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Determinants of the shape of emotion intensity profiles

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BRIEF REPORT

Determinants of the shape of emotion intensity profiles

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It has been shown that variability in the shape of emotion intensity profiles can be described in terms of three functional features, namely steepness at onset, skewness and number of peaks. However, it remains unclear which factors account for variability in each of these features. In the present study participants were asked to report intensity profiles of positive and negative emotions on a daily basis. Information was further collected regarding potential determinants of the functional features of the intensity profiles at three levels: trait-, episode-, and moment-determinants. Regarding steepness at onset, it was found for positive and negative emotions that intensity profiles have an especially explosive start when the eliciting stimulus is important, when the stimulus is still present during the beginning of the episode, and, in case of positive emotions, when the participant is an extravert. Concerning skewness, it was found for positive and negative emotions that profiles reach their peak more often towards the end when the eliciting stimulus is important, when the stimulus is absent during the beginning of the episode but present towards the end, and, in case of negative emotions, when the stimulus is uncontrollable. Regarding the number of peaks, it was found that profiles more often have multiple peaks when the eliciting stimulus is absent during the middle of the emotional episode.

Keywords: Emotion intensity profiles; Determinants; Functional data analysis; Steepness at onset; Skewness; Number of peaks.

Emotions are processes that unfold over time. Consequently, a complete understanding of emotions and emotion characteristics can be reached only when their inherently dynamic nature is taken into account (Davidson, 1998; Hemenover, 2003; Schimmack, Oishi, Diener, & Suh, 2000; Verduyn, Van Mechelen, & Tuerlinckx, 2011).

A salient characteristic of emotions is their intensity. During an emotional episode intensity varies, resulting in an intensity profile over time. Such intensity profiles may take quite different forms and an important task for emotion research is to describe and explain this variability (Frijda, 2007). However, this is not too easy as intensity profiles may not only differ between different

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episodes of one specific emotion, but also between different emotions and between persons.

Remarkably, studies on intensity profiles are scarce. In most studies on intensity its dynamic nature has been ignored as intensity is typically assessed by overall time-independent measures (e.g., a single score on a Likert scale). This practice is troublesome as quite different intensity profiles may lead to the same overall intensity score. For example, two fear episodes may be rated similarly on a time-independent intensity scale but one (elicited, e.g., by seeing a spider) may have a steep onset followed by a gradual return to baseline while the other (elicited, e.g., by anticipating an exam) may only reach its highest intensity towards the end. In some studies (e.g., Hemenover, 2003; Sbarra, 2006) the dynamic nature of intensity has been taken into account by assessing intensity repeatedly over time (e.g., collecting a score on a Likert scale every hour). However, even though this methodology may provide insight into the dynamics of emotional intensity, the resulting intensity data typically reflect only an approximation of (a part of) the full intensity profile.

Only a few studies have addressed variability in full intensity profiles. These include studies by Sonnemans and Frijda (1994) and Verduyn, Van Mechelen, Tuerlinckx, Meers, and Van Coillie (2009). Sonnemans and Frijda (1994) were the first to perform an in-depth examination of intensity profiles. The authors found that intensity profiles displayed considerable variability in shape and described this variability in terms of a number of features including the number of peaks and dips, the intensity of the highest peak and the area underneath the profile. However, the features in question were selected in an ad hoc manner and their relative importance, in terms of how much of the total variance in profile variability they accounted for, was not clear.

Verduyn, Van Mechelen et al. (2009) tackled these limitations by inferring features directly from the intensity profile data. In particular, by conducting a functional principal component analysis (Ramsey & Silverman, 2005) on the profile shapes, they identified three features that together accounted for 84% of the variability in profile shapes: (i) *steepness at onset*, that is, some profiles are characterised by an explosive start whereas other ones are not; (ii) *skewness*, that is, some profiles are positively skewed (viz. they reach their peak at the start) whereas other profiles are negatively skewed (viz. they reach their peak towards the end); and (iii) *number of peaks*, that is, some profiles have only one peak whereas other profiles have several of them. These three features can be considered building blocks of intensity profiles that can be used to describe variability in profile shapes, as each intensity profile can be approximated by a weighted sum of them.

However, in order to understand variability in profile shapes one should not only examine which features most optimally describe this variability but also the factors that influence these features. In particular, one should identify the determinants of steepness at onset, skewness and number of peaks of intensity profiles. On a theoretical level, a variety of determinants can be thought of. As a whole, one could classify them in three groups: trait-, episode- and moment-determinants (Verduyn, Delvaux, Van Coillie, Tuerlinckx, & Van Mechelen, 2009).

Trait-determinants are stable both within and across intensity profiles. Two traits that have been found to be related to emotional intensity are neuroticism and extraversion. In particular, neuroticism is positively related to the intensity of negative emotions whereas extraversion is positively related to the intensity of positive emotions (e.g., DeNeve & Cooper, 1998; McCrae & Costa, 1991). Therefore, it can be expected that neuroticism and extraversion are related to building blocks of intensity profiles of negative and positive emotions, respectively. In particular, two specific hypotheses can be formulated at this point: First, neuroticism and extraversion could be positively related to steepness at onset as individuals high in neuroticism and extraversion have been shown to be especially reactive to negative and positive stimuli, respectively (Gross, Sutton, & Ketelaar, 1998; Larsen & Ketelaar, 1991). Second, neuroticism and extraversion could be positively related

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to negative skewness (i.e., intensity profiles that reach their peak towards the end): On the one hand, individuals high in neuroticism are less likely to regulate negative emotions than individuals low in neuroticism. On the other hand, individuals high in extraversion are more likely to savour their positive emotions than individuals low in extraversion (Ng & Diener, 2009; Suls & Martin, 2005).

Episode-determinants are stable within but not across intensity profiles. This class of determinants includes perceived characteristics of the eliciting event as reflected by appraisals. Sonnemans and Frijda (1995) found that primary appraisals (reflecting event importance) and secondary appraisals (reflecting event controllability) are among the strongest determinants of emotional intensity. Consequently, both types of appraisals are likely also determinants of the shape of intensity profiles. In particular, two specific hypotheses can be made: First, event importance could be positively related to steepness at onset as it has been shown that event importance is positively related to the initial intensity of emotions (Verduyn, Delvaux et al., 2009). Second, event controllability could be negatively related to negative skewness in the case of negative emotions as coping potential allows people to down-regulate their negative emotions (Lazarus & Folkman, 1984).

Moment-determinants are variable both within and across intensity profiles. Two moment-determinants that have been found to be related to emotional intensity are physical and mental reappearances of the emotion-eliciting event during an emotional episode. In particular, physical and mental reappearances of the elicitor are positively related to emotional intensity and may even lead to a reactivation of the emotion (Frijda, 2007; Sbarra & Emery, 2005; Verduyn, Delvaux et al., 2009). As a consequence, three specific hypotheses can be made regarding the relation between the presence of the eliciting event and the shape of intensity profiles: First, intensity profiles might have a steep onset if the eliciting event physically or mentally reappears during the beginning of the emotion episode. Second, intensity profiles might have an especially negatively skewed shape if the eliciting event reappears at the end of the episode whereas it remains absent during its beginning. Third, intensity profiles might show a temporary decline resulting in multiple peaks if the eliciting stimulus does not reappear during the middle of the episode.

The present study was conducted to test these hypotheses. Before doing so, we first wanted to replicate the finding of Verduyn, Van Mechelen et al. (2009) that steepness at onset, skewness and number of peaks are the main building blocks of intensity profiles. Subsequently, we wanted to examine the influence of the trait-determinants neuroticism and extraversion, the episode-determinants event importance and controllability, and the moment-determinants pertaining to physical and mental reappearances of the elicitor, on the building blocks of intensity profiles.

To meet these aims, intensity profiles of negative and positive emotions were collected by means of a daily diary methodology. This methodology was chosen to minimise memory distortions (Bolger, Davis, & Rafaeli, 2003) that may have affected previous retrospective studies on intensity profiles (Sonnemans & Frijda, 1994; Verduyn, Van Mechelen et al., 2009). In particular, participants were asked for a number of evenings to report on intensity profiles of two negative (anger and sadness) and two positive emotions (joy and gratitude) that they had experienced earlier that day. The set of emotions corresponds to the set used in an earlier study on intensity profiles (Verduyn, Van Mechelen et al., 2009) except that affection was replaced by gratitude, and therefore allows for a straightforward comparison of results.

METHOD

Participants

Participants were 188 University of Leuven students (26 men and 162 women). Course credit was given for participation. The mean age of the participants was 19 years ($SD = 1.9$).

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Materials and procedure

Participants were invited to the lab in groups of 20. They were informed that they were to take part in a study on emotional experience that would last five consecutive days. Moreover, they were told that this study would entail completing a questionnaire before going to bed on the emotions that they experienced earlier that day. To ensure that they would provide information regarding emotional episodes rather than moods, participants were asked to focus on experiences that were clearly elicited by specific internal or external events (Beedie, Terry, & Lane, 2005). Furthermore, to ascertain that all intensity profiles would end at an intensity level of zero, participants were asked to report only emotions that had already ended. The end was defined as the point in time at which the emotion was no longer felt for the first time; if the emotion was experienced again later on, participants were asked to consider this as a new episode (Verduyn, Delvaux et al., 2009; Verduyn et al., 2011). After these instructions, they were provided with the web address for the daily questionnaire.

The daily questionnaire was divided into four blocks, each block corresponding to a different emotional experience (anger, sadness, joy and gratitude). Block order was randomised for each participant on each day. In order not to overload participants, every evening they were only asked to provide information on two episodes in total (i.e., two episodes of the same emotion or one episode of two different emotions). If participants experienced more than two episodes of the same emotion, they were asked to provide information on the two most recent ones only. If participants experienced in total less than two episodes of the four target emotions, questions were asked about filler emotions until information regarding two episodes was provided (the data regarding these filler emotions will not be included in the present analysis). The specific questions that were asked on each experienced emotion will be explained below.

Episode duration. Participants first had to rate the duration of the episode. For this purpose they were asked to estimate the number of hours, minutes and/or seconds that the episode lasted.

Intensity profiles. Next, they were asked to draw as precisely as possible the course of the intensity of the emotion over time. For this purpose, a two-dimensional grid was presented. The *Y*-axis represented emotional intensity and was divided into seven intervals with labels ranging from "*No emotion*" to "*Very intense*". The *X*-axis represented the time dimension and ranged from zero to a number that corresponded to the answer given on the duration question.

Moment-determinants. Next, participants were asked to indicate whether and when the eliciting stimulus reappeared physically and mentally. For this purpose the intensity profile was divided into three equally spaced time intervals by superimposing two vertical lines on the drawn intensity profile. For each interval participants were first asked to indicate with yes/no whether the eliciting stimulus was physically present and, second, whether they had thought about the eliciting stimulus (i.e., mentally present).

Episode-determinants. Next, the intensity profile was removed from the screen and participants were asked to indicate on an 8-point scale the importance of the eliciting stimulus (0 = *Not important at all*, 7 = *Very important*), and the degree to which they could control it (0 = *No control at all*, 7 = *A lot of control*).

Trait-determinants. Information regarding neuroticism and extraversion was collected prior to the study in an unrelated study. Both traits were measured by the corresponding scales of the Dutch translation of the NEO-FFI (Hoekstra, Ormel, & De Fruyt, 1996).

RESULTS

Building blocks of intensity profiles

The intensity profiles were recorded with a resolution of 475 time points and such that the

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first time point always pertained to the beginning and the last one to the end point of the emotional episode (which implies that time was dealt with relative to total duration). Each set of points was transformed into a function by means of linear interpolation and, subsequently, again discretised into 150 equally distanced time points, which were used for the further analyses. Next, the data per time point were centred across all available profiles in order to remove the mean intensity profile from the data. Finally, the centred data were subjected to a functional (*T*-technique type) principal component analysis (FPCA; Ramsay & Silverman, 2005). Functional PCA decomposes data into component loadings and component scores. The component loadings take the form of component profiles over time and represent the functional features that describe the variability in the profile data. The component scores indicate to which extent each intensity profile is characterised by the functional features.

The appropriate number of components was determined by means of a scree plot. Based upon the elbow-criterion, a three-component solution was retained. This solution explained 87% of the profile variability.

In order to examine whether the same functional features were found as in the study by Verduyn, Van Mechelen et al. (2009), the component loadings were subjected to a Procrustes rotation (Lorenzo-Seva & Ten Berge, 2006) towards the solution of Verduyn, Van Mechelen et al. The similarity between both solutions was measured by means of Tucker's congruency coefficients. These were .96, .96 and .89 for the first, second, and third component, respectively. Consequently, the components can again be interpreted as steepness at onset, skewness and number of peaks.

This interpretation is further corroborated by a visual representation of the rotated component solution in Figure 1. In line with the suggestions of Ramsay and Silverman (2005), this figure displays reconstructed intensity profiles of emotional episodes scoring high (i.e., two standard deviations above the mean), average, and low (i.e., two standard deviations below the mean) on the component in question, while taking an average score on the other components. From this figure, it appears that a high component score on the first component corresponds to an intensity profile with a steep onset, whereas a low score corresponds to an intensity profile that is far less explosive (reflecting differences in steepness at onset). Episodes scoring high on the second component have relatively low intensity in the first half and an especially high intensity towards the end, while the reverse holds for the episodes scoring low on the component in question (reflecting differences in skewness). With regard to the third component, a high component score yields an intensity profile that contains two peaks, unlike a low score, which yields a profile with a

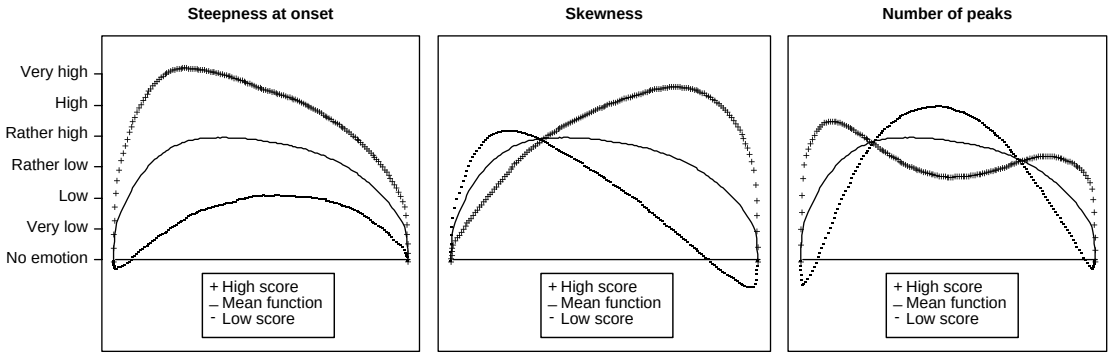

Figure 1. *Reconstructed intensity profiles scoring high, average, and low on the component in question while taking an average score on the other components.*

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single peak only (reflecting differences in the number of peaks).

Before examining the determinants of the three building blocks of intensity profiles, we explored possible differences between emotions in these building blocks. Regarding steepness at onset, joy was found to be more explosive than gratitude, $\chi^2(1) = 5.44$, $p < .05$, which, in turn, was more explosive than anger, $\chi^2(1) = 4.05$, $p < .05$, and sadness, $\chi^2(1) = 8.21$, $p < .01$. With regard to skewness, joy was found to be more negatively skewed than gratitude, $\chi^2(1) = 20.50$, $p < .001$, anger, $\chi^2(1) = 20.95$, $p < .001$, and sadness, $\chi^2(1) = 13.40$, $p < .001$. Regarding the number of peaks, anger was found to have fewer peaks than joy, $\chi^2(1) = 5.55$, $p < .05$, and gratitude, $\chi^2(1) = 5.15$, $p < .05$. All other pairwise comparisons were not significant ($ps > .05$).

Determinants of building blocks of intensity profiles

To identify determinants of the shape of intensity profiles, the component scores were subjected to a series of multilevel analyses in which the trait-, episode- and moment-determinants under study were entered as predictors. These analyses were conducted separately for positive and negative emotions as we expected that some determinants may differentially affect intensity profiles depending on the valence of the emotion in question. Finally, it should be noted that in all analyses we included a random intercept to capture dependencies due to each participant reporting multiple intensity profiles. The results of these multilevel analyses are shown in Table 1.

Steepness at onset. Regarding trait-determinants, evidence was found for the expected positive relation between extraversion and steepness at onset of positive emotions, whereas no support was found for the expected relation between neuroticism and steepness at onset of negative emotions. Concerning episode-determinants, we found a positive relation between event importance and steepness at onset for both positive and negative emotions, in line with our expectations. With regard to moment-determinants, the presence of the eliciting stimulus during the first time interval was, as expected, positively related to steepness at onset. In particular, for negative

Table 1. *Regression weights of determinants of steepness at onset, skewness and number of peaks for positive and negative emotions*

	Steepness at onset		*Skewness*		*Number of peaks*	
	Positive	*Negative*	*Positive*	*Negative*	*Positive*	*Negative*
Trait-determinants						
Neuroticism	.00	.00	−.01	.00	−.01	−.01
Extraversion	.02*	.01	.00	.01	.01	.01
Episode-determinants						
Importance	.15***	.12***	.06**	.12***	.03	−.04
Controllability	−.03	−.04	.02	−.09***	.01	−.01
Moment-determinants						
Physical presence						
Interval 1	.09	.31*	−.24**	−.34**	.15	.32*
Interval 2	.11	−.39**	.14	.41**	−.32***	−.43**
Interval 3	.00	−.10	.39***	.00	.25***	.29*
Mental presence						
Interval 1	.38***	−.01	−.40***	−.52***	.05	.25
Interval 2	−.11	.01	.13	−.03	−.28***	−.23
Interval 3	.02	−.02	.38***	.52***	.25***	.14

Note: *$p < .05$; **$p < .01$; ***$p < .001$.

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emotions it was found that intensity profiles have an especially explosive start when the eliciting stimulus is physically present whereas for positive emotions profiles have an especially steep onset when the stimulus is mentally present. Surprisingly, the physical presence of the eliciting stimulus during the second interval was negatively related to steepness at onset of negative emotions.

Skewness. Regarding trait-determinants, our hypotheses were not confirmed as not one of the relations in question was significant. Concerning episode-determinants, in line with our expectations we found that intensity profiles of negative emotions reach their peak towards the end (i.e., negative skewness) when respondents did not feel capable of controlling the event. Interestingly, for positive and negative emotions it was also found that intensity profiles were especially negatively skewed when the eliciting event was highly important. With regard to moment-determinants, our expectation that intensity profiles are negatively skewed when the eliciting event is present towards the end of the episode and not during the beginning was largely confirmed.

Number of peaks. We expected a negative relation between the presence of the eliciting stimulus during the middle of the profile and the number of peaks of a profile and this hypothesis was largely confirmed. Interestingly, physical and mental reappearances during the first and third interval were positively related to the number of peaks although these relations were significant in some cases only.

DISCUSSION

In the present study, we aimed to contribute to a deeper understanding of emotion dynamics by examining intensity profiles. The shape of intensity profiles was found to be highly variable. Moreover, replicating our earlier work (Verduyn, Van Mechelen et al., 2009), to a large extent this variability can be described in terms of three functional features, steepness at onset, skewness and number of peaks. This result also lines up with claims on emotion dynamics by other scholars: Davidson (1998) considered rise time, which is related to steepness at onset,[1] as a crucial parameter to describe variability in intensity profiles. For his part, Frijda (2007) stressed that profiles do not necessarily reach their peak towards the beginning but often become stronger over time, which reflects differences in profile skewness. Finally, Larsen (1987) found evidence for individual differences in the frequency with which emotions are (re)activated, which immediately relates to variability in the number of peaks.

For each feature, differences between emotions were found. The most notable finding was that intensity profiles of positive emotions (compared to negative ones): (i) are more often explosive; (ii) more often reach their peak towards the end; and (iii) more often contain multiple peaks. These differences could tentatively be related to a general tendency to up-regulate positive emotions.

Most importantly, we not only described variability in profile shapes but also partially explained it in terms of a number of trait-, episode-, and moment-determinants. Below, we will successively discuss the results for each of the three functional features.

Steepness at onset. This feature was related to each determinant type. Regarding trait-determinants, it was found that extraversion was positively related to steepness at onset for intensity profiles of positive emotions. This confirms previous research showing that extraverts are especially reactive to positive events (Gross et al., 1998). Surprisingly, however, neuroticism appeared to be unrelated to the steepness at onset of negative emotions. Concerning episode-determinants, highly important events were found to give rise to explosive profiles in case of both positive and negative emotions. This replicates earlier findings

[1] Whereas rise time reflects how long it takes before a given level of intensity is reached, steepness at onset pertains to the slope of the intensity profile at the start of the episode irrespective of a preset level of intensity.

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that event importance and initial emotional intensity are positively related (Verduyn et al., 2011). Furthermore, this finding could also be related to the adaptive function of emotions (Levenson, 1994) as it is functional for the organism to be fully activated from the very start when something important is at stake. With regard to moment predictors, for negative emotions it was found that profiles have an especially explosive start when the elicitor physically reappears during the beginning (e.g., in case of anger a physical reappearance of the antagonist may act as fuel that stirs up the emotional fire) whereas for positive emotions this is the case when the elicitor reappears mentally (e.g., in case of gratitude seeing the benefactor again may be less effective to up-regulate the emotion than bringing the moment at which the present was given back to mind).

Skewness. This feature was related to episode- and moment-determinants. Regarding episode-determinants, it was found that negative emotions are less negatively skewed when respondents feel capable of controlling the eliciting event. This makes sense as, in general, people can be expected to down-regulate negative emotions when feeling capable of doing so. Beside this expected relation, it was also found that for high-impact events, emotional intensity more often increases during the second half of the intensity profile (i.e., negative skewness) whereas this is less often the case for daily hassles. This may reflect the fact that high-impact events are typically associated with multiple consequences, some of which may only become apparent after some time. Concerning moment-determinants, our hypothesis that intensity profiles would be especially negatively skewed when the eliciting event was absent at the beginning and present towards the end was largely confirmed for both positive and negative emotions. This provides further evidence that reappearances of the eliciting stimulus are positively associated with emotional intensity regardless of whether this reappearance is physical or mental.

Number of peaks. When the eliciting stimulus is absent during the middle of the episode, the probability is relatively high that the profile will display several peaks, especially when the stimulus also reappears at the beginning or towards the end. In general, this confirms our expectation that mental or physical reappearances may reactivate an emotional episode.

Conclusion and future studies

This study examined changes in emotional intensity over time. Replicating our previous findings, we demonstrated that steepness at onset, skewness and number of peaks account for a large amount of variability in emotion intensity profiles. Moreover, we identified a number of significant determinants that underlie the three features of intensity profiles. In particular, aspects of both the emotion-eliciting stimulus and the emotion-experiencing person were found to play a major role in this regard. Emotion-eliciting stimuli are not merely static entities that precede the emotional episode. Instead, they may intermittently reappear during the episode and these dynamic aspects are equally important to consider when studying the shape of intensity profiles as their static counterparts (e.g., event importance). Similarly, both static (e.g., structural individual differences in emotion reactivity) and dynamic aspects (e.g., emotion regulatory behaviour) of the emotion-experiencing person should be taken into account to understand variability in profile shapes.

Even though the current study provides insights into the mechanisms underlying changes in emotional intensity over time, future studies are needed to deepen our understanding of them. First, the construct validity of the three features of intensity profiles needs to be further established. For this purpose, one may experimentally manipulate factors that are expected to influence the profile features and verify whether corresponding changes in the features occur. Second, to further our understanding of individual differences in intensity profiles the relation between affect-related traits (other than extraversion and neuroticism) and the features of intensity profiles could

be examined. This may also contribute to a better understanding of differences between normal and psychopathological affect dynamics. Finally, features of intensity profiles may also contribute to a more fine-grained understanding of the impact of emotion-regulation strategies on the subsequent time course of emotions.

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