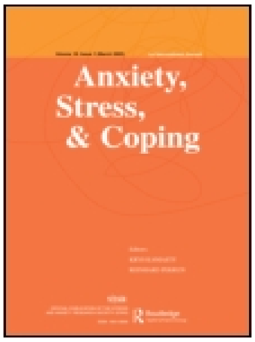

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Human freezing in response to affective films

Muriel A. Hagenaars[a]*, Karin Roelofs[a,b] and John F. Stins[c]

[a]*Behavioral Science Institute, Radboud University Nijmegen, Nijmegen, The Netherlands;* [b]*Donders Institute for Brain, Cognition and Behaviour, Radboud University Nijmegen, Nijmegen, The Netherlands;* [c]*Research Institute MOVE, Faculty of Human Movement Sciences, VU University Amsterdam, Amsterdam, The Netherlands*

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Human freezing has been objectively assessed using a passive picture viewing paradigm as an analog for threat. These results should be replicated for other stimuli in order to determine their stability and generalizability. Affective films are used frequently to elicit affective responses, but it is unknown whether they also elicit freezing-like defense responses. To test whether this is the case, 50 participants watched neutral, pleasant and unpleasant film fragments while standing on a stabilometric platform and wearing a polar band to assess heart rate. Freezing-like responses (indicated by overall reduced body sway and heart rate deceleration) were observed for the unpleasant film only. The unpleasant film also elicited early reduced body sway (1–2 s after stimulus onset). Heart rate and body sway were correlated during the unpleasant film only. The results suggest that ecologically valid stimuli like films are adequate stimuli in evoking defense responses. The results also underscore the importance of including time courses in human experimental research on defense reactions in order to delineate different stages in the defense response.

Keywords: freezing; orienting; tonic immobility; body sway; stabilometric platform; anxiety

Introduction

Freezing is used as a main outcome measure of anxiety in many animal studies but has been relatively neglected in human studies. However, automatic responses to threat, such as for example, avoidance (flight), are important determinants for the development and maintenance of anxiety disorders (Brewin & Holmes, 2003; Rachman, 1980). As such, freezing may also play an important role in the etiology of anxiety, possibly by its consequences for the processing of threat-related information. The very few studies on postural immobility in humans indeed found self-report or experimentally induced peritraumatic immobility to be associated with later psychological impairment like intrusive memories (Hagenaars, Brewin, Van Minnen, Holmes, & Hoogduin, 2010; Hagenaars, Van Minnen, Holmes, Brewin, & Hoogduin, 2008) or even posttraumatic stress disorder (Bovin, Jager-Hyman, Gold, Marx, & Sloan, 2008; Galliano, Noble, Puechl, & Travis, 1993; Heidt, Marx, & Forsyth, 2005).

Hillman, Rosengren, and Smith (2004) introduced the use of a stabilometric platform in combination with affective picture viewing. Some recent studies have

*Corresponding author. Email: m.hagenaars@psych.ru.nl

applied this paradigm to defense responses and were able to assess freezing objectively, using the main indicators of freezing: reductions in mobility and heart rate (Azevedo et al., 2005; Facchinetti, Imbiriba, Azevedo, Vargas, Volchan, 2006; Hagenaars, Stins, & Roelofs, 2012; Roelofs, Hagenaars, & Stins, 2010). All these studies used pictoral stimuli (affective pictures or emotional faces) to investigate freezing in response to threat (unpleasant pictures) relative to pleasant and neutral situations (pleasant and neutral pictures). Although viewing unpleasant pictures may resemble a trauma or threatening experience by the simultaneous experience of horror and entrapment (Marx, Forsyth, Gallup, Fusé, & Lexington, 2008), it is of great importance to investigate human freezing in response to other, preferably more ecologically valid stimuli as well. To our knowledge, this has not been done thus far. The present study therefore aims to study freezing by using continuous, moving stimuli that depict the actual unfolding of an event in time; that is, film fragments. This step is needed in order to test whether freezing responses still stand during the presentation of more complex stimuli. This would thereby provide extra validation for the passive viewing paradigm as a means to evoke defense responses. A second reason for investigating freezing in response to films is that films are used in increasing frequency in experimental paradigms as an analog for trauma (Hagenaars et al., 2008, 2010; Holmes, Brewin, & Hennessy, 2004; Verwoerd, De Jong, & Wessel, 2008), or to evoke stress (e.g., Henckens, Hermans, Pu, Joëls, & Fernández, 2009). Unpleasant films have indeed been shown to evoke emotional responses including feelings of anxiety and horror (e.g., Hagenaars et al., 2008, 2010), intrusive memories (e.g., Holmes et al., 2004), changes in heart rate and cortisol levels (e.g., Henckens et al., 2009), and fear-potentiated startle (Kaviani, Gray, Checkley, Kumari, & Wilson, 1999), but it remains unknown whether films also elicit automatic defense responses like freezing.

Therefore, the aim of this study was to test whether a complex, ecologically valid stimulus would evoke freezing-like responses. It was expected that an unpleasant film would evoke freezing (bradycardia and reduced body sway), relative to pleasant and neutral films. As freezing has not been studied earlier using a film clip, the time course of freezing was also explored, with an additional focus on early responses.

Method

Participants

Fifty female students, randomly selected at Leiden University and VU University Amsterdam, participated voluntarily in the present study after providing written informed consent. As gender is known to affect postural parameters (Hillman et al., 2004), we selected only women. They received course credits or cash money for their participation. Their mean age was 21 years and 7 months ($SD = 3$ years and 7 months).

Apparatus and material

Body sway

Center of pressure (COP) excursions in anterior-posterior (AP) and medio-lateral (ML) direction were recorded with a custom made 1×1 m stabilometric platform at a sample frequency of 100 Hz.

Heart rate

A polar band (Heart Rate Telemetry Systems) was used to record heart rate. It was placed at the height of the sternum. The signal was converted to beats per minute (BPM) with LabVIEW.

Film stimuli

Three 1-minute film fragments with different valence categories were selected. The film fragments all depicted road traffic scenes. A neutral road traffic scene was constructed by filming a cross road with cars, pedestrians, and motor bikes passing by. A scene from "Herbie goes to Monte Carlo" (Walt Disney) was selected for the pleasant category, because it included action and some humor, but not to the extent that participants actually had to laugh, which would have interfered with the posturographic recordings. The unpleasant scene consisted of real life footage (compiled by Steil, 1996) showing the aftermath of a fatal car accident including car wrecks, injured victims, and dead bodies being moved. This scene has been used in experimental studies before to model a traumatic experience (e.g., Hagenaars et al., 2008; Holmes et al., 2004) and proved effective in evoking anxiety and horror. We selected film scenes that were homogeneous in that they did not include specific events within the 60 s. This was done so that the scenes would be optimally neutral, pleasant, and unpleasant and optimally comparable to pictoral stimuli. The 60 s duration of the films was chosen because this duration was used in similar studies with pictoral stimulus presentation on a stabilometric platform.

The films were presented full screen at eye-height on a 17-inch height adjustable computer screen. The screen was approximately 1 m in front of the participant and had a visual angle (height $\times$ width in degrees) of $15.5^\circ \times 10.8^\circ$.

Valence, arousal and immobility

Valence and arousal were rated using the self-assessment manikin (Lang, 1980), with higher scores indicating negative valence and more arousal. Participants were also asked to rate the degree of immobility that each film elicited on a similar scale, with higher scores indicating more feelings of paralysis.

Procedure

Participants attached the polar band prior to testing. They then sat down and watched a 4-minute neutral nature film scene to make them feel at ease and normalize heart rate. After that, they stepped onto the middle of the stabilometric platform and watched the monitor, on which the instructions were displayed. Participants were instructed to stand upright with stocking feet approximately 30 cm apart, and their arms relaxed along the trunk. The light in the room was dimmed when the participants stepped onto the platform. A brief practice trial with letter presentations preceded the actual experiment.

The actual experiment consisted of a passive viewing task. The order of the three films (neutral, pleasant and unpleasant) was counterbalanced and randomly assigned to the participants. A 5-second black screen followed by a 2-second white fixation cross was presented between the films. The total viewing time was 4 minutes and 21 s (60 s practice + 180 s film + 21 s interval). Participants were also shown pictures for other purposes; those results are reported elsewhere (Hagenaars et al., 2012). Self-report film ratings were completed after the posturographic measurements.

Posturographic and statistical analyses

Heart rate deceleration and reduced body sway were used to define freezing. The mean heart-rate in BPM was determined for the three emotion films separately. Posturographic analyses were performed using MATLAB. The *x* and *y* time series were low-pass filtered with a second order Butterworth filter with a cut-off frequency of 10 Hz. The length of the sway path of the COP (SP-length) was used as a primary outcome measure for freezing, as this refers to an overall, non-directional amount of body sway.

Separate repeated measures MANOVAs with Emotion (neutral, pleasant, unpleasant) as within factor were used to determine mean differences in self-report valence, arousal and immobility levels. For heart rate and SP-length, the 60 s film-viewing time was divided in 3-second blocks (typical picture presentation time in freezing studies; Azevedo et al., 2005; Facchinetti et al., 2006; Roelofs et al., 2010), in order to examine changes over time. Differences in heart rate and SP-length were determined using separate 20 (Time) × 3 (Emotion) repeated measures ANOVAs.[1] Early responses were explored more closely by dividing the first 3 s into 500 ms blocks.

Results

Self-reports

Repeated measures MANOVA analyses showed a main effect for Emotion on Valence, Arousal and Immobility ($F(6, 44) = 76.24$, $p < .001$, $\eta_p^2 = .91$). Univariate analyses revealed significant differences between all emotion categories for Valence ($F(2, 48) = 196.47$, $p < .001$, $\eta_p^2 = .80$), with the pleasant film rated most and unpleasant film least pleasant ($M = 4.50$, $M = 3.06$, and $M = 8.10$ for neutral, pleasant and unpleasant respectively). Arousal ratings also differed significantly ($F(2, 48) = 67.47$, $p < .001$, $\eta_p^2 = .58$) with post hoc comparisons indicating significant differences between all emotion categories (all *p*s < .001) with the neutral pictures rated as least and the unpleasant pictures as most arousing ($M = 2.70$, $M = 4.78$, and $M = 7.04$ for neutral, pleasant and unpleasant respectively). Self-report immobility ratings differed significantly ($F(2, 48) = 122.79$, $p < .001$, $\eta_p^2 = .72$) with post hoc comparisons showing that self-report immobility was significantly higher in unpleasant ($M = 5.78$) versus neutral ($M = 1.84$) and pleasant ($M = 2.10$) films (both *p*s < .001). There were no differences in self-report immobility between neutral and pleasant films ($p = .27$).

Heart rate

A 20 (Time) × 3 (Emotion) repeated measures ANOVA yielded significant effects for Emotion ($F(2, 48) = 5.97$, $p = .004$, $\eta_p^2 = .11$), Time ($F(2, 19) = 7.52$, $p < .001$,

$\eta_p^2 = .13$), and the Time × Emotion interaction ($F(2, 38) = 3.29$, $p < .001$, $\eta_p^2 = .06$), indicating that heart rate had a different course for unpleasant, pleasant and neutral films (see Figures 1 and 2). Post hoc comparisons showed that heart rate was significantly lower for unpleasant versus pleasant films from 22 s to 60 s (all *p*s < .05). Heart rate was significantly lower for unpleasant versus neutral films from 25 s to 33 s and from 52 s to 60 s (all *p*s < .05).

With respect to early heart rate responses, there was no effect of Emotion for the first 3 s after stimulus onset ($F(2, 98) = .86$, $p = .43$, $\eta_p^2 = .02$).

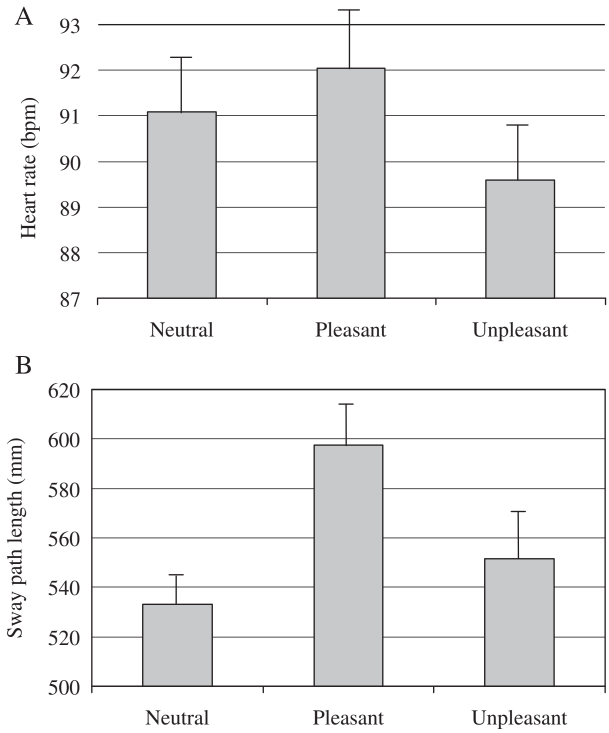

Figure 1. Mean heart rate (panel A) and sway path length (panel B) in response to neutral, pleasant and unpleasant films. Error bars represent SEMs.

Posturography

A 20 (Time) × 3 (Emotion) repeated measures ANOVA yielded a significant Emotion effect for SP-length ($F(2, 48) = 17.11$, $p < .001$, $\eta_p^2 = .26$), indicating an effect of film valence on body sway (see Figures 1 and 3). Post hoc comparisons showed shorter SP-lengths for the unpleasant and neutral films relative to the pleasant film (both *p*s < .005). There were no significant effects for Time ($F(2, 19) = 1.49$, $p = .16$, $\eta_p^2 = .03$) or Time × Emotion ($F(2, 48) = 1.25$, $p = .14$, $\eta_p^2 = .03$).

With respect to early posturographic responses, the effect of Emotion was already significant in the first 3 s after stimulus onset ($F(2, 98) = 4.01$, $p = .02$, $\eta_p^2 = .08$). More detailed testing indicated that the effect was at earliest observed in the 1- to 2-second time window ($p < .05$; see Figure 3).

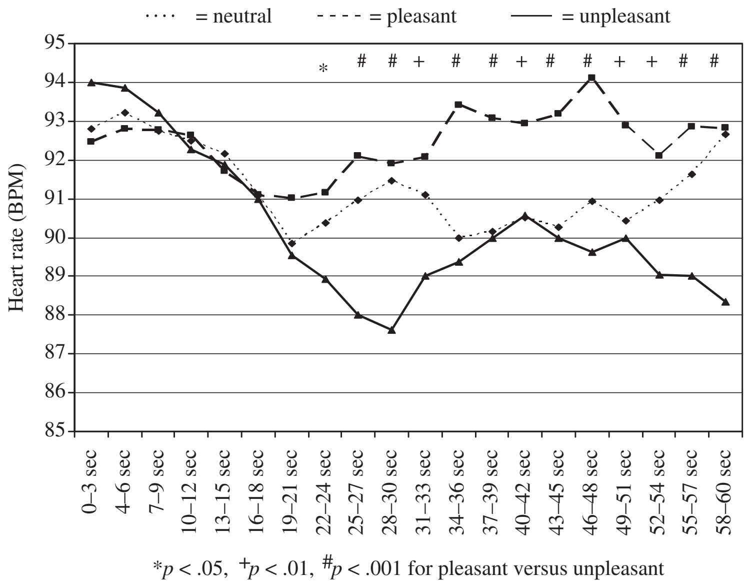

Figure 2. The course of heart rate during the 1-minute film clip presented in 3-second blocks.

In sum, only the unpleasant film elicited reductions in both heart rate and body sway, indicating a sustained freezing-like reaction. In addition, heart rate showed a significant, delayed and sustained decrease over time in response to the unpleasant film, relative to the pleasant and neutral films, whereas reductions in SP-length took place early after stimulus onset, but fluctuated over time.

Heart rate–posturography relationship

Mean heart rate and SP-length were correlated during unpleasant films ($r = .30$, $p = .037$), but not during neutral ($r = .10$, $p = .51$) and pleasant films ($r = .23$, $p = .13$), indicating that decreases in heart rate were associated with decreases in SP-length during the unpleasant films only.

Discussion

The present study tested whether a film clip could elicit freezing-like responses in humans. Responses to a 1-minute unpleasant film included low body sway and heart rate deceleration, which indeed may indicate freezing responses. Previous research has shown affective films to be effective tools in eliciting self-report and physiological stress responses (like changes in heart rate and hormone levels; Henckens et al., 2009). We have now shown that films may also elicit basic freezing-like defense responses that are central to the defense cascade. Like in affective picture viewing, affective film viewing also meets the optimal criteria for eliciting freezing: horror and restraint. However, films include the actual unfolding in time of an event and may therefore be more ecologically valid. This makes it a useful paradigm for eliciting stress and studying defense related responses.

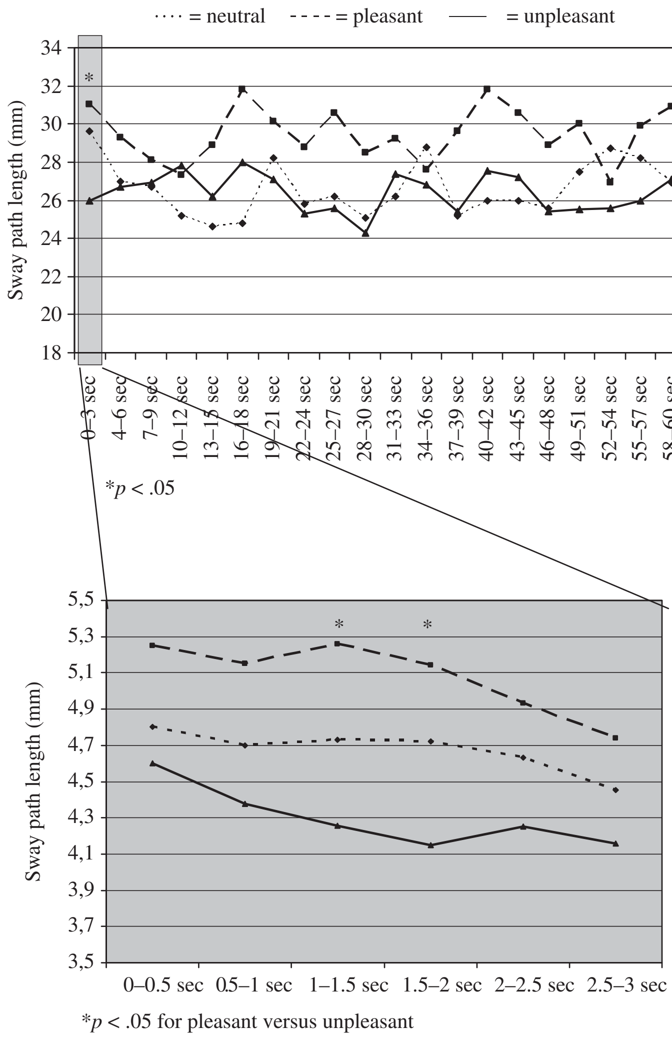

Figure 3. The course of sway path length during the 1-minute film clip presented in 3-second blocks (panel A), and the course of sway path length in the first 3 s after stimulus onset, presented in 500 ms blocks (panel B).

The use of films as continuous stimuli also has the great advantage in that it allows the investigation of processes over time. The present study showed that reductions in heart rate and body sway in response to the unpleasant film were both prolonged. In addition, the effects of heart rate developed over time, while there was no such time-effect for body sway. Future research should replicate and extend these innovative findings. Furthermore, although film images included visual motion, effects on heart rate and body sway were relatively stable. It seems that the film was perceived and processed as one continuous event in terms of defense responses, and not as a series of scenes. Our data are in line with animal studies that usually define freezing as an immobility period that lasts at least 3 s (Kalin, Shelton, Rickman, & Davidson, 1998; Rogers, Shelton, Shelledy, Garcia, & Kalin, 2008). Indeed, freezing durations can last from seconds to up to 30 minutes (Vianna & Carrive, 2005). Prolonged freezing behavior may include overall immobility as, in addition to orienting per se, it also serves survival purposes like minimizing detection by predators (Eilam, 2005; Gallup, 1977).

Interestingly, the present study also found early (1–2 s) body sway reductions in the first 3 s in response to the unpleasant film. These early changes in body sway may represent an attentional orienting or risk assessment response aimed at optimizing perception, which is sometimes distinguished from prolonged defensive responses like freezing (Blanchard, Griebel, Pobbe, & Blanchard, 2011; Bradley, 2009; Eilam, 2005; Rogers et al., 2008). Attentional orienting in animals is considered an early, automatic perceptual process, reflecting attention to the stimulus (Blanchard et al., 2011). Freezing, in addition to optimizing perception, also minimizes detection by predators and prepares for fight or flight actions (Lang, Bradley, & Cuthbert, 1997). The present study is a first step in the exploration of several defense-related physiological variables in a prolonged time course. It is of great importance that research tries to chart the time course of orienting, freezing, fight, flight and tonic immobility, as theoretical models imply that these may be subsequent stages (Lang et al., 1997; Marx et al., 2008) that occur after threat detection. Threat processing is a complex response including immediate and sustained responses and different functional systems (such as attentional and motivational systems). Film clips offer a unique opportunity to study the time course of these processes.

The present study was limited by the inclusion of females only, so findings have to be replicated in males. Also, participants showed minimal body sway in response to the neutral film, which could suggest increased body sway for the pleasant film. We tend to interpret the findings as decreased body sway for the unpleasant film, though, preferring the pleasant–unpleasant comparison over the neutral-unpleasant comparison. First, defense behavior including orienting and attentive processing may not be valance-specific but rather associated with arousal (indicative of sympathetic activity, e.g., Codispoti, Surcinelli, & Baldaro, 2008). Our neutral film was only mildly arousing, thus not activating primary motive systems, and so the pleasant–unpleasant comparison would be more useful than the neutral-unpleasant comparison. Second, our neutral film did not depict any remarkable events or meaningful events as part of a "narrative". Other studies examining posturography used a picture viewing paradigm, with new pictures being presented every few seconds, so that even in the neutral category participants are presented with new events (i.e., pictures) frequently (Azevedo et al., 2005; Hagenaars et al., 2012; Roelofs et al., 2010). Those studies all found similar elevated levels of body sway for neutral and pleasant pictures, suggesting some events are needed for minimal attentive processing (and sympathetic activation), and indicating the importance for a control condition with similar arousal levels. Future research should use a neutral film that includes non-emotional action, or use a more interesting neutral film depicting a non-emotional event or "story". Finally, note that freezing is characterized by decreased heart rate, as well as decreased movement and those two factors are simultaneously present in the unpleasant condition only.

The results should also be replicated using an unpleasant film that does not depict physical injury, ruling out the possibility that the association with blood and injury was responsible for the decreases in heart rate. Although our results are in line with previous findings based on non-injury stimuli, such as angry faces and ferocious animals (Hillman et al., 2004; Roelofs et al., 2010), this still has to be confirmed empirically. The fact that arousal levels for the pleasant film were lower than those for the unpleasant film is difficult to prevent. That is, in order to evoke freezing, stimuli may have to be highly unpleasant. The only pleasant stimuli that have the potential to induce similar comparable arousal levels might be erotica. We chose not to use such a film, because erotica can be ambiguous in pleasantness for women, and may elicit a wide range of emotions, including negative emotions such as embarrassment and shame. The present pleasant film depicted a traffic situation and was also arousing. In addition, explanations of the effects solely in terms of arousal do not seem likely. That is, if only arousal would be causing the effects, then the effects of the pleasant and unpleasant film would be in the same direction and differ in magnitude only. In contrast, the pleasant film elicited increases in heart rate, while the unpleasant film caused heart rate deceleration, suggesting both arousal and valance factors played a role. Explanations in terms of movement effects (e.g., movement causing increases in heart rate) can be ruled out as well, as heart rate and body sway were related during the unpleasant film only, and no such relationship was found for the neutral and pleasant film.

In sum, it was found that affective film viewing adequately elicits prolonged freezing responses, indicating that aversive films trigger basic defense reactions. This is a promising finding as films are used with increasing frequency in experimental stress paradigms. In addition to the overall freezing effect, the results revealed an early reduction of body sway. Being extremely sensitive, the stabilometric platform may prove an excellent tool in investigating defense-related postural responses and early attentional and motivational processes.

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Note

1. The SP-length analyses were rerun while controlling for weight and height. This yielded similar results for all analyses. Also, there were no significant differences in heart rate ($F(2, 98) = 1.07$, $p = .35$) or SP length ($F(2, 98) = .64$, $p = .53$) during the inter-stimulus black screen periods.

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