Attentional biases toward humor: Separate effects of incongruity detection and resolution

Article *in* Motivation and Emotion · April 2014

DOI: 10.1007/s11031-013-9374-1

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Motiv Emot (2014) 38:287–296
DOI 10.1007/s11031-013-9374-1

ORIGINAL PAPER

Attentional biases toward humor: Separate effects of incongruity detection and resolution

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Published online: 1 October 2013

Abstract Previous research has indicated that the comprehension of humor involves two stages: incongruity detection and incongruity resolution. However, little is known about the temporal parameters of these stages and the degree to which they influence attentional processing. In the current study, 155 participants completed a dot-probe task to examine these questions. On each trial, humor versus control, novel (incongruent but not humorous) versus control, or neutral versus neutral image pairs were presented for 300, 400, or 500 ms. A probe immediately replaced the experimental image (valid trial) or control image (invalid trial). An attentional bias toward humor and novelty by 300 ms was shown by faster probe-detection reaction times (RTs) on valid compared to invalid humor and novel trials for all three exposure times. When compared to the neutral trials, humor and novel stimuli elicited slower RTs, indicating a difficulty in attentional disengagement. An exploratory analysis found that subjective humor ratings predicted the disengagement bias at 500 ms, but not at 400 or 300 ms. These results suggest that incongruity *detection* biases attention by 300 ms, whereas incongruity *resolution* may only contribute at 500 ms.

Keywords Humor · Incongruity · Attentional disengagement · Emotion-attention interactions · Dot-probe task

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Introduction

Emotions play a critical role in selecting important environmental stimuli for attention (Pessoa et al. 2002). This emotional modulation of attention has been found in numerous paradigms assessing several different subtypes of attention including attentional capture (Anderson 2005; Anderson and Phelps 2001), orienting (Öhman et al. 2001), and attentional control (Strauss and Allen 2009; Williams et al. 1996). Research has also shown that the degree of this modulation can be influenced by the types of stimuli displayed, with emotional faces and threat-related stimuli being particularly salient (Hariri et al. 2002). However, despite the vast literature assessing emotion-attention interactions, there are still numerous empirical questions yet to be addressed. Notable among these is the influence of humor—a complex experience involving both emotion and cognition—on the prioritization of attention. The current research addresses this issue by examining the degree to which humorous stimuli capture and hold attention, and whether this modulation is due to perceptual novelty or to the subjective emotional experience of mirth that is elicited when humor is understood.

Several different theories of humor exist, each proposing slightly different mechanisms for its perception and comprehension (Cundall Jr 2007). For instance, superiority theories (see Meyer 2000, for a review) posit that humor serves as a method of asserting one's superiority over others; in this case, mirth arises due to the self-enhancement that occurs as a result of someone else's misfortune. As another example, Arousal and Relief theories suggest that tension is caused when we encounter a situation that is initially unclear; comprehending the situation leads to a release of tension, often in the form of humor and laughter (Berlyne 1971; see also the benign-violation theory of

McGraw and Warren 2010). Although these theories can account for some aspects of humor perception, each theory has limitations in terms of the scope of humorous experiences they can explain (Cundall Jr 2007). Due to its relative comprehensiveness, the incongruity theory (IT; Suls 1972; see also Wyer and Collins 1992) is among the most widely accepted theories of humor, and is the focus of this paper. The IT posits that humor relies on incongruity, and is processed in two stages: incongruity *detection* and incongruity *resolution*. During the initial stages of perception, two or more items or concepts are assessed. If an incongruity is detected, that stimulus should produce greater interest than other stimuli. This prioritized processing then leads the perceiver to use problem-solving to understand the incongruity. Such a resolution could be perceptual (identifying a physical impossibility) or conceptual (identifying a social norm violation) in nature (Goel and Dolan 2007). Once an incongruity is resolved, the perceiver experiences a positive emotional state (i.e., mirth; see Mobbs et al. 2003). Importantly, the subjective experience of mirth is only elicited in the incongruity resolution phase of processing, after the stimulus has already been attended. Therefore, humor-related attentional biases are more likely to occur at later stages of attention.

In contrast, some research implies that incongruity resolution is *not* necessary for humor appreciation to occur. Pien and Rothbart (1976) found that children viewing a cartoon image depicting an unresolved incongruity still appreciated the humor of the image, although the children still preferred cartoons that contained a resolution (see also Shultz 1974; Shultz and Horibe 1974). What is unclear from these results is whether resolution is *necessary* for humor elicitation to occur; perhaps the children were mentally resolving the incongruities on their own (a possibility astutely pointed out by the researchers). Put more succinctly, does humor elicitation require two (or more) stages to occur? And, if so, would each stage of humor perception produce its own unique effect on attention?

To date, existing research has provided only indirect evidence for an attentional bias toward humor. For example, Strick et al. (2010) used eye-tracking to demonstrate that fixations were longer for humorous than for non-humorous images. These researchers found that recall was superior for humorous than for novel and neutral stimuli, suggesting that the greater attention allocated to these stimuli during encoding enhanced subsequent recall (Schmidt 1994, 2002; Schmidt and Williams 2001). Schmidt (1994) also found that subjective humor ratings (mirth) predicted recall, irrespective of the researcher's intended classification of the stimulus (humorous vs. neutral). However, the long exposure durations used in these studies (6–15 s) do not allow inferences about more rapid attentional processing to be made.

To date, Juckel et al. (2011) is the only study to directly examine the temporal dynamics of humor appreciation. In this experiment, participants watched a humorous video while wearing digital reference markers on the forehead and mouth. Kinematical parameters of laughter were measured using ultrasonic signals emitted from these reference markers. Graphs indicated that laughter occurred between approximately 500 and 3,000 ms after stimulus onset. While these response times reflect wide individual differences in emotional expression, they still suggest that incongruity can be resolved as quickly as 500 ms, meaning that incongruity detection must occur at even shorter durations.

Consistent with this view, novelty research has found that incongruity may bias attention at short durations independent of feelings of mirth. Daffner et al. (2000) detected an orienting response toward novel stimuli in an event-related potential (ERP) study, represented by a peak N2 waveform in the frontal lobe at approximately 260 ms post-stimulus onset, followed by a P3 wave in the parietal lobe. Larger N2-P3 waveforms were associated with longer viewing durations. This pattern was interpreted as reflecting a "need for further exploration and cognitive processing" (Daffner et al. 2000, p. 393), as would be necessary to resolve incongruity. Thus, the detection of incongruity—which occurs during the perception of humorous *and* novel stimuli—occurs within 300 ms of stimulus onset. The incongruity resolution associated with the processing of humor would therefore occur after 300 ms, providing a separate modulation of attention.

The current research

The current study used a dot-probe task to directly explore attentional biases toward humor at short durations and to delineate the temporal parameters of incongruity detection and resolution. In a dot-probe task, two stimuli (primes) are presented in different spatial locations. After these items disappear, a target item (a probe) is displayed in the same location as one of the primes. Presumably, probe-detection RTs will be faster if the probe appears in a location that had been previously attended. Therefore, RTs will be faster for probes following attentionally salient stimuli such as emotional images (Frewen et al. 2008; MacLeod et al. 1986).

In the current research, image pairs were constructed for three conditions: humor, novel, and neutral. Emotional humor and novel images were each paired with non-emotional controls. A probe replaced either the emotional (valid trial) or control (invalid trial) image on each trial. Image pairs were matched as much as possible in terms of content and perceptual features (e.g., see Fig. 1) to ensure

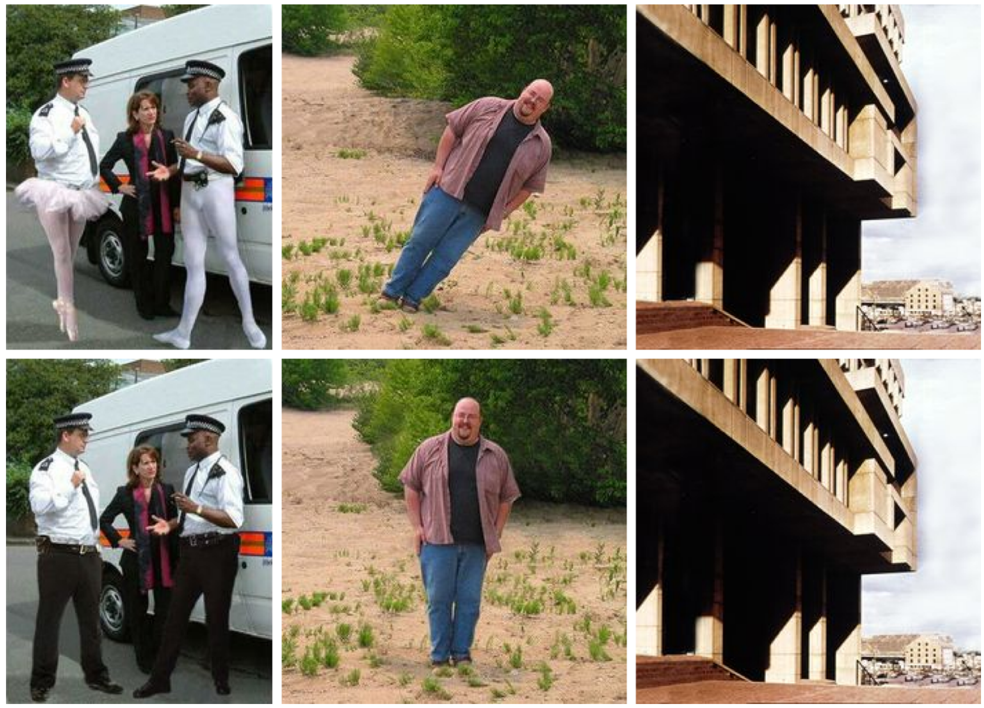

Fig. 1 Examples of **a** a humorous image (*top*) and corresponding humor-control image (*bottom*), **b** a novel image (*top*) and corresponding novelty-control image (*bottom*), and **c** a neutral image paired with itself for the dot-probe task

that valid-invalid RT differences were solely due to humor or novelty. The novel condition was included to observe the effects of incongruity detection independent of humor-induced feelings of mirth. While the humor images relied on social norm-violations, novel images relied on physical impossibilities. The neutral condition paired identical images to obtain baseline RTs (see Koster et al. 2004).

Exposure durations of 300, 400, and 500 ms were selected in order to distinguish between the effects of incongruity detection and resolution. Daffner et al. (2000) found novelty-based ERP effects at 260 ms, a duration comparable to orientation effects found with other positive stimuli (Tamir and Robinson 2007). Incongruity resolution, as shown by the laughter RTs reported by Juckel et al. (2011), may occur at approximately 500 ms. This duration has also consistently provided sufficient time to elicit dot-probe biases in other studies using emotional stimuli (Bradley et al. 2003; Holmes et al. 2009; Kemps and Tiggemann 2009).

Finally, research suggests that attentional biases increase for mood-congruent information (Becker and Leinenger 2011; Strauss and Allen 2006; Wadlinger and Isaacowitz 2006), and that positive mood increases humor appreciation (Wicker et al. 1981). Therefore, humorous or neutral mood-induction videos were presented to participants prior to the dot-probe task on the premise that the humor video would increase the effects of mirth on an attentional bias.

The current research tested five hypotheses. First, we predicted that humor would bias attention, a result that would be represented by faster RTs toward valid compared to invalid humor-pair trials. Second, we predicted that novelty would bias attention independent of mirth, a result that would be confirmed by faster RTs to valid compared to invalid novel-pair trials. Third, we hypothesized that novelty and humor would result in a difficulty in attentional disengagement due to the cognitive exploration associated with incongruity. This would be signified by slower RTs toward invalid humor and novel trials compared to baseline neutral-pair trials. Fourth, we hypothesized that incongruity detection would bias attention by 300 ms. This would be shown by a difficulty in attentional disengagement by 300 ms for the humor and novel pairs. Finally, we hypothesized that mirth would only have a unique influence on attention at 500 ms due to the processing time required for incongruity resolution.

Methods

Participants

One hundred fifty-six introductory psychology students from the University of Winnipeg participated in this study in exchange for partial course credit. Data from one participant were excluded due to difficulty following dot-probe instructions, leaving a final sample of 155 participants (47 male, 107 female, and one participant with unspecified gender). Ages ranged from 17 to 43 ($M = 20.01$, $SD = 4.53$). Participants were tested in small groups ranging from one to seven individuals. All participants had normal or corrected-to-normal vision, and all participants provided informed written consent prior to participating.

Previous research has shown that depression both attenuates humor appreciation (Uekermann et al. 2008) and eliminates dot-probe attentional biases (Neshat-Doost et al. 2000; Peckham et al. 2010); therefore, in the current study, only students who scored 18 or below on the Beck depression inventory (BDI-II; Beck et al. 1996) were eligible to participate. This BDI-II measure was included in a 'mass-testing questionnaire' completed by students at the beginning of their psychology course.

Materials

Pictures

Emotional pictorial stimuli included 48 humor and 48 novel digital coloured photographs, each matched with a non-humorous or non-novel control image, respectively. Pairs were matched as much as possible in terms of perceptual features such as content, color, and vibrancy. The control images were created by either modifying the humorous or novel image using Adobe Photoshop CS5 (Adobe Systems Incorporated, San Jose, CA) or by modifying similar images taken from internet sources. All images were resized to 250 × 250 pixels (6.61 × 6.61 cm), and black strips were added to the sides of rectangular images that could not be scaled to a square.

These 192 images were selected from a larger set of 270 images, which 39 Introductory Psychology students rated on 7-point humor and novelty scales (1 = *not at all*, 7 = *very*) during a pilot study. The best humor pairs and novel pairs were selected with the criteria that each humor image had a mean score above 4 on the humor scale, each novel image had a mean score above 4 on the novelty scale and below 3 on the humor scale, and each control image had mean scores below 3 on both scales. Paired-sample *t* tests confirmed that humor images ($M = 4.52$, $SD = 1.33$) were more humorous than their controls ($M = 1.98$, $SD = .78$), $t(38) = 11.50$, $p < .001$, and the novel images ($M = 2.90$, $SD = 1.26$), $t(38) = 9.86$, $p < .001$. Humor ($M = 4.80$, $SD = .96$) and novel images ($M = 4.86$, $SD = .94$) did not differ on novelty ratings, $t(38) = -.65$, $p = .522$. Both humor and novel images were more novel than their controls (humor-control: $M = 1.93$, $SD = .80$, $t(38) = 16.59$, $p < .001$; novel-control: $M = 1.64$, $SD = .58$, $t(38) = 17.77$, $p < .001$).

An additional 60 neutral images taken from the International Affective Picture System (Lang et al. 2005) were used for practice trials ($n = 12$), and the neutral condition ($n = 48$) of the dot-probe task. These images have been previously rated, normed and used in numerous previous studies of emotional perception. Each of the neutral images was paired with itself in order to provide a baseline RT in the dot-probe task (Koster et al., 2004).

The dot-probe task was created using E-Prime version 2.0 (Psychology Software Tools, Inc., Pittsburgh, PA). Stimuli were displayed on 15" Dell colour monitors connected to Dell Optiplex 800 computers.

Mood-induction videos

Two short videos (4 min each) depicting animals, children, adults, and sports players were constructed from video clips taken from the website YouTube.com. Clips were edited together using Adobe Premier Pro CS5 (Adobe Systems Incorporated, San Jose, CA) without audio. The humor mood-induction video was comprised of humorous clips (e.g., a young child smearing whipped cream all over his face), and the neutral mood-induction video was comprised of neutral clips (e.g., a young child sitting quietly and eating cereal). Thirty-eight of the participants in the image-rating pilot study also rated the videos on 7-point Likert scales in terms of humor and positive affect. Ratings confirmed that the humor video ($M = 6.39$, $SD = .72$) was more humorous than the neutral video ($M = 2.13$, $SD = 1.14$), $t(37) = 19.19$, $p < .001$, and more positive ($M = 6.08$, $SD = 1.02$) than the neutral video ($M = 3.11$, $SD = 1.43$), $t(37) = 10.59$, $p < .001$. Mood-induction videos were presented using Windows Media Player.

Mental rotation task

Participants completed six mental rotation questions between each block of the image-rating task in order to reduce the monotony of the task. Thirty-six pairs of three-dimensional shapes were taken from Shepard and Metzler (1971). The shapes within each pair occur at different rotations relative to each other, and participants had to rotate them in their mind to determine whether they were the same or different in geometric shape.

Procedure

Dot probe task

Upon entering the lab, participants were given verbal instructions for the dot-probe task and completed the 12 neutral-pair practice trials. This dot-probe tutorial was completed prior to viewing the mood-induction video in order to minimize the time between the mood-induction and experimental dot-probe trials. Half of the participants viewed the humor video, whereas the other half viewed the neutral video. All participants in each session watched the same video. Immediately after the video and prior to the dot-probe task, participants rated their mood on a computerized 9-point Likert scale (1 = *most negative possible*, 9 = *most positive possible*).

Each trial of the dot-probe task began with a fixation cross presented at the center of the screen for either 1,000 or 1,500 ms. The fixation cross was followed by the presentation of an image-pair for 300, 400, or 500 ms. The images appeared directly above and below the fixation, with a distance of 50 pixels (1.32 cm) between their inner edges. A black dot with a diameter of 50 pixels (1.32 cm) immediately replaced the top or bottom image at the center point of the image, with the inner edge being 125 pixels (3.97 cm) from the fixation point. The dot remained present until the participant made a response. Participants were asked to respond as quickly and accurately as possible by pressing '5' or '2' on the number keypad if the probe appeared on the top or bottom, respectively. It was emphasized that their RTs were being measured. An inter-trial interval of 750 ms preceded the next trial. For the 12 practice trials, RT and accuracy were displayed for 2,000 ms in place of an inter-stimulus interval.

There were 144 experimental trials comprised of 48 trials each from the neutral, humor, and novel image categories. These were broken into three blocks of 48 trials, each containing 16 randomly assigned neutral, humor, and novel pairs, four of which occurred at each exposure time. Each pair was presented only once to prevent habituation effects. In order to counterbalance image location, probe location, and exposure time without using multiple presentations, 12 versions of the experiment were constructed. Each image pair occurred in each combination of these factors in one version (e.g., experimental image on top and control image on bottom, probe on top, 300 ms). Between 12 and 16 participants completed each version, half of whom watched the humor or neutral mood-induction video.

Image rating task

After the dot-probe task, participants rated the 48 humor and 48 novel experimental images in order to quantify how humorous, interesting, and novel they found each item. This was done in order to account for high individual differences in humor appreciation when analyzing the effects of mirth (Schmidt 1994). Specifically, these ratings made it possible to conduct post hoc analyses in which the stimuli were grouped according to each individual participant's humor ratings.

During this task, images were displayed individually and appeared above a 7-point Likert scale (1 = *not at all*, 7 = *very*). The image and scale remained present until a response was made on the number keypad. Participants were instructed to provide their initial reaction without analyzing it too thoroughly. Ratings were broken up into three blocks of 32 trials. All images were rated on the same scale within each block (e.g., novelty), and block order was counterbalanced between participants. Participants completed six paper-and-pencil questions of the mental rotation task between each block to reduce the monotony of the task.

Results

Data from error trials were discarded. These trials accounted for 1.9 % of the data. To remove outliers, trials were excluded if their RTs were less than 200 ms, greater than 1,000 ms, or more than 3 standard deviations above that participant's mean RT (Holmes et al. 2009). After error trials were removed, outliers accounted for a further 1.2 % of the data.

Manipulation check for video

An independent t-test confirmed that participants in the humor video condition ($M = 7.26$, $SD = 1.33$) rated their mood higher than those in the neutral video condition ($M = 6.55$, $SD = 1.16$), $t(153) = 3.44$, $p = .001$. Based on mood-congruent processing biases, it would therefore be expected that these participants would rate the images as more humorous. Mean humor scores were calculated across the 96 experimental images (48 humor, 48 novel). Regression analysis confirmed that mood correlated positively with overall humor ratings, $r = .24$, $t(153) = 3.11$, $p = .002$, indicating a mood-dependent increase in humor appreciation.

Overall analysis

Mean RTs for humor, novel, and neutral image categories were calculated separately for trials where the probe replaced the experimental image (valid trials) and control image (invalid trials) at each of the three exposure times for a total of 18 mean RTs per participant. The identical neutral-pair trials were randomly split to create comparison groups. These data were entered into a 3 × 2 × 3 × 2 mixed design GLM analysis, with three within-subjects factors (image category, validity, and exposure time) and one between-subjects factor (video). There were significant main effects for image category, $F(2, 306) = 98.24$, $p < .0001$, validity, $F(1, 153) = 26.00$, $p < .0001$, and exposure time, $F(2, 306) = 61.00$, $p < .0001$, but not for video, $F(1, 153) = .01$, $p > .05$. Specifically, RTs were slowest for humor trials and

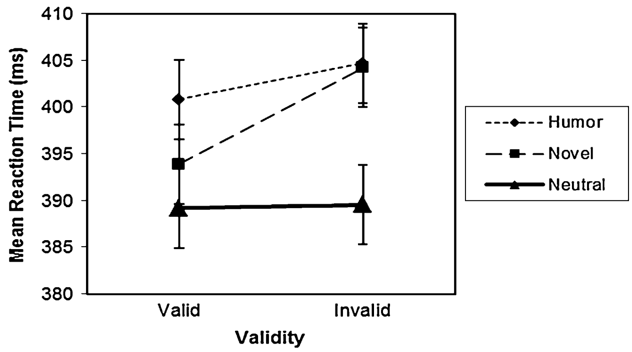

Fig. 2 Mean reaction times (ms) toward valid and invalid trials by image category. Neutral trials constitute two randomly assigned comparison groups. *Error bars* represent ± 1 standard error of the mean. Hypotheses 1 and 2 were tested by comparing RTs for valid and invalid trials for humor and novel trial types. Hypothesis 3 was tested by comparing the invalid humor and novel trial RTs with the right-hand group of neutral trial RTs (labelled invalid)

fastest for neutral trials. Valid trials were faster than invalid trials, and RTs tended to decrease as exposure time increased. There was a significant image category × validity interaction, $F(2, 306) = 13.341, < .0001$. The pattern of means depicted in Fig. 2 conforms to Hypotheses 1 and 2. Valid trials were faster than invalid trials for the humor and novel image categories, but not for the neutral image category (see Fig. 2). None of the other interactions were significant. Note that none of the video effects were significant. So, while current affective state influenced humor appreciation, this did not have a measureable effect on the attentional bias noted in the image category × validity interaction. Video was therefore dropped from further analyses.

Attentional bias (hypotheses 1 and 2)

To further explore the significant image category × validity interaction, planned comparisons were conducted within a 3 (image category: humor, novel, neutral) × 2 (validity: valid, invalid) repeated-measures analysis of variance (ANOVA). These tests confirmed that RTs were faster on valid ($M = 400.82$ ms, $SD = 52.59$ ms) compared to invalid trials ($M = 404.70$ ms, $SD = 56.34$ ms) for the humor image category, $t(154) = 2.52$, $p = .013$, Cohen's $d = .07$. Valid trials ($M = 393.89$ ms, $SD = 52.59$ ms) were also faster than invalid trials ($M = 404.23$ ms, $SD = 54.96$ ms) for the novel image category, $t(154) = 6.96$, $p < .0001$, Cohen's $d = .20$. No differences existed between the first ($M = 389.18$ ms, $SD = 49.46$ ms) and and second ($M = 389.52$ ms, $SD = 51.21$ ms) groups of neutral trials, $t(154) = .24$, $p = .808$. These results indicate that the spatial location of the humor and novel stimuli was attended upon probe presentation and suggest that incongruity detection biases attention.

Difficulty in attentional disengagement (hypothesis 3)

Another series of paired-sample t tests were conducted to test Hypothesis 3, that both humor and novel images would slow attentional disengagement. The critical tests compared the invalid RTs in the humor and novel image categories to those in the neutral image category (Kemps and Tiggemann 2009). As expected, for invalid trials, the humor image category elicited slower RTs than the neutral image category, $t(154) = 10.26$, $p < .001$, Cohen's $d = .30$, as did the novel image category, $t(154) = 9.95$, $p < .001$, Cohen's $d = .29$. The humor and novel image categories did not differ, $t(154) = .34$, $p = .735$. On valid trials, participants again responded more slowly to the humor category than to the neutral category, $t(154) = 8.31$, $p < .001$, Cohen's $d = .24$, and this held true for the novel category, $t(154) = 3.38$, $p = .001$, Cohen's $d = .10$. The humor category further elicited slower RTs than the novel category, $t(154) = 5.83$, $p < .001$, Cohen's $d = .13$. These results support the attentional disengagement hypothesis, given that RTs were slower toward humor and novel stimuli on invalid trials compared to baseline, despite instructions to respond as quickly as possible. The persistence of this result on the valid trials underscores the degree to which participants had a difficulty disengaging their attention. They continued to process these stimuli at the expense of probe detection even when the probe occurred in the attended location; this effect was stronger for humor than for novelty.

Temporal parameters of incongruity detection (hypotheses 4)

The overall GLM analysis found a null effect for the image category × validity × exposure time interaction, suggesting that the disengagement bias found in Hypothesis 3 remains present and stable for each of the three exposure times. Although this poses a challenge for Hypothesis 5 (see "discussion" below), it aligns with Hypothesis 4 which predicts that humor and novelty slow disengagement by 300 ms.

This prediction was more rigorously examined by quantifying the disengagement bias for the humor and novel pairs at 300 ms and comparing that quantity to 0. In order to calculate disengagement bias scores (Field et al. 2004), RTs for the humor, novel, and neutral image categories at 300 ms were first averaged across validity, since the difficulty in disengagement persisted for valid and invalid trials. The averaged neutral RT was then subtracted from the humor and novel RT averages. Given that humor and novel trials elicited slower RTs than neutral trials, positive values reflect a greater disengagement bias. One-sample t tests confirmed that the 300 ms disengagement bias scores differed significantly from 0 for both humor ($M = 10.78$ ms), $t(154) = 5.84$, $p < .0001$, Cohen's $d = .47$, and novel pairs ($M = 7.91$ ms), $t(154) = 4.056$, $p < .0001$, Cohen's $d = .33$. This confirms that incongruity detection biases attention by 300 ms.

Temporal parameters of incongruity resolution (hypothesis 5)

Hypothesis 5 predicted that the mirthful humor pairs would only display greater biases than novel pairs at 500 ms, yet none of the exposure time interactions from the overall analysis were significant (all p's > .05). Considering the greater disengagement bias for humor pairs noted in Hypothesis 3, this suggests that the humor-pairs elicited greater disengagement biases than novel pairs at all three exposure times. However, it seems unlikely that incongruity resolution would contribute toward the bias as early as 300 ms. One possibility is that the increased humor bias reflects prolonged problem-solving rather than incongruity resolution (mirth). Alternately, due to the highly subjective nature of humor appreciation (Schmidt 1994), it was possible that both image categories contained a unique mix of humorous and non-humorous images for each participant. The current image categories would therefore not adequately separate trials that elicited mirth from trials that did not. Participants' subjective ratings of the images were used to explore this possibility.

For each participant, mean RTs were calculated for the dot-probe trials containing experimental stimuli that they rated as low (1–3) and high (5–7) on the humor scale. Ratings toward the humor and novel images were considered. Eighty-one percent of the stimuli rated as high came from the humor image category, while the remaining 19 % of high stimuli came from the novel image category. Almost half (44 %) of the humor image ratings remained in the low range, confirming high subjectivity in humor appreciation.

Mean RTs for low and high humor ratings were calculated separately for 300, 400, and 500 ms for a total of 6 mean RTs. Mean RTs toward neutral dot-probe trials at each exposure time were then subtracted from the respective low and high humor rating means to create rating-dependent disengagement bias scores (Field et al. 2004). As depicted in Fig. 3, bias scores toward high humor ratings increased as exposure time increases, whereas bias scores toward low humor ratings remain steady across exposure times.

A 2 (humor rating: low, high) × 3 (exposure time: 300, 400, 500 ms) repeated-measures ANOVA revealed a main effect of humor rating, such that low humor ratings disengaged attention less than high humor ratings, $F(1, 137) = 8.86$, $p = .003$. The humor rating × exposure time interaction was non-significant, $F(2, 274) = .31$, $p = .732$.

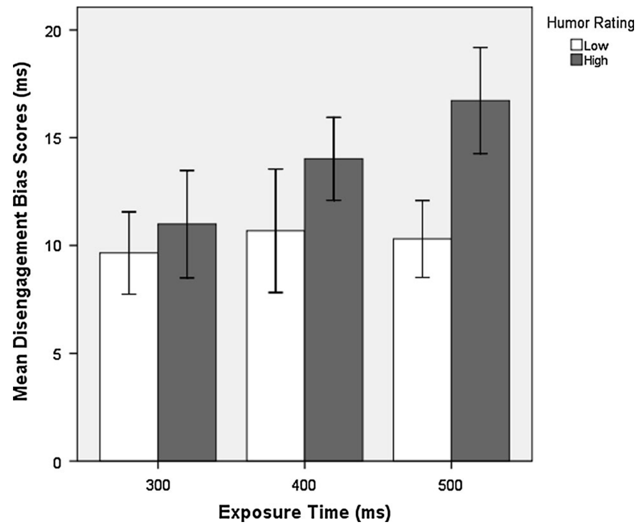

Fig. 3 Mean disengagement bias scores (ms) for stimuli rated low and high on humor at the 300, 400, and 500 ms exposure times. *Error bars* represent ± 1 standard error of the mean

However, considering the expected pattern of means, planned comparisons were run to test the a priori hypothesis of greater humor-dependent disengagement biases at 500 ms. These confirmed a significant disengagement bias difference between low ($M = 10.32$ ms, $SD = 22.38$ ms) and high ($M = 16.75$ ms, $SD = 30.08$ ms) humor ratings at 500 ms, $t(146) = 2.17$, $p = .032$, Cohen's $d = .29$, but not at 400 ms, $t(146) = .40$, $p = .292$, or 300 ms, $t(146) = 1.08$, $p = .693$.

Importantly, when the same rating-dependent analyses were performed to compare low and high novelty ratings and low and high interest ratings, no differences emerged at any of the three exposure durations (all $ps > .243$). The difference between high and low humor ratings at 500 ms can therefore more confidently be attributed toward the feelings of mirth associated with the humorous stimuli. Although exploratory in nature, these results align with Hypothesis 5 and suggest that incongruity resolution may contribute toward a humor bias by 500 ms.

Additional analyses

In order to rule out the possibility that the current results were due to differences in the visual complexity of the humor, novel, and neutral stimuli, an additional ratings study was performed. Thirty-one new participants were asked to rate the test images on a 1–7 Likert scale based on how visually complex they found each image; images consisting of a single object would be an example of low complexity and images consisting of several objects, shapes, and colours would be an example of high complexity. Based on the results of this study, we removed 8 humor pairs, 12 novel pairs, and 20 neutral images from the analyses in order to ensure that the humor, novel, and neutral stimulus sets were equivalent on this variable.

After removing this subset of trials, the humor ($M = 4.18$) and novel ($M = 4.26$) conditions did not differ on visual complexity, $t = -.679$, $p = .50$. The humor-control images ($M = 3.17$) also matched the novel-control images ($M = 3.06$), $t = 1.63$, $p = .113$. However, the both the humor images, $t = 7.97$, $p < .001$, and novel images, $t = 7.60$, $p < .001$, remained more visually complex than their controls.

In order to match the visual complexity of each neutral slide to that of the humor and novel slides given the difference between emotional and control humor and novel images, neutral images ($M = 3.51$) were matched to the mean complexity of all of the other images ($M = 3.67$), $t = 1.68$, $p = .10$. Paired sample t tests confirmed that the humor image category (humor and humor-control images), novel image category (novel and novel-control images), and neutral image category did not differ on visual complexity (all p values $> .05$).

In additional to the overall GLM analysis, Hypotheses 1 through 4 were re-analyzed using this new data set. The direction and significance levels of all results remained unaltered (importantly, all significant p values remained <.05). However, due to the reduced number of trials, this data set lacked sufficient power to re-examine Hypothesis 5. The bias scores used to test Hypothesis 5 are, in essence, difference scores. When one component of the difference score is omitted (as occurred when some trials were removed), it is impossible to calculate a bias score. As a result, the number of trials per participant became too small to be of use for these supplementary statistics. Still, the results for Hypothesis 5 are unlikely to be influenced by visual complexity differences between image groups. Firstly, the bias scores were averaged across valid and invalid trials, and included trials from both the humor and novel image categories, thereby minimizing any complexity difference effects that existed between these groups. Moreover, each participant had unique groups of high and low humor trials based on their own ratings, creating a randomized placement of each image pair, such that highly complex images could appear in the high humor group of trials for one participant, and in the low humor group of trials for the next.

Discussion

The current study provides the first evidence for an attentional bias toward humor at short durations. That this bias occurs by 300 ms signifies rapid detection of incongruity, in spite of the cognitive demands associated with assessing the relationships among incongruent concepts. That the bias at 300 ms reflects incongruity detection rather than resolution can be inferred from the consistent positive disengagement bias scores toward the trials rated low on humor across exposure times. This time frame further coincides with frontal-parietal ERPs toward novelty at 260 ms (Daffner et al. 2000).

The results of this study also provide tentative support for the two-stage model of humor perception, with high subjective humor ratings only enhancing disengagement bias scores at 500 ms; 200 ms after the effect of incongruity detection. However, these results, although promising, do come with a caveat: although the t tests demonstrating this unique effect of humor at 500 ms were a priori planned comparisons, the overall humor rating $\times$ exposure time interaction was not significant. Therefore, the results should be viewed as exploratory, rather than definitive, in nature. Assuming these results are replicable, they would imply that incongruity resolution does in fact add a unique element to the perception of humor. Our significant main effect of humor rating already points to this more generally, as high humor ratings disengaged attention more than low humor ratings.

One factor that may facilitate the replication of these data is the use of longer exposure durations. The fact that our exploratory analysis only showed a larger attentional bias for subjectively humorous images than for non-humorous images at 500 ms suggests that any effect of humor will be detected at longer durations. Examining humor-attention interactions over a wider variety of temporal intervals (e.g., 200–3,000 ms) would allow researchers to more accurately characterize humor's effects on attentional processes. Indeed, given that 500 ms was the shortest kinematical laughter RT reported by Juckel et al. (2011), it is possible that our study underestimated the degree to which humor modulates attention.

A second issue for future studies is to determine what cognitive and/or attention processes are occurring *between* incongruity detection and incongruity resolution. There are a number of potential processes that could be occurring during this time. Notable among these are curiosity and problem-solving, which may allow participants to sustain their attention to the stimulus after the incongruity has been detected and before it has been resolved. In the current study, RTs were consistently slower toward humor pairs compared to novel pairs, despite the fact that mirth did not purportedly contribute until 500 ms. One possible explanation is that the social-norm violations in our humor pairs required additional processing prior to resolution compared to the physical impossibilities in our novel pairs. Goel and Dolan (2007) acknowledge that children find physical impossibilities more humorous, whereas adults prefer social-norm violations, suggesting that social-norm violations are indeed more cognitively complex (see also

McGhee 1972, for a Piagetian account of cognitive development and changes in humor appreciation).

This additional processing could also potentially account for the subsequent elicitation of mirth for social-norm violations relative to physical impossibilities. When incongruities are too easily resolved, they are perceived as obvious or commonplace. Rather, moderate processing difficulty is required to arouse curiosity for exploration, and mirthful surprise at resolution (Langevin and Day 1972); in fact, Wyer and Collins (1992) suggest that the amount of humor that could potentially be elicited is a function of the effort required to resolve the conflict. In order to test this hypothesis, future studies could use stimuli of varying cognitive complexity (i.e., simple humor vs. humor that requires a greater amount of problem-solving; see Strick et al. 2009, for procedures of assessing the cognitive demands of humorous stimuli). Such a manipulation would allow researchers to examine (1) the influence of cognitive complexity on humor appreciation ratings and (2) the relative contributions of humor appreciation ratings and cognitive complexity on the resulting RT differences in dot-probe type paradigms.

Manipulations of the stimulus sets could also be used to contrast different theories of humor. Superiority theories posit that humor is related to mocking or diminishing someone else, in contrast to the problem-solve explanations of incongruity theories. It is possible that humor may modulate attention for incongruity-related stimuli while not influencing attentional biases toward stimuli depicting scenes in which someone is doing something that others might mock. The stimuli used in the current research did not allow us to make this type of contrast.

Finally, it is possible that adding electrophysiological measurements to all of these studies could provide novel insights into the relationship between humor and attention. Event-related potentials (ERPs) have millisecond-level temporal resolution, which would provide researchers with useful information about the neural structures involved with different stages of processing. Although such a method would not provide precise pictures of the brain, it *would* allow researchers to make inferences about the types of processes that are occurring at different times. For instance, if more activity was detected in frontal regions during the incongruity detection-resolution gap, it would suggest that some form of executive function (e.g., problem-solving or attentional control) was taking place.

In conclusion, the current study suggests that humor does in fact modulate attention. It also provides tentative support for the two-stage model of humor perception, with incongruity detection and resolution each affecting attention in unique ways. Given the relative paucity of research investigating humor-attention interactions, there are a number of possible future empirical tests that should be performed to extend the current results. Such studies would help to clarify how humor interacts with attentional and cognitive processes, and would provide important insights into a largely neglected area of our positive emotional experience.

Acknowledgments This research was supported by a grant from the Natural Sciences and Engineering Research Council (NSERC) of Canada.

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