The Attentional System is Tuned to Initially Orient to Happy Faces when Competing with Angry Faces: An Eye-tracking Investigation

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Abstract

We investigated the emotion-based modulation in the attentional mechanism by presenting angry and happy faces simultaneously in the extrafoveal vision. In a letter discrimination task at the fixation, pairs of task-irrelevant happy and angry faces were displayed peripherally (≥5° away from the fixation) to study the valence-facilitated attentional capture under mutual competition for processing resources. Selective orienting was assessed using eye movement measures such as the probability of first fixation on these emotional face images. Results revealed a higher probability of first fixation for happy faces than angry ones. Processing of affective stimuli in the extrafoveal indicates early occurring covert orienting of attention followed by overt attention in the foveal vision. The attentional capture advantage by happy faces occurred in the absence of differences in arousal levels. We propose that happy faces have a unique capacity to capture attention when competing with angry faces.

Keywords: Attentional capture; emotion; selective orienting; eye-tracking

Introduction

From an evolutionary perspective, exogenous capture of attention could be considered a crucial comprehensive way of understanding adaptive mechanisms in identifying salient events around us to reorient attentional resources to them and enhance the processing mechanism (Carretié, 2014). Because of this adaptive significance, emotional stimuli are prioritised in resource-limited human information processing. Events of affective content are salient to an individual as they can modify and update goals and consequently alter the direction of attention towards the relevant stimuli. In visual attention, eye tracking studies have shown that factors such as selection history, reward learning and emotional representations compete for selection in the oculomotor priority map and direct eye movements (Belopolsky, 2015). Studies have shown that emotional cues systematically modulate the motor control of the relevant sense organ where the focal processing of emotional pictures has greater fixations than the neutral images regardless of perceptual complexity (Bradley et al., 2011). Emotionally arousing stimuli preferentially determine ocular movements suggesting the selective orienting of attentional mechanisms for further processing. Relatedly, eye movement research has shown that emotional scenes, whether presented alone (Kissler & Keil, 2008) or simultaneously (Alpers, 2008; Calvo et al., 2008; McSorley & van Reekum, 2013; Nummenmaa, Hyönä, & Calvo, 2006, 2009) in extrafoveal vision, capture more attention than neutral scenes. Thus, there is a selective orienting of attention to areas depicting emotional content relative to the non-emotional content within the same scenes when presented in the extrafoveal region (Humphrey, Underwood, & Lambert, 2012; Niu, Todd, & Anderson, 2012; Pilarczyk & Kuniecki, 2014).

Like emotional scenes, facial expressions have a vital role in how the affective content engages our attentional resources. These expressions could reflect a person's emotional state, motives, and intentions (Calvo et al., 2014). Previous studies have empirically supported that emotional faces capture our attention (Purcell & Stewart, 1986, 1988). Therefore, it is important to understand the underlying cognitive mechanisms involved in the attentional capture by emotional faces. Considerable empirical evidence shows that the human attentional system shows sensitivity to different facial emotions (Fox et al., 2000; Hansen & Hansen, 1988). Additionally, research suggests that individuals may orient to "fearful" faces more quickly than "happy" faces (Tipples, 2006). Thus, threat advantage hypothesis (Ohman, Lundqvist, & Esteves, 2001) explains the inclination to search for “bad” things around us. While this threat superiority argument predicts selective orienting to threatening stimuli, results are inconclusive across studies. If we must consider the adaptive mechanism and threat superiority, the unpleasant stimuli should be detected rather than the pleasant stimuli. However, varying results from eye-tracking studies where emotional and non-emotional pictures were presented extrafoveally have revealed that pleasant images attract attention to a greater (Nummenmaa et al., 2006), a lesser (McSorley & van Reekum, 2013), or a similar extent (Alpers, 2008) as compared to unpleasant images.

When comparing the specificity of emotions, evidence supporting both the threat-advantage hypothesis (Tipples, 2006; Ohman, Lundqvist, & Esteves, 2001) and the recognition advantage of happy faces (Kirita & Endo, 1995; Leppänen & Hietanen, 2004; Juth, Lundqvist, Karlsson, & Öhman, 2005, Experiment 4; Leppänen, Tenhunen, & Hietanen, 2003; Juth et al., 2005) are found in the literature. It is such inconclusive evidence that questions which category of emotions captures our attention. To get a

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complete picture of emotion-based modulation in the attentional mechanism, it is essential to study both positive and negative simultaneously. Directly examining the potential processing priority of emotional content, one must provide both images simultaneously while performing a task. To our knowledge, studies have used pleasant and unpleasant scenes simultaneously to the periphery of the visual field to compete for processing resources and compared the selective attentional capture of the emotional content of the scenes.

Fernández-Martín and Calvo (2016) have explored this potential advantage in capturing attention with pleasant and unpleasant scenes under mutual competition for attention-processing resources as they were task-irrelevant. They have used the eye-tracking paradigm to infer the initial selective orienting revealing the automaticity of attention. They investigated whether the emotional significance as opposed to the perceptual properties of scenes has an advantage of driving the initial orienting and later attentional engagement. Results from this study show that the attentional system is tuned into an initial orientation towards pleasant images when competing with unpleasant ones. Notably, this study has used IAPS (International Affective Picture System) scene images as stimuli, where the scenes are complex. The arousal levels were not controlled for pleasant and unpleasant images, suggesting the selective orienting might be due to these significant arousal differences in the stimuli. Also, the low-level visual differences are quite high between pleasant and unpleasant images (Gupta & Singh, 2021). Therefore, it is important to use those images where low-level visual differences between positive and negative images are low. Another limitation of this study is in the participant population and the generalization of the obtained results to the normal population. They have used only female participants for the experiment causing a gender bias. These limitations suggest that the study was not well-controlled. Therefore, in the present study, we used face images with happy and angry expressions using a similar eye-tracking paradigm to test whether we can replicate the findings of Fernández-Martín and Calvo's (2016) study. For this, we have used arousal-matched emotional faces of the same identity for exploring the potential preference of attentional mechanisms towards angry and happy faces.

Our study aims to investigate the initial orientation and attentional engagement of angry and happy face images when they compete for attentional resources. The major question of this research is which category of emotion (positive vs. negative) when irrelevant to the task is prioritised in the oculomotor priority map, to initially orient the limited attentional resources and engage the attention under mutual competition.

Methodology

Participants

Thirty volunteers (17 females and 13 males) aged 19 to 33 years (M = 24.07 years, SD = 3.51 years), participated in the experiment. These volunteers were recruited through flyer advertisements, reported normal to corrected-to-normal vision, and provided written informed consent before the experiment. All subjects were in good health, free of medications with no psychiatric or neurological disease history. The effect size was estimated to be 0.80, based on previous research on the selective orientation of attention to pleasant and unpleasant visual scenes (Fernandez-Martin & Calvo, 2016).

Apparatus

Experiment builder software ((SR Research Ltd., Ontario, Canada) was used to present stimuli. It was administered in a dimly lit room on an LCD monitor with 1920*1280 resolution and 60 HZ refresh rate. Eye movement data was recorded using Eyelink 1000 Plus desktop mount with a sampling rate of 1000Hz. For the experiment, each participant's head was stabilized, and their viewing distance was kept constant at 70 cm with the use of a forehead bracket and chin rest.

Stimuli

Happy, Angry and Neutral emotional faces of 21 identities from the NimpStimp (Tottenham et al., 2009) database were used for this experiment. In these, the emotions happy (4.86) and angry (5.04) were matched for their arousal level (p = 0.171*)* based on the SAM scale ratings from a previous study (Sutton et al., 2019). Neutral faces of these same identities were used as a control condition.

Procedure

The experimental design is an adapted version of the free-viewing paradigm used for selective orienting of pleasant and unpleasant stimuli in the study by Fernández-Martín and Calvo (2016). The experiment began with a 9-point calibration. The sequence of events is shown in the figure. Each trial started with the drift correction following a fixation cross at the centre of the screen displayed for 500 milliseconds. A letter ('a' or 'b') was presented at the centre of the screen at the same location as the fixation cross, which participants were instructed to look at for 500 milliseconds. This was followed by stimuli of two emotional faces presented at the periphery of the screen and a letter at the centre of the screen Participants were asked to fixate only on the letter and give the keypress response of whether the letters were the same (50% of cases) or different to the one displayed before. In this stage, participants were told to ignore the images and respond to the letters as fast as possible. Trials were aborted if participants did not follow this instruction (Less than 5% of the trials removed because of this anticipatory fixations). Further, the letter disappeared upon responding and both images remained on the screen until the participant fixated on them (one, the other or both) for 1000 milliseconds. Each trial had an inter-trial interval of 1000 milliseconds. The image was subtended 10°(height) and 12° (width) at a 70cm viewing distance with the inner edges of the images 5° distant from the central fixation letter.

Each participant was presented with 252 trials consisting of angry, happy, and neutral images of 21 identities counterbalanced on both sides in a randomized order with 20 practice trials. As a measure of early selective attentional orientating, we recorded (a) the probability of first fixation falling on the emotional stimuli, following the offset of the centrally present letter (i.e., when the images remained displayed), and (b) entry time, or the duration of time elapsed from the offset of the letter until first fixation on the image. For measuring attentional engagement, we recorded (a) dwell time or total fixation duration on these images, and (b) the number of fixations or fixation counts on each image stimuli. For the fixation detection parameter, we used 80ms for the minimum fixation duration.

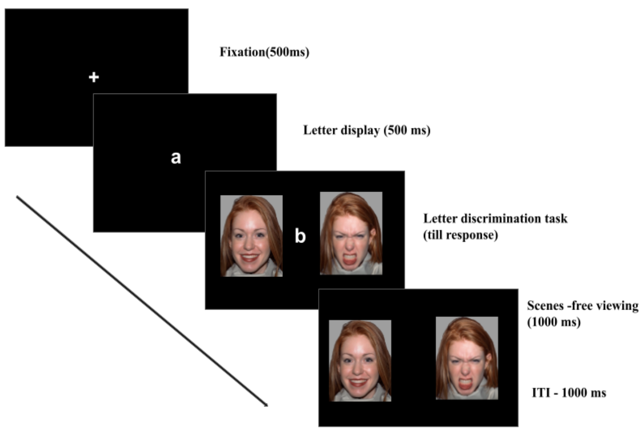

Figure 1: Sequence of events on each trial. Each trial started with a drift correction followed by these events. Emotional images and visual field are counterbalanced across trials. Eye movement measures are taken from the offset of letter in the letter discrimination task. Free viewing screen stays for 1s from moment the first fixation is made on any of the two images on the screen.

Results

The statistical analysis was done using RStudio to filter the eye tracking measure and JASP software. The outlier removal included, removing entry time data points exceeding three standard deviations from the mean, and the fixation duration below 80ms accounting for 3.17% of the total number of fixations and based on the accuracy of the letter discrimination task. Three participants who scored below 90% were removed from the data set before the analysis. The total data loss was 13%.

Analysis of Eye Movements

We employed a 3x2 factorial design, where participants were exposed to all combinations of 3 (Valence: Angry, Happy and Neutral) × 2 (Visual field: left vs. right). A repeated measures ANOVA was conducted to analyse the effects of emotion and visual field on eye movement measures. We have analysed the results for separate conditions i.e. when different pairs of emotions were presented simultaneously (Angry Happy, Happy Neutral and Angry Neutral). (See table 1,2a,2b and 2c)

Probability of the First Fixation For, the probability of the first fixation, the main effects of valence, $F(1,26) = 8.801$, MSE = 0.210, $p < 0.001$, $\eta_p^2 = 0.253$, revealed that the happy faces were more likely to be fixated than the angry and neutral faces. In addition, a paired comparison of emotions performed to examine the effects of valence was found significant in angry-happy (t (26) = -3.077, p = 0.005) and happy-neutral (t (26) = 3.830, $p < 0.001$). We have obtained significant results for separate conditions, when happy presented along with angry faces, $F(1,26) = 11.171$, MSE = 0.621, $p = 0.003$, $\eta_p^2 = 0.301$ and when happy presented along with neutral faces, $F(1,26) = 11.753$, MSE = 0.272, p = 0.002, $\eta_p^2 = 0.311$. The interaction effect of valence and visual field was insignificant, $F(1,26) = 0.703$, MSE = 5.113*10^-4, $p = 0.703$, $\eta_p^2 = 0.013$

Entry time for entry time analysis, the effect of valence did not reach any statistical significance ($F(1,26) = 0.814$, MSE = 388.302, $p = 0.449$, $\eta_p^2 = 0.030$). Paired comparison results have no significance for any emotions and separate conditions. The interaction effect of valence and visual field was found to be insignificant, $F(1,26) = 1.210$, MSE = 865.585, $p = 0.306$, $\eta_p^2 = 0.044$

Number of Fixations Results for the number of fixations have shown no effects for valence ($F(1,26) = 2.593$, MSE = 0.327, $p = 0.084$, $\eta_p^2 = 0.055$). In the case of separate condition-based analysis, we obtained significant results when happy and neutral faces were presented together, ($F(1,26) = 6.533$, MSE = 1.609, $p = 0.017$, $\eta_p^2 = 0.201$), revealing that happy faces were fixated more than neutral faces when presented simultaneously. For other conditions, no significant results were found. The interaction effect of valence and visual field was found to be insignificant, $F(1,26) = 0.915$, MSE = 0.022, $p = 0.407$, $\eta_p^2 = 0.034$

Dwell Time Analysis has found no effect based on the valence ($F(1,26) = 2.142$, MSE = 1962.208, $p = 0.128$, η_p^2 = 0.076). Apriori paired comparison of emotions examining the effect of valence has shown marginal significance in the angry-happy (t (26) = -1.847, p = 0.076). No significant results were found for separate conditions. The interaction effect of valence and visual field was insignificant, $F(1,26)$ = 0.234, MSE = 148.701, $p = 0.792$, $\eta_p^2 = 0.009$

Table 1: Mean Score of eye movement measures for each valence

	Angry		Happy		Neutral		*p* -value	
Eye Movement Measures	**M**	**SD**	**M**	**SD**	**M**	**SD**		
Probability of first fixation	0.457	0.091	0.571	0.111	0.471	0.056	< 0.001	
Entry Time (ms)	310.363	57.220	307.864	56.912	313.223	62.974	0.449	ns
No of Fixations	2.386	0.646	2.520	0.789	2.383	0.654	0.084	ns
Dwell Time (ms)	314.445	82.221	327.642	96.405	322.061	86.258	0.128	ns

Note. LVF: left visual field; RVF: right visual field

Table 2a: Mean scores of eye movement measure for condition-based analysis results: Angry and Happy trials only

Emotion		Angry			Happy		*p* -value	
Eye Movement Measures		**M**	**SD**		**M**	**SD**		
Probability of first fixation		0.425	0.118		0.576	0.118	0.003	
	LVF	0.367	0.212	RVF	0.633	0.212	0.003	
	RVF	0.482	0.265	LVF	0.518	0.265	0.723	ns
Entry Time (ms)		345.872	114.964		343.309	108.679	0.880	ns
	LVF	328.242	116.888	RVF	353.993	130.165	0.144	ns
	RVF	363.502	151.350	LVF	332.625	113.732	0.325	ns
No of Fixations		2.319	0.630		2.487	0.802	0.196	ns
	LVF	2.349	0.741	RVF	2.464	0.768	0.437	ns
	RVF	2.285	0.610	LVF	2.503	0.885	0.123	ns
Dwell Time (ms)		316.067	88.808		330.956	101.868	0.162	ns
	LVF	307.560	91.901	RVF	339.426	103.162	0.019	
	RVF	323.610	98.273	LVF	319.902	106.112	0.804	ns

Table 2b: Mean scores of eye movement measure for condition-based analysis results: Happy and Neutral trials only

Emotion		Happy			Neutral		*p* -value	
Eye Movement Measures		**M**	**SD**		**M**	**SD**		
Probability of first fixation		0.571	0.111		0.471	0.056	0.002	
	LVF	0.518	0.252	RVF	0.520	0.217	0.984	ns
	RVF	0.625	0.210	LVF	0.422	0.189	0.012	
Entry Time (ms)		307.864	56.912		313.223	62.974	0.311	ns
	LVF	304.200	65.937	RVF	310.366	58.662	0.459	ns
	RVF	311.528	57.102	LVF	316.081	75.242	0.665	ns
No of Fixations		2.566	0.788		2.316	0.655	0.015	
	LVF	2.567	0.812	RVF	2.340	0.711	0.058	ns
	RVF	2.551	0.808	LVF	2.290	0.670	0.032	
Dwell Time (ms)		322.624	92.072		323.841	87.456	0.856	ns

	LVF	314.812	88.682	RVF	329.752	107.950	0.186	ns
	RVF	327.358	98.173	LVF	317.721	79.476	0.491	ns

Table 2c: Mean scores of eye movement measure for condition-based analysis results: Angry and Neutral trials only

Emotion		**Angry**			**Neutral**		***p*** **-value**	
Eye Movement Measures		**M**	**SD**		**M**	**SD**		
Probability of first fixation		0.457	0.091		0.471	0.056	0.484	ns
	LVF	0.402	0.213	RVF	0.520	0.217	0.153	ns
	RVF	0.512	0.225	LVF	0.422	0.189	0.252	ns
Entry Time (ms)		310.363	57.220		313.223	62.974	0.500	ns
	LVF	305.935	58.156	RVF	310.366	58.662	0.563	ns
	RVF	314.790	66.354	LVF	316.081	75.242	0.903	ns
No of Fixations		2.424	0.667		2.402	0.660	0.794	ns
	LVF	2.427	0.755	RVF	2.411	0.667	0.884	ns
	RVF	2.405	0.656	LVF	2.395	0.710	0.923	ns
Dwell Time (ms)		313.637	78.865		321.227	87.185	0.225	ns
	LVF	312.881	77.396	RVF	327.920	102.286	0.280	ns
	RVF	315.560	88.452	LVF	312.177	85.082	0.796	ns

Discussion

In the present study, we used continuous eye movement monitoring to investigate the selective orienting and later attentional engagement of emotional facial expressions in the peripheral vision while performing a task completely irrelevant to these emotions. We have focused on happy and angry emotional faces of the same identity to study the recognition advantage of these emotions. Our findings revealed that under mutual competition for attentional resources in the peripheral vision, happy faces capture attention compared to angry and neutral faces. This was shown by the preferential orientation of eye movements, i.e. the probability of the first fixation on happy faces rather than angry or neutral faces.

Many studies have used continuous eye movement measures to explore selective attentional processing of emotional pictures (Bradley et al., 2000; Hermans et al., 1999; Miltner et al., 2004; Mogg, Millar et al., 2000; Rohner, 2002). However, many of these studies have compared the role of individual differences in a specified population either trait anxiety (Rohner, 2002), social anxiety (Bradley et al., 2000), GAD (Mogg, Millar, & Bradley, 2000) or phobia (Hermans et al., 1999; Miltner et al., 2004). These results may not be an accurate representative of the cognitive processing of a normal population. Therefore, this approach to studying a category of emotions in the normal population of both genders could account for its representative value. Prior research has shown heightened attention in the cognitive and neural systems, for emotional stimuli relative to neutral stimuli (Bradley, Keil, & Lang, 2012; Carretié, 2014; Mohanty & Sussman, 2013). Studies have found that emotional faces capture our attention (Purcell & Stewart, 1986, 1988) and have used targets with affective context to examine the influence of attention-orienting on emotional faces (Bayliss et al., 2010; Pecchinenda et al., 2008). In this context, we have made some contributions. First, in prior research, affective stimuli were presented as cues, targets, or distractors to study the spatial attention processing of these stimuli; where these stimuli required attentional resources because they were task relevant. In many cases, these stimuli were presented singly and in central vision. In this study, we have used a dual-paradigm, along with the peripheral display where these emotional face images were task-irrelevant, followed by their availability to the central vision allowing us to examine the selection or preferential processing of the emotions and later attentional engagement; also distinguish between the covert and overt attention. This approach adds specificity to the 'heightened attention' to emotional stimuli concept.

Second, prior research has addressed the emotion recognition or discrimination in the peripheral vision; few on the selective processing of emotional scenes presented extrafoveally with evidence of emotional scenes capturing covert attention compared to neutral scenes. (Alpers, 2008; Calvo et al., 2008; Nummenmaa et al., 2009). Here, we have directly compared the simultaneous competition for attention when emotional faces are task irrelevant. In a straightforward interpretation, our findings of selective orienting to happy faces, when they compete with angry and neutral faces, support the 'positivity attentional bias hypothesis (Nummenmaa et al., 2006). This also aligns with previous findings on positive emotional stimuli and their unique attentional capturing power capacity (Anderson et al., 2011; Gupta et al., 2016). It was evident that there is an attentional bias towards positive stimuli (happy faces) which contradicted "fearful" faces more quickly than "happy" faces (Tipples, 2006). This was evident from the condition-based findings that when presented along with angry and neutral faces, happy faces have priority over the other. Indicating that when attentional resources are limited positively-valenced stimuli are prioritised over the others (covert attention) followed by eye movement towards those stimuli (overt attention). Such selective orienting towards positive stimuli could also be the result of minimal attentional resource requirement to process positive emotions as opposed to negative emotions Gupta, 2012, 2022; Gupta and Dea´k, 2015; Gupta and Srinivasan, 2015; Gupta et al., 2016; Srivastava and Srinivasan, 2010; Pandey & Gupta, 2023). It could also suggest the least susceptibility to inhibition by positive emotions under limited resources compared to negative emotions (Gupta and Srinivasan, 2015) is casing this positivity bias.

This orienting advantage cannot be attributed to the perceptual factors, as angry and happy face stimuli were arousal-matched and of the same identity. Suggesting that selective orienting effects were driven by emotional valence significance through covert attention, which led to overt attention. While attending the attentional resources to the central letter discrimination task, participants in their peripheral vision have processed these emotional stimuli. In addition, the covert orienting of attention occurred before any fixations on these images, and attention to these images was task-irrelevant, suggesting that affective valence processing in the peripheral vision was automatic. Thus, our findings explain this exogenous nature of attentional capture by happy faces in comparison to angry and neutral faces. Thirdly, when it comes to attentional engagement, we have observed a similar pattern for the number of fixations under separate condition-based findings for happy images when compared with neutral. Indicating that happy faces were more engaging than other emotional faces, revealing that happy faces are preferred more than angry or neutral faces to look at. Our results found that in the later attentional engagement process, both happy and neutral were higher in their dwell time measure to angry faces. This supports the positivity hypothesis, where unattended happy faces captured attention more than unattended angry images as evidenced by the increased number of fixations (Eastwood, Smilek, & Merikle, 2001).

Taken together, our results are inconsistent with those indicating the preferential orientation of attention towards threatening faces supporting the negativity hypothesis (Fox et al., 2000; Mogg & Bradley, 1999; O¨hman, Lundqvist, & Esteves, 2001; Tipples, Atkinson et al., 2002). On the other hand, our findings are consistent with the results, that found enhanced attention to pleasant images over unpleasant ones Calvo and Lang (2004, 2005, 2005). Thereby, it is evident that the human attentional system prefers emotional stimuli when competing with neutral images, among those emotions happiness is preferred over anger. When angry and neutral compete, neutral images engage attention more than angry, suggesting the least preference to engage in negative emotions. Thus, the threat advantage disappears in favour of emotionality, under no arousal difference condition.

The present study provides evidence for attentional capture by positive affective stimuli (happy) under mutual competition. This emotional bias is seen in the initial orientation of attentional capture. Orienting and engaging attention to potentially harmful and beneficial stimuli aligns with the evolutionary perspective of attentional processing. However, this study signifies the early stages of selection preferentially orients to happy faces. From these results, we found that the initial orientation of attention is tuned to happy faces. Interestingly, studying other relevant factors like reward competing with emotions, could facilitate a better understanding of these emotional representations.

Conclusion

In conclusion, our study focuses on the nuanced dynamics of attentional processing concerning facial expressions, particularly preferential orientation towards happy faces in the peripheral vision when competing for processing resources. Importantly, our findings prove the positive attentional bias hypothesis, revealing a clear preference for affective stimuli over negative and neutral ones in capturing attention. Moreover, this observed automaticity of emotional valence processing in the extrafoveal vision highlights the efficiency of the human attentional system in prioritizing potentially beneficial stimuli. In this, the emotion-based modulation of attention was purely due to their valence difference and not arousal levels. Our findings suggest that positive stimuli like happy faces have a unique capacity to capture attention. This advantage over happy faces might seem counterintuitive in terms of evolutionary significance: early detection of threat cues has a higher priority relative to reward cues. While this study contributes to the cognitive mechanisms underlying the attentional processing of emotions, future research could explore how other relevant factors would interact in the emotional representations and their interplay with attentional allocation.

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