Attentional scope, rumination, and processing of emotional information: An eye-tracking study

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Abstract

Rumination is considered as a relatively maladaptive form of repetitive thinking that has a marked impact on mood. Individual differences in attentional scope have been proposed as an important mechanism rendering some individuals more prone to ruminate than others. The attentional scope model of rumination posits that rumination is related to a narrowed attentional scope, which may affect processing of neutral and emotional information. This study (n = 56) aimed to extend research on the relation between rumination and attentional scope while processing neutral, positive and negative information. To assess attentional scope, a moving window task was applied which involved reading both neutral and emotional sentences. The result of reading rate indicated that individuals with higher levels of trait rumination showed a narrower attentional scope in general. In addition, the total reading time of individuals with higher levels of trait rumination was shorter when processing neutral and positive sentences through a constrained window frame, but this was not the case when processing negative sentences. These findings suggest that even though high trait ruminators use an overall constrained manner of processing, they may still process negative information differently compared to other types of information.

Keywords: rumination; attentional scope; mood; emotion processing; eye-tracking

Introduction

For decades, great efforts have been made to investigate rumination and its impact on depressive symptoms. According to the response styles theory, rumination is characterized by repetitive self-focused thinking about the implications, causes, and meanings of one's negative feelings (Nolen-Hoeksema, 1991). Accumulating evidence has shown that rumination has a deleterious impact on mood, problem solving, and cognitive functioning (Watkins, 2008). It has also been found that habitual use of rumination prospectively predicts the onset and maintenance of depression (Just & Alloy, 1997; Kuehner & Weber, 1999; Nolen-Hoeksema & Morrow, 1993). Therefore, identifying factors that make individuals more vulnerable to engage in persistent rumination is essential to understand and potentially treat this key cognitive risk factor for depression.

A number of information-processing factors have been associated with the repetitive nature of rumination. For instance, cognitive inhibition impairments (i.e., problems in the ability to inhibit the processing of irrelevant information) have been considered one of the main mechanisms contributing to difficulties interrupting persistent negative thoughts in high trait rumination (Joormann, 2010). Furthermore, impaired disengagement of attention from negative information has also been proposed to account for limited control over negative thinking in high ruminators (Koster, De Lissnyder, Derakhshan, & De Raedt, 2011). Inspired by research revealing that sustained self-focus of high ruminators may not be limited to negative information (Joormann & Tran, 2009) and that high ruminators tend to show better performance on tasks requiring focused attention (Altamirano, Miyake, & Whitmer, 2010; Zetsche & Joormann, 2011), a novel theoretical model, the attentional scope model of rumination, has been recently proposed (Whitmer & Gotlib, 2013). In this framework, *attentional scope* is considered the primary source of individual differences that determines the susceptibility to ruminate in response to negative affect. In general, individuals with a more narrow attentional scope are thought to allocate more resources on the information that is in the center of their attention than individuals with a broad attentional scope. Accommodating previous findings showing both negative-specific and general information processing deficits associated to rumination, this model assumes that high ruminators may process all types of information in a more focused manner (irrespective of current mood state), compared to low ruminators. This explains performance benefits in high ruminators on focused tasks. Yet, under sad or depressed mood states, high ruminators' attentional scope would become even more narrowly focused on negative mood-relevant information relative to other types of information, leading to an unproductive narrow focus on negative self-related themes.

The most distinctive characteristic of the attentional scope model of rumination is that it argues that the individuals' attentional scope can affect their processing of all types of information, irrespective of current mood. Hence, it can provide an explanation for findings showing that levels of rumination influence the processing of not only negative material but also a broad range of information (Hilt, Leitzke, & Pollak, 2016; LeMoult, Arditte, D'Avanzato, & Joormann, 2013). In a recent study trying to investigate the relation between rumination and attentional scope (Fang, Sanchez, & Koster, 2017), undergraduates reporting high versus low levels of trait rumination performed a moving window task, which is a well validated paradigm to investigate individual's attentional scope during reading (McConkie & Rayner, 1975; Pollatsek, Rayner, Fischer, & Reichle, 1999; Rayner, 1998). In this task, participants read sentences that were either presented with or without varying window sizes that restricted participants' reading scope. The content of a sentence that participants could see depended on the size of an invisible window frame which was moved contingent with participants' gaze position. The rationale of this paradigm is that, if the attentional scope of an individual is larger than the window frame, then the limited window would make it more difficult to process the sentence compared to natural reading. According to the model, individuals with a narrow attentional scope may perceive less peripheral information and instead focus more deeply on the information that is in the center of their attention. Therefore, an individual's attentional scope in this task is inferred by comparing performance on different window size conditions and a baseline condition (no restricted window condition). Participants in this previous study (Fang et al., 2017) performed a moving window task during which neutral sentences were presented and their eye movements while reading were recorded. It was found that, when reading neutral sentences, individuals in the high trait rumination group were better able to read sentences (with less total fixation time, fast speed etc) presented in a small window size than individuals in the low trait rumination group. This study provided direct evidence of a narrow attentional scope (at the perceptual level) in habitual ruminators, as predicted by the attentional scope model of rumination. Nevertheless, due to the fact that only neutral sentences were used in this study, it is unclear whether these results can be generalized to other types of information, particularly emotionally relevant positive and negative information.

Concerning processing of negative information, the attentional scope model of rumination predicts more focused attention on negative information relative to other types of information for individuals with higher rumination levels when they are in a low mood, due to a negative mood congruent effect. However, whether this specificity of processing negative information still remains when individuals are not in a negative mood is not clear. The model proposes that, irrespective of the current mood states, the attentional scope of individuals with higher rumination levels would be narrower than the one of individuals with lower rumination levels during the processing of not only negative but also neutral and positive material. To be noted, the model has not precisely delineated whether individuals with high levels of rumination process negative material differently from other types of information after controlling for mood state. Previous studies have shown that high levels of trait rumination are associated with attention biases towards negative information relative to positive or/and neutral stimuli (De Lissnyder, Koster, Derakshan, & De Raedt, 2010; Donaldson, Lam, & Mathews, 2007; Duque, Sanchez & Vazquez, 2014). Noteworthy, in these studies, valence-specific attention biases in relation to rumination remained significant, even after statistically controlling for the influence of depressive symptom levels. Whereas these results refer to associations between rumination and the orienting of attention (i.e., attentional bias) at visual attention levels, it remains unclear whether the valence of information also influences the breadth of attention (i.e., attention scope) in relation to rumination at the perceptual level. In our study, we examined the relation between rumination and attentional scope during the processing of neutral and affectively valenced information, while controlling for individual differences in mood states.

The present study

The present study sought to extend the research with regard to the relation between rumination and attentional scope while controlling for the influence of mood states by using the moving window paradigm (Fang et al., 2017). According to the assumptions of the attentional scope model of rumination, individuals with different levels of rumination are thought to exhibit different sizes of attentional scope which, irrespective of mood state, would affect their performance during the processing of both neutral and emotional information (Whitmer & Gotlib, 2013). Therefore, the first research question was to test whether trait rumination is associated with performance benefits when processing neutral and emotional sentences in restricted attentional window frames. In line with previous research using this paradigm (Fang et al., 2017), we adapted the moving window task to evaluate attentional scope (McConkie & Rayner, 1975). We hypothesized that individuals high in trait rumination would be characterized by a narrower attentional scope and, therefore, would be better in processing sentences (i.e., with less total fixation time, fast speed in reading time) presented in constrict window size conditions, in comparison to individuals low in trait rumination, characterized with broader attentional scope. Second, to test whether the relation between attentional scope and trait rumination is influenced by the valence of the sentence, we presented different types of emotional stimuli. According to previous studies indicating rumination-related differential processing of negative information after controlling for depressive symptom levels (e.g., De Lissnyder et al., 2010; Donaldson et al., 2007), we predicted that the relation between rumination and attentional scope in constrict window size conditions would show different manifestations for processing negative sentences and non-negative sentences.

Method

Participants

In the current study, a total of 64 undergraduates (36 females, 28 males) completed the experimental session. The sample size needed to establish a similar effect was calculated by G*Power 3.1 (Faul, Erdfelder, Lang, & Buchner, 2007). The results showed that a total sample of 62 is required to find a medium effect size (partial $\eta^2 = .06$) (Cohen, 1969; Richardson, 2011), with $\alpha = .05$ and $power = .80$. Since we used trait rumination as a continuous variable instead of group ordinal variable, the sample size we calculated should provide sufficient statistical power for the current study. The participants were native Dutch speakers with normal or corrected-to-normal vision. One participant was excluded from the analyses because of a highly elevated depression score (score of 37; > 3 SD on BDI-II, see below), two participants were excluded for not adequately completing the questionnaires (i.e., missing items in the rumination scale) and five participants were ruled out due to poor task performance (standard deviation score of total reading time and number of fixation ≥ 3). The characteristics of the remaining 56 participants (age: $M = 20.32$, $SD = 2.82$; 31 female) are shown in Table 1. Our sample showed sufficient variation in trait rumination (range: 22-70). The local Ethics Committee approved the study protocol. All participants provided informed consent and were paid with 10 euros for their participation.

Self-reported measures

Symptom and trait measurements. Depressive symptoms were assessed with the 21-item Beck Depression Inventory (BDI-II; Beck, Steer, & Brown, 1996; Van der Does, 2002). The occurrence and severity of depressive symptoms over the past two weeks were rated by participants on a 4-point scale (Cronbach's α = .84). Trait rumination was assessed with the 22-item Ruminative Response Scale (RRS; Nolen-Hoeksema & Morrow, 1991; Raes, Hermans, & Eelen, 2003; Treynor, Gonzalez, & Nolen-Hoeksema, 2003). Participants were asked to rate items on a 4-point scale while thinking about how they usually respond when they are in a negative or depressed mood (Cronbach's α = .93).

State measurements. We measured mood states provided that the aim of our study was to examine the relation between attentional scope and rumination while controlling for current mood state effects. Specifically, mood was assessed on three (i.e., happy, sad and agitated) 100 mm Visual Analogue Scales (VAS) ranging from "neutral" to "as much as I could imagine" (see Rossi & Pourtois, 2012). Additionally, in order to control for the influence of state rumination, the 6-item Momentary Ruminative Self-focus Inventory (MRSI; Marchetti, Koster, & De Raedt, 2013) was administered before and after the moving window task. Participants were asked to rate the extent of ruminative self-focused thinking at the moment on a 7-point scale ranging from "totally not agree" to "totally agree" (Cronbach's α = .82).

Moving window task

A series of short (mean length of sentences = 30.10 characters, range: 22-47 characters) and syntactically simple Dutch sentences were used in the current study. The reading material comprised three types of valence, which were 60 positive (e.g., "My life is interesting."), 60 negative (e.g., “I am a born loser.”), and 60 neutral sentences (e.g., “My table has four legs.”). Self-referential processing has been considered as one of the fundamental characteristics of rumination (Disner, Beevers, Haigh, & Beck, 2011; Nejad, Fossati, & Lemogne, 2013). A previous study suggested that trait rumination is more strongly associated with a narrowed attentional scope when processing self-related compared to other-related information (Grol, Hertel, Koster, & De Raedt, 2015). Therefore, in order to increase the chance to detect the relation between rumination and attentional scope, all the reading materials in the task were self-referent sentences. The positive and negative sentences were selected from a pool of validated self-referent sentences obtained from a previous study (Everaert, Duyck, & Koster, 2014). In line with previous research (Everaert et al., 2014), neutral sentences were generated using WordGen (Duyck, Desmet, Verbeke, & Brysbaert, 2004) and were matched with emotional sentences on word length and frequency. Through a sentence rating study in an independent sample (n = 30) we established that, the valence of the positive sentences was significantly more positive than neutral sentences. Negative sentences were rated more negatively than the neutral sentences. The arousal level was not significantly different between positive and negative sentences, both of which were significantly higher than neutral sentences. All the sentences were randomly assigned to four blocks of different window sizes. The length of sentences was matched among the four window size conditions and the three types of valence. Four different window size conditions were used: (1) small window condition (2-4 characters visible; 12.5 mm of size); (2) medium window condition (6-8 characters; 25 mm.); (3) large window condition (12-14 characters; 50 mm); and (4) no window condition (without restricted frame). Each window size condition consisted of 3 blocks (i.e., positive, negative, and neutral block), each of which contained 15 sentences (trials). The order of the window size conditions was counterbalanced among participants. The presentation of blocks within each window size condition was also randomized for every participant.

At the beginning of each trial, a fixation cross was presented on the left side of the screen. Participants were required to look at the cross for at least 200 ms until the target sentence was displayed on the screen. They were then asked to read the whole sentence and to press the space bar as soon as they understood the meaning of the sentence. In the three moving window conditions, only limited numbers of characters could be seen through the invisible window frame (larger or smaller, depending on the condition) and the window frame was moving contingent with the individual's gaze. The rest of the sentence outside the window frame was blanked. Participants were instructed to read the sentence naturally (i.e. moving their eyes naturally from left to right so that they could read the full sentence, but also allowing re-reading previous parts of the sentence in case they did not understand the meaning of the sentence at the first time). After several sentences, participants were randomly asked to answer a simple question concerning the content of the preceding sentence by choosing the correct answer from two options. This encouraged participants to process the meaning of the sentences, as instructed.

In line with the previous study (Fang et al., 2017), attention indices comprised the total fixation time, the number of fixations, and the reading rate. Specifically, the total fixation time was the summation of all fixations' duration within a sentence. The number of fixations was the total number of fixations that were recorded within a sentence. Reading rate was the average number of words processed per minute. Though all three measures used in the current study provide information on processing difficulty during reading, each of them also has its own characteristics. For example, the number of fixations can be used as an index of reading strategy (Brzezicka, Krejtz, von Hecker, & Laubrock, 2011) and is related to processes of selective attention (Everaert & Koster, 2015). In our paradigm, a higher number of fixations indicate higher degree of processing difficulty. As for reading rate, it controls for the length of the sentence in terms of its number of words, which makes the results easily comparable with results from other studies. However, sentence processing not only happens by reading words but also occurs outside word reading (Rayner, 1998). For this purpose, using total fixation time can keep all the original information during reading the whole sentence. Moreover, this index it has been associated with processes of sustained attention (Everaert & Koster, 2015), which may be used to detect distinctive processing occur only in the sustained (vs. selective) attention component.

Eye tracking

Eye movements during the moving window task were recorded with a Tobii TX300 eye-tracker system, which utilizes a dual-Purkinje eye-tracking method (Crane & Steele, 1985) and samples eye-gaze coordinates at 300 Hz (i.e., a coordinates' estimation every 3.3 ms). E-prime Professional software (Schneider, Eschman, & Zuccolotto, 2012) was used to run the presentation of experimental stimuli and control the recording of eye movements. The eye-tracking system synchronized automatically with E-prime at the start of each trial by using E-prime extensions for Tobii (i.e., Clearview PackageCalls). The distance between participants and the eye tracker was approximately 60 cm. Eye movement signals were converted to visual fixation data using Tobii Studio software.

Procedure

Participants were first asked to complete a written informed consent and to complete self-report questionnaires with regard to depressive symptoms, trait rumination, and state measurements at baseline. Then, they were instructed to perform the moving window task, which included one practice block and four main experiment blocks (one for each window condition, randomly presented). State measurements were measured again immediately following the moving window task performance. The details of all trait and state measurements that were administered in the study can be seen in Table 1. At the end of the experiment, participants were debriefed and received 10 euro for their participation.

Data preparation and analytical strategy

The criteria for data exclusion were the same as in the previous study using this paradigm (Fang et al., 2017). Thus, all trials with average fixation duration < 100 ms were excluded (0.36% trials in total), and trials in which reading time was equal or larger than 3 SD of each window size condition were excluded as well (1.11% trials in total). Final data analyses were conducted on the remaining 9933 observations (98.53% trials in total).

A series of linear mixed effect (LME) models were performed (Baayen, Davidson, & Bates, 2008), for each of the three attentional scope indices (i.e., total fixation time, number of fixations, and reading rate) in R version 3.3.2 using lme4 package (Bates, Maechler, Boler, & Walker, 2015). In each LME model, the variables included in fixed effects were adjusted based on different purposes whereas intercepts for participants and items were always comprised in the random effects. We first tested the full model in which the centered RRS score (continuous covariate), window size (small, medium, large, and no window), valence of sentence (negative, neutral, and positive), and corresponding interactions among these variables were entered as fixed effects.

To test our hypotheses, a two-way interaction between window size and the RRS score was expected for the first hypothesis (i.e., the relation between attentional scope and trait rumination), and a three-way interaction between window size, the RRS score, and valence was expected for testing the second hypothesis (i.e., the relation among attentional scope, trait rumination and valence of sentences). In the further analyses of the expected interactions, separate mixed models were conducted in each window size condition (or for each valence of sentence), with RRS included in fixed effects as continuous covariate, and participant and item included as random effects. Baseline positive and negative mood were controlled only in the subsequent follow-up analyses to see whether the significant two-way interactions still remained significant after taking into account the effect of current mood states, allowing us to examine the relation between rumination and attentional scope when the influence of the mood states was kept constant[2]. In order to avoid collinearity, all continuous variables were centered before the LME analysis.

Results

Main associations among eye movement indices and trait rumination

First, there was a significant positive relationship between total fixation time and number of fixations, $r = .86$, $p < .001$, a significant negative correlation between number of fixations and reading rate, $r = -.78$, $p < .001$, and a significant negative correlation between total fixation time and reading rate, $r = -.88$, $p < .001$. Next, the relation between trait rumination and each eye movement index was examined separately. The results revealed that higher trait rumination was significantly correlated with a shorter total reading time, $r = -.31$, $p < .05$, and a higher reading rate in general, $r = .37$, $p < .01$, but was not correlated with the number of fixations index, $r = -.20$, $p = .14$.

Total Fixation Time

The best fitted model was selected by comparing the Akaike Information Criterion (AIC) for different maximum likelihood models. One variable was added or subtracted each time until the best option was found. The results of the full model showed a significant effect of the RRS, F (1, 54.00) = 6.07, $p < .05$, window size, F (3, 168.00) = 114.21, $p < .001$, and a significant two-way interaction between window size and RRS, F (3, 9835.10) = 15.82, $p < .001$. Moreover, the three-way interaction among window size, RRS, and valence was also significant, F (6, 9834.80) = 2.76, $p < .05$ (other $Fs < 1.76$, $ps > .17$) (see Fig. 2). To clarify the three-way interaction, separate mixed models for different valences showed that the interaction between window size and RRS was significant for neutral sentences, F (3, 3124.88) = 3.12, $p < .05$, and for positive sentences, F (3, 2986.09) = 17.05, $p < .001$, but not for negative sentences, F (3, 2979.73) = 1.88, $p = .13$. Therefore, we conducted separate mixed models only for neutral and positive sentences in each different window size condition while controlling for baseline mood[3].

For neutral sentences, there was a tendency that RRS predicted performance in the small window condition, b = -25.97, SE = 14.16, t (51.13) = 1.83, p = .07, 95% CI = [-53.37, 1.43], in the medium window condition, b = -13.25, SE = 7.06, t (50.86) = 1.88, p = .07, 95% CI = [-26.90, 0.41], and in the large window condition, b = -10.77, SE = 5.03, t (52.03) = 2.14, $p < .05$, 95% CI = [-20.50, -1.05], but not in the no window condition, b = -4.61, SE = 6.40, t (52.07) = 0.72, p = .48, 95% CI = [-16.93, 7.72]. Results indicated that, although trait rumination did not influence total fixation time in natural reading, individuals with different trait rumination levels were influenced by the constrained window frames. Specifically, individuals with higher RRS scores had shorter total fixation times in all conditions in which text could only be perceived through a limited window.

For positive sentences, separate mixed models in different window size conditions revealed that the RRS significantly predicted performance in the small window condition, b = -36.13, SE = 16.43, t (51.98) = 2.20, $p < .05$, 95% CI = [-67.85, -4.41] and marginally significant in the medium window condition, b = -12.54, SE = 6.91, t (51.71) = 1.81, p = .08, 95% CI = [-25.92, 0.84], but not significantly in the large window and no window condition (ps > .24). The results of positive sentences was quite similar to what was shown in neutral sentences, in that individuals with higher RRS scores had shorter total fixation times in the most restricted window conditions.

Number of Fixations

Results of the full model showed a significant effect of window size, F (3, 168.00) = 70.06, $p < .001$, and a significant two-way interaction between window size and RRS, F (3, 9687.50) = 9.19, $p < .001$ (other Fs < 2.44, ps > .12). To further analyze the two-way interaction between window size and RRS, a separate mixed model was conducted in each window size condition. However, after controlling for current positive and negative mood, no significant effects were found in any of the window size conditions (*ts* $< .001$, *ps* $> .99$).

Reading Rate

Results of the full model showed significant effects of RRS, F (1, 54.00) = 8.66, $p < .01$, window size, F (3, 167.70) = 325.20, $p < .001$. Moreover, we found a significant two-way interaction between window size and RRS in reading rate, F (3, 9663.60) = 24.44, $p < .001$ (other *Fs* < 1.07, *ps* $> .38$).

To further analyze the two-way interaction between window size and RRS, a separate mixed model was conducted in each window size condition while controlling for positive and negative mood levels at baseline. No significant effect was found in the no window condition, b = 4.00, SE = 5.26, t (51.94) = 0.76, p = .45, 95% CI = [-6.11, 14.12], reflecting that trait rumination did not influence total reading time in natural reading. As expected, RRS significantly predicted performance in the small window condition, b = 5.47, SE = 2.64, t (51.89) = 2.08, $p < .05$, 95% CI = [0.40, 10.54], and also marginally significantly predicted performance in the medium window condition, b = 7.00, SE = 3.87, t (51.56) = 1.81, p = .08, 95% CI = [-0.46, 14.45], and in the large window condition, b = 9.31, SE = 4.70, t (51.88) = 1.98, p = .05, 95% CI = [0.25, 18.36]. In sum, results showed that reading rate was influenced by trait rumination only when reading through various restricted windows but not in natural reading. Specifically, individuals with higher RRS scores had a faster reading rate than individuals with lower RRS scores in the restricted window conditions.

Discussion

In the present study we aimed to extend the research on the relation between rumination and attentional scope while processing neutral and emotional information. To assess attentional scope, we applied a gaze-contingent moving window task which involved reading both neutral and emotional sentences. Performance benefits for individuals with higher levels of trait rumination (i.e., these participants being less influenced by the constrained window frame) were reliably found not only when processing neutral sentences, as tested in Fang et al. (2017), but also when processing positive sentences. However, this benefit was not observed in total fixation time when processing negative sentences. We discuss these effects in more detail below.

First, our findings revealed that trait rumination predicted performance when individuals were reading both neutral and positive sentences with reduced window sizes, which was reflected by shorter total fixation time and faster reading rate in individuals with higher levels of rumination. Evidence of performance benefits for high ruminators in neutral sentences processing are in accordance with previous research. For example, Grol et al. (2015) found that individuals with higher levels of brooding (i.e., a maladaptive subtype of rumination) displayed a narrower attentional scope for neutral self-related information relative to other-related information. Recently, Fang et al. (2017) reported that, after controlling for positive and negative mood states, individuals with high levels of trait rumination showed a faster reading rate for neutral sentences than the ones with low levels of trait rumination. Our findings are in line with the idea that higher levels of trait rumination are associated with a more narrow attentional scope when processing neutral information. Moreover, with the inclusion of emotional sentences, the current study shows a similar association between attentional scope and trait rumination during processing of positive sentences.

It is important to note that the mean valence of the neutral sentences in the current study was 5.79, which was higher than the neutral value point 5 on a scale from 1 (negative) to 9 (positive). Hence, the valence of the neutral sentences is somewhat closer to the positive side of the scale than to the negative one. This is consistent with previous demonstrations of how neutral information could be influenced by other socially relevant emotional information (Bliss-Moreau, Moadab, & Machado, 2017; Suess, Rabovsky, & Rahman, 2015). However, based on the results of the sentence rating study, the rating on neutral sentences was significantly less positive than the positive ones[1]. We can, therefore, assume that similarities in the moving window by rumination interactions for neutral and positive sentences in the main experiments were not due to similarities on the perceived valence or arousal of these two types of sentences. In addition, this performance benefit in high ruminators was also found in reading rate across all types of sentences. Taken together, these findings provided supportive evidence for the prediction of the attentional scope model of rumination, by showing that high levels of rumination would have a more narrow attentional scope for neutral and positive information (Whitmer & Gotlib, 2013).

Second, we found that high levels of trait rumination predicted faster total fixation time when processing neutral and positive sentences, but this was not the case when they were reading negative sentences. These findings seem to suggest that the better performance of individuals with high levels of trait rumination when processing neutral and positive sentences through constrained window frames may be compromised or masked when processing negative sentences. However, which feature of the negative sentences influences the processing remains to be explored. In addition, it is important to note that the expected three-way interaction was only significant for total fixation time but not for other attention indexes. It has been suggested that inhibition impairments for negative information emerge when information is attended (so on an index of sustained attention: total fixation time), but not on other attention indices related to selection (number of fixations) (Everaert & Koster, 2015). Accordingly, the difference in processing of negative information may only occur during sustained attention and encoding of the meaning of the information but not during the early attentional selection. This might explain specific differential effects in the processing of negative information regarding the total fixation time index. In contrast, this might also explain the absence of three-way interactions in reading rate since this would be a relatively pure reading index, not sensitive enough to detect differences among visual attention components (i.e., selection vs. sustained attention). However, we realize that this is a tentative conclusion based on a null result, and thus future research should further examine these findings.

The current study addressed the main hypotheses proposed in the attentional scope model of rumination and provided direct supportive evidence in the emotional information processing domain. Our findings could be relevant clinically. First, individuals high in rumination are found to process focal information at the expense of other available information. It could be that if these individuals get stuck into thinking about problems, they needed to learn how to divert attention in order to effectively solve their problems. Second, our results provide a nuanced view on rumination, where this response style is maladaptive in some contexts but can also be beneficial when constricted attention is required to perform a central task. However, there are still some limitations in the current study. First, we used an unselected sample in our study which may limit the generalization of the observed findings to depressed or remitted depressed patients. Nevertheless, the variability in rumination scores in the current study is comparable to the previous studies testing cognitive impairments/processes as a function of habitual use of rumination. Second, neither the size of attentional scope nor the level of rumination were manipulated, hence the direction of the causal relationship between them cannot be determined. Therefore, due to the cross-sectional nature of our study, we can only make conclusions with regard to whether there is a relationship between attentional scope and rumination but not the direction of their causal relationship. Despite this, our study is one of the first to establish this association between rumination and perception, which we think may open new venues for experimental and longitudinal research with potential clinical implications. Third, since the minimum sample size was estimated based on a similar previous study using only neutral sentences in the task, we cannot make firm conclusion on the absence of effects for negative sentences. Future studies aimed to examine the relation between attentional scope and rumination in the processing of information with different valences should take into account that the effect for negative sentences might be much smaller than for positive and neutral ones, and therefore a larger sample size than the one used in our study might be required.

Conclusion

In summary, the current study aimed to investigate and extend the research on the relation between rumination and attentional scope. This is the first study demonstrating that higher levels of trait rumination are associated with faster speed of reading when processing both neutral and emotional information after controlling for baseline mood. This shows that individuals with high levels of rumination exhibit a narrower attentional scope during reading. In addition, the results of total reading time showed that individuals with higher levels of trait rumination performed better when processing neutral and positive sentences under constrained window frame conditions, but this benefit was not significant anymore when processing negative sentences. These findings suggest that even though high trait ruminators use a constrained manner in processing in general, they may still process negative information differently compared with other types of information.

Footnote

[1] In this rating study, 30 participants (age: M = 21.67, SD = 2.63; 23 female), which were similar in age and gender distribution to the sample tested in the main moving window study (i.e., 56 participants, age: M = 20.32, SD = 2.82; 31 female), completed a sentence evaluation task. For the measure of valence, the results showed that the valence of positive sentences (M = 6.91, SD = 0.83) was significantly (p < .001) more positive than neutral sentences (M = 5.79, SD = 0.44), and the valence of neutral sentences was significantly (p < .001) more positive than negative ones (M = 2.60, SD = 1.00). For the measure of arousal level, results showed that there was no significant difference (p = .59) between positive (M = 4.90, SD = 1.57) and negative sentences (M = 4.71, SD = 1.50), whereas the arousal level of the neutral sentences (M = 3.80, SD = 1.32) was significantly lower than both positive (p < .001) and negative ones (p = .02). Further, we performed more analyses with regard to the nature of neutral and positive sentences: One-tailed t-tests were performed on the valence of all three sentences separately, with a comparison to the value point of 5 (the value of neutral on a scale from 1 to 9). The results showed that all three kinds of sentences were significantly different from this point value (ps < .001). We then directly compared the valence between positive and neutral sentences, and found a significant difference between them, t (29) = 8.14, p < .001. In addition, we also run another one-tailed t-test on neutral sentences comparing to the value point 6, which is the lowest level that was conceived as positive on the scale. The results showed that neutral sentences were significantly different from this point too (t = .262, p < .01).

[2]We also entered the state rumination score as covariance in all models and found similar results as when they were not included in the models. Given that the attentional scope model of rumination

mainly stresses the influence of mood state on attentional scope, we do not report these further results in the manuscript. These results are available upon request.

[3]Further, we checked whether the two-way interaction between trait rumination and window size were still present without the covariates (i.e., baseline positive and negative mood) in the model. The results showed that this two-way interaction is still significant in all restricted window sizes on both total fixation time and reading rates ($ps < .05$). Thus, we kept the results of these analyses in the main text as the evidence for the hypothesis that the relation between rumination and attentional scope is still present if effects of mood are controlled. Also, since depressive symptoms were significantly correlated with the RRS scores ($r = .66$, $p < .001$) in the current study, using BDI score as covariate would remove the shared variance of the RRS and BDI, which could then reduce the actual effect of RRS on attentional scope (Miller & Chapman, 2001). Therefore, we did not use BDI score as covariate in our model.

Acknowledgements

This research was supported by a research Grant (201306770031) from China Scholarship Council (CSC) awarded to Lin Fang, and a grant of the Research Foundation Flanders (FWO, reference 117438) awarded to Alvaro Sanchez-Lopez.

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Table 1

Characteristics of participants (N = 56)

	Mean	*SD*	*Range*
Age	20.32	2.82	17-31
Gender (female:male)	31:25		
BDI-II	9.80	6.47	0-24
RRS	39.77	12.41	22-70
MRSI T1	25.36	7.25	7-40
MRSI T2	24.54	6.58	11-40
VAS_happy T1	50.09	28.44	0-93
VAS_happy T2	52.50	28.14	0-97
VAS_sad T1	15.84	20.32	0-94
VAS_sad T2	12.48	15.22	0-55
VAS_agitated T1	30.30	25.58	0-95
VAS_agitated T2	31.12	24.43	0-84

Note: BDI-II, Beck Depression Inventory-II; RRS, Ruminative Response Scale; MRSI, Momentary Ruminative Self-focus Inventory; T1, Time 1 (before the experimental task); T2, Time 2 (after the experimental task); VAS, Visual Analogue Scale.

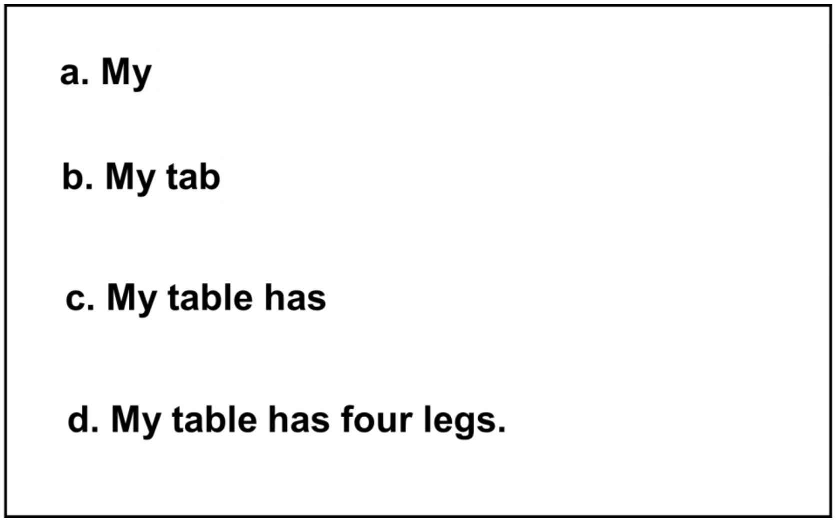

Fig.1 In a moving window task, only the letters in the reading window could be seen, whereas the text outside the window was masked by blank. a. small window condition (2-4 characters visible; 12.5 mm of size). b. the medium window condition (6-8 characters; 25 mm.). c. the large window condition (12-14 characters; 50 mm). d. no window condition.

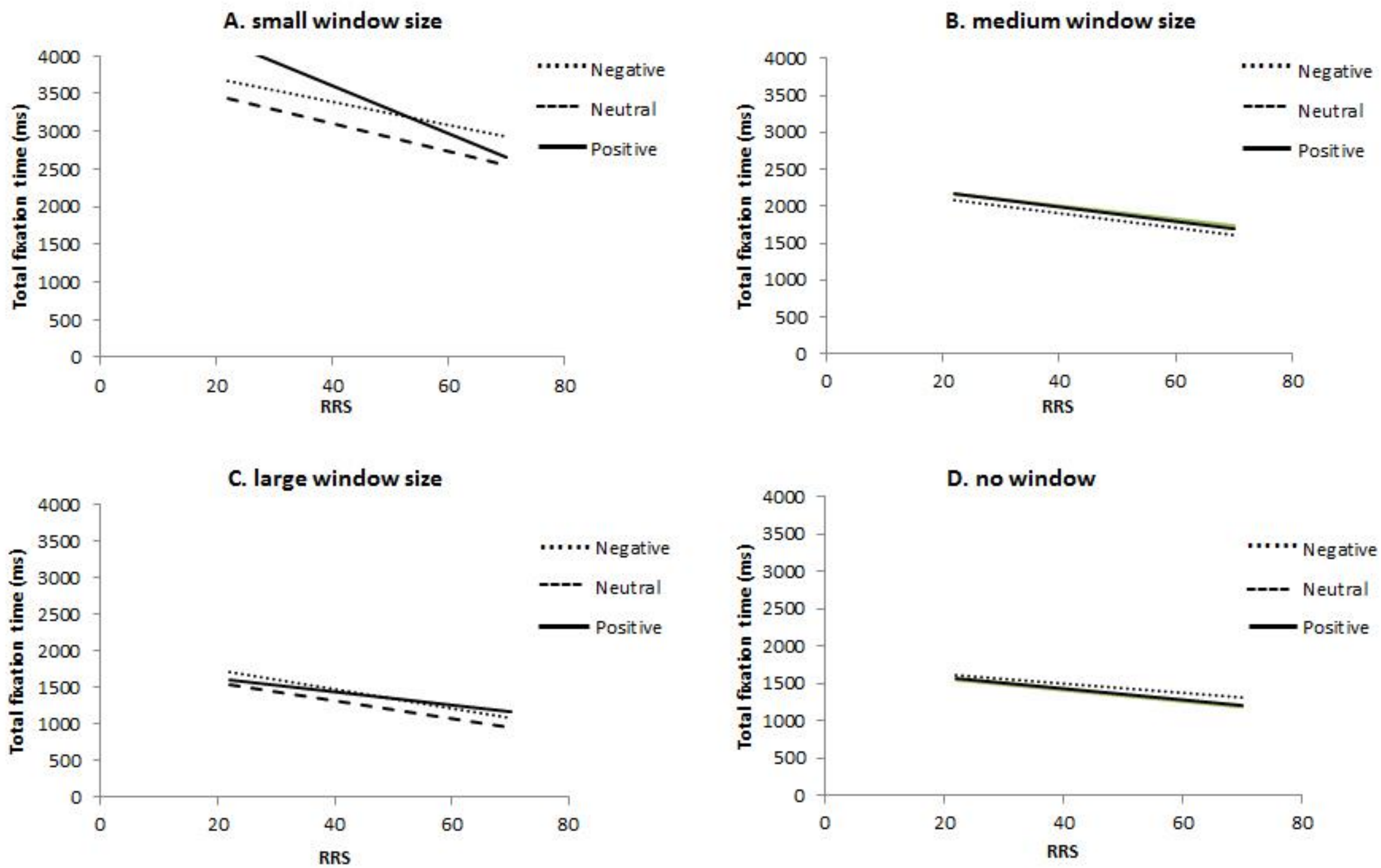

Fig.2 Total fixation time for different valences of sentence as a function of the RRS score in each window size condition. Each panel represents a window size condition: (A) small window size (B) medium window size (C) large window size and (D) no window condition. Separate lines illustrate participants' performance in processing sentences with different valences. RRS, Ruminative Responses Scale.