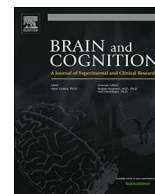




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## Sex differences in humor processing: An event-related potential study

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## ABSTRACT

Numerous behavioral studies and a handful of functional neuroimaging studies have reported sex differences in humor. However, no study to date has examined differences in the time-course of brain activity during multi-stage humor processing between the sexes. The purpose of this study was to compare real-time dynamics related to humor processing between women and men, with reference to a proposed three-stage model (involving incongruity detection, incongruity resolution, and elaboration stages). Forty undergraduate students (20 women) underwent event-related potential recording while subjectively rating 30 question-answer-type jokes and 30 question-answer-type statements in a random order. Sex differences were revealed by analyses of the mean amplitudes of difference waves during a specific time window between 1000 and 1300 ms poststimulus onset (P1000–1300). This indicates that women recruited more mental resources to integrate cognitive and emotional components at this late stage. In contrast, men recruited more automated processes during the transition from the cognitive operations of the incongruity resolution stage to the emotional response of the humor elaboration stage. Our results suggest that sex differences in humor processing lie in differences in the integration of cognitive and emotional components, which are closely linked and interact reciprocally, particularly in women.

## 1. Introduction

Humor comprehension is a set of implicit cognitive processes involving the detection and resolution of embedded ambiguities in contexts, leading to positive feelings of mirth or reward feedback that are produced through humor appreciation. The following joke, which was obtained from the Internet (<https://www.rd.com/jokes/customer-service/>), can illustrate the underlying process:

*I was at the customer-service desk, returning a pair of jeans that was too tight.*

*“Was anything wrong with them?” the clerk asked.*

*“Yes,” I said.*

*“They hurt my feelings.”*

The punch-line “They hurt my feelings” disrupts the expected outcome and conflicts with reality (because jeans would not actively “hurt” a person’s feelings), thereby inducing a sense of surprise. To fit the punch line to the developing context, a strategy of searching stored mental scripts for possible resolutions of this cognitive conflict is activated. The ambiguities must (at least partially) be resolved through cognitive logic and appear plausible to some degree with respect to the setup context, thus inducing the subsequent positive emotional response or laughter phenomenon. According to Wyer and Collins’

comprehension–elaboration theory of humor (1992), the following processes contribute to humor comprehension: detecting incongruent information, experiencing surprise, and reestablishing coherence when incongruent information is reinterpreted using various schema. Additionally, humor comprehension and humor appreciation have been regarded as a sort of cognitive problem-solving ability, as proposed in Suls’ incongruity resolution theory (1972). Thus in combination, these two established theories suggest a process of detection of incongruity between a prediction and reality, resolution of incongruity through comprehending a situation, and, finally, a feeling of mirth or reward. These three components constitute an integrated processing of humor, with the first two stages functioning as the premise that leads to the final stage of humor elaboration.

## 1.1. Sex differences in humor processing: behavioral aspects

Behavioral studies have determined sex differences with regard to humor appreciation. For example, regarding *humor content*, men appreciate humor involving erotic or violent content more than women do (Brodzinsky, Barnett, & Aiello, 1981), as is evident from the larger erotic priming effect and faster response to erotic targets seen in males (Geer & Melton, 1997; Mussweiler & Forster, 2000). With respect to *humor structure*, women enjoy nonsensical or absurd humor more than men do

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(Brodzinsky & Rubien, 1976; Brodzinsky et al., 1981; Terry & Ertel, 1974). Considering the *social roles* and *social functions* of humor, men have been found to be more likely to act as humor creators to gain self-esteem or achieve superiority (Bressler & Balshine, 2006; Crawford & Gressley, 1991; Martin, 2007). In contrast, women are more likely to act as humor appreciators and tend to laugh more in social interactions (Bressler & Balshine, 2006; Chan, 2016; Li et al., 2009; Martin, 2007; Vrticka, Black, & Reiss, 2013). So far, sex differences in humor have mostly been elucidated through the evolutionary perspective of Darwin's sexual selection theory (1871), indicating that the two sexes may have different preferences for specific types and social roles of humor. More specifically, Miller's evolutionary theory of humor (1998, 2000) proposes that a "sense of humor" may be an indicator of "good genes" and thus of desirability as a potential mate, particularly for women choosing their male mate (Martin, 2007).

As mentioned, humor appreciation is the end product of complex humor comprehension. Thus, it is reasonable to doubt that the observed sex differences in humor appreciation originate from the cognitive processing of the premise of a joke. Albeit, behavioral studies reporting sex differences in humor comprehension are scant. This is because providing proper explanations of questions exploring implicit cognitive processing, such as humor comprehension, according to explicit behavioral performances is difficult. Hence, investigating integrative humor processing at the neural level may help clarify whether humor comprehension contributes to the underlying mechanisms of sex differences regarding humor appreciation. Furthermore, neuroscientific investigations may provide a new perspective beyond the evolutionary in understanding sex differences in relation to humor processing.

### 1.2. Neural evidence of sex differences in humor processing

Recently, the topic of how people comprehend and appreciate humor is getting more attention in the field of neuroscience. On the basis of the comprehension-elaboration theory (Wyer & Collins, 1992), Chan et al. (2013) proposed a three-stage neural circuit model of verbal humor processing which they developed based on functional magnetic resonance imaging (fMRI) data. These data demonstrated corresponding neural correlates for each prerequisite stage of the integrative humor process (e.g., activation of the right middle temporal gyrus and right middle frontal gyrus was responsible for identifying semantic incongruities at the incongruity detection stage). Other neuroimaging studies have identified a key role for the temporo-parietal junction (TPJ) and anterior cingulate cortex (ACC) during the humor process (Azim, Mobbs, Jo, Menon, & Reiss, 2005; Kohn, Kellermann, Gur, Schneider, & Habel, 2011; Mobbs, Greicius, Abdel-Azim, Menon, & Reiss, 2003; Moran, Wig, Adams, Janata, & Kelley, 2004; Vrticka et al., 2013; Watson, Matthews, & Allman, 2007). In a review article, Vrticka et al. (2013) noted that in the humor process, the TPJ region appears to be the main region associated with the cognitive component, whereas the mesocorticolimbic dopaminergic pathways and the amygdala appear to be dominant for the emotional component.

Specific neural correlates of sex differences in humor processing have been reported in a small number of studies. For example, Azim et al. (2005) used fMRI to examine sex differences in brain activation elicited by humorous cartoons. The results showed that the left temporal-occipital junction (BA 37), which is part of the ventral-stream involved in visual processing, was activated in both sexes, representing semantic processing occurring during the coherence development process of joke comprehension. However, women exhibited higher neural activity in the left prefrontal cortex (PFC) and mesolimbic regions than men. The authors therefore suggested that, for women, humor processing involves a greater degree of executive processing regarding coherence and language-based decoding. In a later study also involving watching humorous cartoons, Kohn et al. (2011) reported that women showed a stronger association between subjective affective ratings and brain areas involved in the ventral emotion processing system (e.g.,

amygdala, insula, ACC), suggesting that women process humor through limbic reactivity, involving the appraisal of its emotional features. In contrast, in men, both the ventral and dorsal processing systems were activated. The authors therefore concluded that men apply more evaluative, executive resources to humor processing than women do, a perspective that contrasts with the interpretation of Azim et al. (2005). In a recent study, Chan (2016) applied fMRI to differentiate the neural correlates of humor processing between the sexes and provided evidence that, regardless of the joke type (bridging-inference joke, exaggeration joke, or ambiguity joke), greater activation was elicited in the anterior prefrontal cortex (aPFC) of women than of men, corresponding to neural processing within the ventral stream. In contrast, men exhibited greater activation in the dorsolateral prefrontal cortex (dPFC), corresponding to neural processing within the dorsal stream. The divergent topographical results from such studies have led to diverse conclusions regarding differences in humor processing between the sexes.

Collectively, these small number of studies have indicated that women and men share extensive overlapping activation in brain areas implicated in cognitive humor processing. Existing findings on sex differences in brain activation have primarily identified the role of the differential processing of emotion, which is evident in the stronger engagement of emotion-related brain areas in women than in men. This occurs irrespective of whether significant behavioral differences in subjective funniness rating are demonstrated between the sexes (Azim et al., 2005; Chan, 2016; Kohn et al., 2011; Vrticka et al., 2013). However, such a conclusion lacks neural evidence focusing on temporal dynamics to strengthen its validity. Since both cognitive processing and emotional humor processing follow a sequential flow (i.e., you will not perceive the humor without first realizing that something is "wrong"), examining real-time neural dynamics in light of the three-stage neural circuit model of humor could contribute further empirical evidence about how different processing from humor comprehension to humor appreciation occurs in the brains of men and women.

### 1.3. Examining humor processing through real-time dynamics

To date, no study has examined real-time dynamics to analyze the differences in humor processing between the sexes. However, a few studies have found corresponding event-related potential (ERP) effects in line with the proposed three stages of the integrative humor process. These studies have either involved reading verbal jokes (Du et al., 2013; Feng, Chan, & Chen, 2014; Ku, Feng, Chan, Wu, & Chen, 2017; Mayerhofer & Schacht, 2015; Shibata et al., 2017) or watching humorous cartoons (Tu et al., 2014). The most consistent finding across these studies is of an enhanced N400 for funny items compared with unfunny and unrelated items (Coulson & Kutas, 2001; Du et al., 2013; Feng et al., 2014; Mayerhofer & Schacht, 2015; Tu et al., 2014). This may be indexing the registration of surprise in humor comprehension (Du et al., 2013; Tu et al., 2014), or the semantic integration difficulties (Mayerhofer & Schacht, 2015) during the preliminary stage of incongruity detection.

Following the N400 effect, starting at approximately 500 ms, a sustained positive deflection is observed at multiple areas, representing the incongruity resolution stage in humor processing. This has been associated with the posterior P600–800 (Du et al., 2013), the central-posterior P600 (500–700 ms, Feng et al., 2014; Ku et al., 2017; 500–800 ms, Shibata et al., 2017), the central-anterior P800–1000 (Tu et al., 2014), or the P1000–1600 without specified regions (Tu et al., 2014). In addition, some studies have observed enhanced negativities for jokes during a similar time interval, such as the frontocentral N600–800 (Du et al., 2013), or left-lateralized sustained negativities (500–900 ms, Coulson & Kutas, 2001). Despite these polarities, the salient positive or negative deflection following N400 indicates the cognitive operation of incongruity resolution during humor processing, comprising the reconstruction of convergent meaning from novel

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