisphere, $F_{(1,26)} = 5.16$, $P < 0.05$). Overall, ERPs to jokes were more negative than non-jokes in a manner characteristic of the N400: broadly distributed, but with a centro-parietal, slightly right hemisphere focus. The N400 is typically associated with the processing of meaningful stimuli: the larger its amplitude, the harder the task of lexical integration [10]. However, these N400 joke effects were only reliable in high (and not low) constraint sentences (post-hoc: Ending, $F_{(1,27)} = 14.55$, $P < 0.001$).

Joke effects between 300 and 500 ms demonstrate the brain's sensitivity to expectations based on *frames*, *scripts*, or *schemas* retrieved from long-term memory [1,12,13], and are consistent with other reports that N400 is sensitive to global aspects of context [15,18]. Although the joke and non-joke endings were equally unexpected according to our cloze measure, non-joke endings were designed to be more consistent with the contextually evoked schema, while joke endings required frame-shifting. Thus, it may be that high constraint sentences allow the reader to commit to a frame that facilitates the processing of non-joke endings, but makes joke endings more difficult to integrate.

The ANOVA also revealed reliable effects between 500–700 and 700–900 ms, but subsequent analysis suggested that the effects varied with participants' ability to 'get' the jokes. Good comprehenders ($n = 14$) averaged 83% correct on the true/false questions following the jokes, while poor comprehenders ($n = 14$) averaged only 64% correct. On questions following non-jokes, all but one participant scored 83% correct or better, indicating that the distinction between good and poor comprehenders reflects difficulty with jokes.

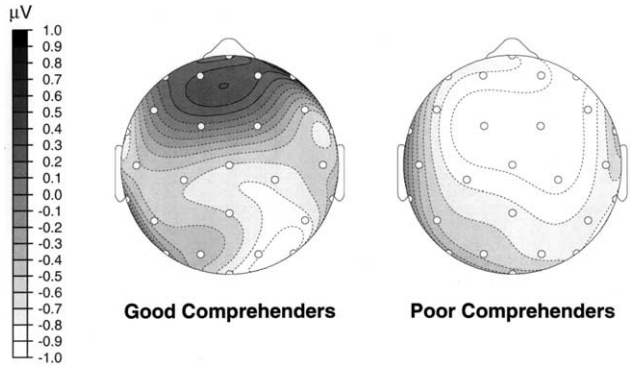

Fig. 2. Voltage maps of mean amplitude of the joke effect (jokes minus non-jokes) measured 300–500 ms in 14 good (left) and 14 poor (right) joke comprehenders.

To evaluate ERP differences related to participants' joke comprehension, we conducted analyses of mean ERP amplitudes between 300–500, 500–700, and 700–900 ms with the between-participants factor, comprehension group, and the within-participants factors, ending, constraint, and various scalp topography factors as above. Between 300 and 500 ms post-word onset, there was no main effect of comprehension group ($F < 1$), but there were indications of a more anterior distribution of the joke-related N400 among poor than good joke comprehenders (Comprehenders × Hemisphere × Laterality × Anteriority, $F_{(3,78)} = 2.93$, $P < 0.05$, $e = 0.86$; Comprehenders × Ending × Hemisphere × Laterality, $F_{(1,26)} = 2.58$, $P < 0.05$; see Fig. 2). Joke effects were also observed between 500–700 and 700–900 ms, though their nature differed as a function of comprehension group (500–700 ms: $F_{(1,26)} = 5.82$, $P < 0.05$; 700–900 ms: $F_{(1,26)} = 9.11$, $P < 0.01$; 500–700 ms: Comprehenders × Ending × Constraint × Hemisphere × Laterality × Anterior/Posterior, $F_{(3,78)} = 3.43$, $P < 0.05$, $e = 0.71$).

Among poor comprehenders, jokes elicited less positive (more negative) ERPs than non-jokes between 500 and 700 ms; joke effects for high constraint stimuli were bilateral and most evident over the anterior scalp (Fig. 3), while for low constraint stimuli (Fig. 4), joke effects were larger over the right and evident only over the posterior scalp (post-hoc: Constraint × Ending × Hemisphere × Laterality × Anterior/Posterior, $F_{(3,39)} = 3.4$, $P < 0.05$, $e = 0.97$). This continued negativity between 500 and 700 ms may reflect vain attempts by the participants to search semantic memory for information that might help them make sense of the jokes. Between 700 and 900 ms, there were no joke effects.

Among good joke comprehenders, the response to jokes between 500 and 900 ms post-onset varied across the two hemispheres: ERPs to jokes were *less positive* than non-jokes over *left lateral sites*, an effect we refer to as a *sustained negativity*, and *more positive* over medial *posterior sites* (500–700 ms: Ending × Laterality × Anterior/Posterior, $F_{(3,39)} = 3.26$, $P < 0.05$, $e = 0.83$; 700–900 ms: Ending × Laterality × Anterior/Posterior, $F_{(3,39)} = 3.22$, $P < 0.05$, $e = 0.83$). Collapsed across ending type, low constraint stimuli elicited a fronto-central positivity, while high constraint stimuli elicited a positivity largest over the occipito-parietal scalp. Visual inspection of the data suggests that constraint effects are due primarily to differences in ERPs to joke endings; analysis reveals a marginal interaction between constraint, ending, and anteriority ($F_{(3,39)} = 3.42$, $P = 0.08$, $e = 0.48$).

The goal of the present study was to assess the psychological reality of frame-shifting, and to differentiate it from surprise. Our results, however, do not afford a simple mapping from the ERP effects to the surprise and coherence stages of joke comprehension. Both good and poor joke comprehenders showed greater negativity for joke than non-joke endings, although only in high constraint sentences and with differing scalp distributions. In good comprehenders, joke endings in high constraint sentences elicited a posterior positivity, reminiscent of the P3b [5,6], which thus may reflect the violation of frame-level expectations in

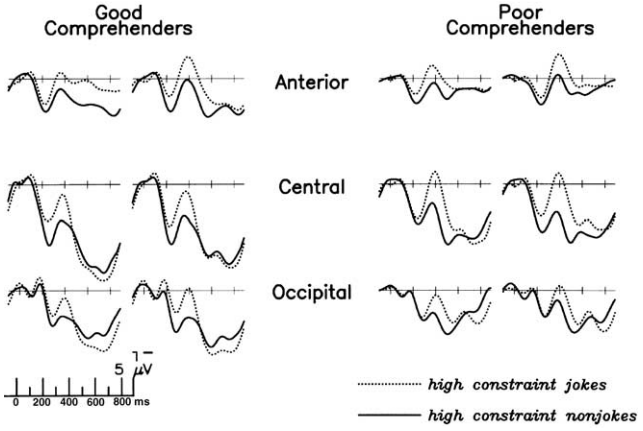

Fig. 3. Grand average ERPs to joke (dotted) and non-joke (solid) endings to high constraint sentences in good joke comprehenders ($n = 14$) and poor joke comprehenders ($n = 14$).

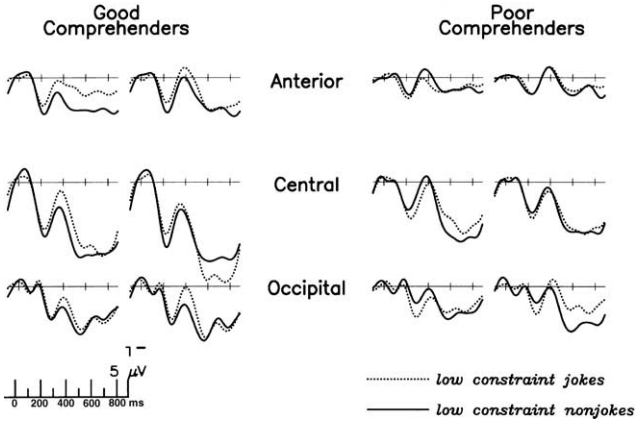

Fig. 4. Grand average ERPs to joke (dotted) and non-joke (solid) endings to low constraint sentences in good (left) and poor (right) joke comprehenders.

the jokes (Fig. 3). In contrast, the joke endings in low constraint sentences elicited a fronto-central positivity (Fig. 4) which may be related to the novelty P3, or P3a, an anterior positivity elicited by stimuli that evoke an orienting reaction, and thought to originate in the superior temporal cortex [7,8].

Jokes also elicited a sustained negativity over anterior left lateral sites for both high and low constraint sentences which may reflect the frame-shifting needed to re-establish coherence. The wave shape and topography of this effect differentiate it from both the posterior positivity elicited by high constraint jokes, and the anterior positivity elicited by low constraint jokes. Rather, it resembles a large, slow-rising positive drift at the same left anterior sites, reported by Kutas and King [9], linked to working memory operations involved in the construction of a mental model. The sustained effect observed here may reflect negative modulation of this slow positive drift due to working memory operations involved in joke comprehension.

While the positivities have been argued to reflect a *surprise* component of joke processing, and the sustained negativity to index *frame-shifting* needed to re-establish coherence, all three effects occur within the same time window. Temporal overlap of these joke-related ERP effects thus make it unlikely that joke processing can be accounted for in terms of a simple two-stage model with surprise and coherence engaged in sequence.

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