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A re-visit of three-stage humor processing with readers' surprise, comprehension, and funniness ratings: An ERP study

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ABSTRACT

Humor processing can be divided into three sub-stages including incongruity detection, incongruity resolution, and elaboration (Chan et al., 2012, 2013; Feng et al., 2014). However, few studies have investigated the three-stage model of humor processing with readers' surprise, comprehensibility and funniness levels, and little discussion has been devoted to its biological underpinning. To verify the credibility of the three-stage model, electroencephalography (EEG) was utilized in corroboration with two types of stimuli including jokes and non-jokes in the present research. Participants were categorized into high vs. low score groups based on their rating scores of surprise, comprehension, and funniness to joke stimuli. The between-group analyses showed that compared with the less surprised group, highly surprised people elicited a primarily larger N400, which may suggest more incongruity perceived in reading jokes. Additionally, good comprehenders mainly elicited a larger P600, probably indicating a more successful resolution of detected incongruity in comparison with poor comprehenders. Finally, the highly amused group elicited a larger late positive potential (LPP) compared with the less amused group, which could reflect more affective elaboration of jokes. Participants' surprise, comprehension, and funniness levels had smaller impacts on other chief electrophysiological components, with the effects varying with different group contrasts. These results provided the evidence that different degrees of surprise, comprehensibility, and amusement to jokes would influence the three sub-stages (incongruity detection, incongruity resolution, and elaboration) respectively in humor processing. The current study thus generally re-verified the stability of the three-stage model through participants' behavioral ratings which had seldom been touched upon.

1. Introduction

Humor is a unique ability in human beings. Successful humor processing is really complicated because it involves a cognitive juxtaposition of mental sets, followed by an affective feeling of amusement. Suls' (1972) incongruity resolution theory was the earliest to propose that people will make a prediction about what the ending, or a punch line, will be when

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reading a text. Once the actual punch line is different from the predicted one, surprise occurs to motivate one to search for possible logical rules and to incorporate the new information that causes initial incongruity. Successful resolution of incongruity could thus lead to a sense of enjoyment. Wyer and Collins' (1992) comprehension and elaboration theory later attempted to break down the stream of humor processing into the comprehension stage including the detection of incongruity and its resolution, followed by the elaboration process to form a mirth experience. In the elaboration process, further inferences are made based on implicit or newly-understood information, and it can lead to the appraisals of humorous stimuli.

Following Wyer and Collins' (1992) theory, Chan, Chou, Chen, and Liang's (2012) functional magnetic resonance imaging (fMRI) study successfully provided the neural correlates of different cognitive and affective components in humor processing. By comparing funny (including stages of humor comprehension and elaboration), unfunny (neither humor comprehension nor elaboration needed), and garden path sentences (including only the comprehension stage), their results showed that the stage of humor comprehension (containing both incongruity detection and resolution) was associated with enhanced activities in the bilateral inferior frontal gyri (IFG) and left superior frontal gyrus (SFG), while the elaboration process of humor was correlated to the activities in left ventromedial prefrontal cortex (VMPFC), bilateral amygdalae, and parahippocampal gyri.

Also, by manipulating funny (including incongruity detection and resolution), unfunny (neither incongruity detection nor resolution needed), and nonsensical sentences (including only incongruity detection), Chan et al. (2013) had further dissociated the neural circuits underlying incongruity detection and resolution in humor comprehension. Incongruity detection was found to be associated with greater neural activations in the right middle frontal and right temporal gyrus (rMFG, rMTG), while the resolution of incongruity activated the left SFG and left inferior parietal lobes (IPL) more. Taken together, these fMRI studies had integrated the traditional two-stage model of humor processing into a three-stage one, namely the incongruity detection, resolution, and elaboration.

However, these cognitive theories of humor processing often put different emphasis on surprise, comprehension, and the appraisal of humor, the three critical components in humor processing. According to recent fMRI studies (Kohn, Kellermann, Gur, Schneider, & Habel, 2011; Mobbs, Hagan, Azim, Menon, & Reiss, 2005), there exists great differences in processing of verbal humor among different readers. Therefore, even though Chan et al.'s (2012, 2013) studies had proposed a three-stage model of humor processing, between-group variances in the perception of surprise, readers' comprehensibility, or emotion arousal (amusement) during humor processing were not taken into consideration, given that humorous forms of occurrence, reception and presentation can be varied greatly across individuals, cultures and genders (Alden, Hoyer, & Lee, 1993; Hehl & Ruch, 1985). More importantly, due to limited temporal resolutions of fMRI techniques, a closer look into the dynamic and the processing stream in each sub-stage of humor processing still seemed unattainable.

Coulson and Kutas's (2001) research is one of the few ERP studies that examined readers' differences in comprehensibility during humor processing. By utilizing one-liner jokes along with non-jokes, the authors investigated neural mechanisms underlying the stages of incongruity detection and resolution by grouping participants into good and poor comprehenders based on their response to comprehension questions. The results indicated that compared with poor comprehenders, good comprehenders exhibited more posterior N400 (350–500 ms) amplitudes and an enhanced late posterior positivity (500–900 ms) when reading high-constraint jokes. Both the high-/low-constraint jokes elicited a left-lateralized sustained negativity (500–900 ms) in the two groups. The authors further proposed that the observed N400 effect could signal the increased difficulty of contextual integration and the brain's sensibility to the inconsistent expectations based on the frames retrieved from long-term memory when reading punch lines. Additionally, the late positivity may comprise a broad P3 family that could reflect the violation of frame-level expectations and/or an orienting reaction. Finally, the sustained anterior negativity may be linked to enhanced working memory load to resolve incongruity during frame-shifting processes in joke comprehension.

Although Coulson and Kutas' (2001) study has provided important information regarding the influences of comprehensibility in the processing of humor, they still failed to map ERP effects to the surprise and resolution stages of incongruity in joke comprehension specifically. More importantly, they could not exclude the possibility that the results they found could be influenced by participants' different degrees of perceived surprise and funniness to the jokes.

More recently, with funny, congruous (unfunny) and incongruous (nonsensical) question-answer type sentences, Marinkovic et al. (2011) found that funny punch lines generated the smallest N400m (350–500 ms) in left anteroventral temporal lobe, which may imply initial lexical-semantic analysis, by recording ERPs and magnetoencephalography (MEG) simultaneously. In addition, these funny sentences elicited the largest posterior P600 (700–1150 ms) with increased activation in anterior medial prefrontal cortex and right dorsolateral prefrontal cortex, which was suggested to reflect ambiguity detection and the subsequent interpretative-integrative processing. On the contrary, with discourse coherent, incoherent, and joke endings, Mayerhofer and Schacht's (2015) failed to find the late left anterior negativity (500–700 ms) or posterior P600s (700–1000 ms) as seen in the previous studies (Coulson & Kutas, 2001; Marinkovic et al., 2011). Joke endings elicited larger N400 (250–500 ms) amplitudes and the late frontal positivity (700–1000 ms) than coherent endings. The authors argued that N400 could reflect expectation violation of readers' initial interpretation at punch lines, while the late frontal positivity probably indexed further emotion responses, which was supported by the data of participants' larger pupil diameters when reading joke endings.

To clearly dissociate the overlapped mapping of cognitive processes with electrophysiological activities underlying humor processing, Feng, Chan, and Chen (2014) investigated the temporal dynamics of cortical activations with funny, unfunny, and