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The interactive effect of neuroticism and extraversion on the daily variability of affective states

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ABSTRACT

The interaction between neuroticism and extraversion is thought to predict affective variability. In this study, neuroticism and extraversion were assessed with questionnaires, and affects were measured by experience sampling, with five daily assessments over 2 weeks. Affective variability was studied within a three-dimensional affective space whose three axes were oriented along the main affective dimensions: positive affect, negative affect, and activation. Quantile regression mixed-effects models allowed predicting zones in which affective states were most likely to occur according to personality. Beyond the well-known effect of personality on affect level, high neuroticism and/or high extraversion were accompanied by heightened affective variability. Results were interpreted as potentially reflecting positive feedback loops oriented toward negative affect for neuroticism, and toward positive affect and activation for extraversion.

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1. Introduction

Our affective experiences can be described as *dynamic*, in that they are constantly fluctuating. These fluctuations can be caused by a variety of factors, including the events we encounter, the cognitive and behavioral attempts we make to regulate our affect, and biological cyclical processes such as circadian mechanisms (Gross, 2015; Kuppens & Verduyn, 2015; Kuppens, Oravecz, & Tuerlinckx, 2010; Pavani, Le Vigouroux, Kop, Congard, & Dauvier, 2017; Pettersson, Boker, Watson, Clark, & Tellegen, 2013). The extent of these affective fluctuations, often referred to as *affective variability* and captured by the standard deviation of intra-individual affect intensity scores over time, has been shown to differ durably and reliably between individuals. Consequently, some researchers have argued that it can be regarded as a trait-like variable (Eid & Diener, 1999; Penner, Shiffman, Paty, & Fritzsche, 1994). As affective variability appears to contribute to certain key aspects of individuals' lives, including their health and wellbeing (for a review, see Houben, Van den Noortgate, & Kuppens, 2015), identifying its main predictors should be an important goal for psychology researchers.

Personality, especially the basic traits of neuroticism and extraversion, has long been hypothesized to be predictive of affective variability (Eysenck & Eysenck, 1985; Williams, 1990). A relationship between neuroticism, extraversion, and mean intensity levels of negative and positive affect has been robustly identified, with neuroticism being mainly related to the mean intensity level of negative affect, and extraversion to the mean intensity level of positive affect (e.g., Hepburn & Eysenck, 1989; Howarth & Zumbo, 1989; McCrae & Costa, 1991; Watson & Clark, 1992; Zautra, Affleck, Tennen, Reich, & Davis, 2005). However, evidence of a relationship between personality traits and affective variability seems more difficult to identify. Numerous conflicting findings have been yielded by studies attempting to reveal such a relationship, with the exception of the association between neuroticism and the variability of negative affect (Eaton & Funder, 2001; Eid & Diener, 1999; Hepburn & Eysenck, 1989; Kuppens, Allen & Sheeber, 2010; Kuppens, Van Mechelen, Nezlek, Dossche, & Timmermans, 2007; McConville & Cooper, 1999; Murray, Allen, & Trinder, 2002; Velting & Liebert, 1997; Williams, 1990, 1993). However, some theoretical accounts (e.g., Larsen & Augustine, 2008; Zautra et al., 2005) suggest that there is a robust relationship between neuroticism, extraversion, and affective variability.

The present study was designed to clarify this relationship. To this end, we analyzed how these two personality traits interact to predict the variability of affective experience. This interactive effect has rarely been subject to proper examination (Eid &

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Diener, 1999; McConville & Cooper, 1999). For example, some researchers have turned the continuous neuroticism and extraversion variables into categorical ones to analyze their interaction (Hepburn & Eysenck, 1989; Murray et al., 2002; Williams, 1990). In the present study, we kept neuroticism and extraversion as continuous variables when analyzing their interaction. Furthermore, in a departure from previous research, we chose to study affective variability within a three-dimensional affective space where the axes were oriented in the direction of the three main underlying dimensions of affective experience, namely positive affect, negative affect, and activation (Stanley & Meyer, 2009). Several prior studies had focused on a single overall dimension of affective variability (Eaton & Funder, 2001; McConville & Cooper, 1999; Murray et al., 2002; Velting & Liebert, 1997; Williams, 1993). Other studies had widened their focus to examine two dimensions of affective variability-either valence and activation variability (Kuppens et al., 2007, 2010) or positive activation and negative activation variability (Hepburn & Eysenck, 1989; Kuppens et al., 2007; Murray et al., 2002). Albeit less frequently, the variability of many discrete affective states had also been analyzed (Eid & Diener, 1999; Williams, 1990).

1.1. Affective state space

In the present study, following recent advances in the understanding of affective state space dimensionality (Larsen & Augustine, 2008; Stanley & Meyer, 2009; Yik, Russell, & Steiger, 2011), we decided to study affective variability in a space with three dimensions: positive affect, negative affect, and activation. Like Yik et al. (2011), we defined activation as a dimension ranging from sleepiness to arousal. However, contrary to these researchers, we divided their valence dimension into two unipolar dimensions, yielding a positive affect dimension ranging from absence of pleasure to pleasure, and a negative affect dimension ranging from absence of displeasure to displeasure[1]. This space is particularly suitable for studying the contribution of personality to affective experiences, as differences in traits such as extraversion and neuroticism can be associated with variations in any direction, defined by a combination of these three dimensions (Aldinger et al., 2014; Smillie, DeYoung, & Hall, 2015; Williams, 1990). Three dimensions were thus needed to study variability in high- and low-activation positive and negative affect, as well as individual differences in the within subject bivariate distribution of positive and negative affects (e.g., differences in their correlation). To plot affective states in this three-dimensional space and observe their dispersion, we had to orient the three axes, and the most natural choice was to use the classic dimensions of positive affect, negative affect and activation. From a mathematical point of view, this was a convenient choice, as any rotation of the three axes would represent the same reality from a different angle. Three coordinates are sufficient to locate the mean level for a given personality profile in a three-dimensional space, but defining the variability within such a space is more challenging, as six parameters are needed (as in a variance-covariance matrix) to take potential correlations into account. We therefore developed a three-dimensional variability modeling approach based on quantile regression that allowed us to study variability in virtually every direction within the affective state space and to plot the characteristic ellipsoid of variability for a given personality profile. We addressed this issue with data collected from nonclinical individuals using an experience sampling method (ESM).

[1] Thus, our positive affect and negative affect dimensions did not correspond to those proposed by Watson, Wiese, Vaidya, and Tellegen (1999), which represented combinations of valence and activation. When the positive and negative affect dimensions put forward by Watson et al. (1999) are mentioned in this article, they are labeled *positive activation* and *negative activation*.

1.2. A dynamic system model for guiding the study of interindividual differences in affective experience dynamics

Identifying the main aspects of affective dynamics that are subject to interindividual differences is a prerequisite for examining how personality contributes to these dynamics. The DynAffect model developed by Kuppens et al. (2010) provides an interesting framework in this context. Not only does this integrative model highlight the three key sources of interindividual differences in the dynamics of affective experiences, but it has also been tested experimentally.

The first source identified by this model is the *affective home base*. This refers to an equilibrium point that all individuals possess, around which their affective feelings fluctuate, and which is supposed to reflect their particular baseline affective level. It is thought to be relatively stable, only changing in the wake of critical life events (e.g., Jeronimus, Ormel, Aleman, Penninx, & Riese, 2013) or effortful practice (e.g., Lyubomirsky, Sheldon, & Schkade, 2005). This home base can be operationalized as a point located in a multidimensional affective state space.

The other two sources of interindividual differences in affective dynamics highlighted by the DynAffect model (Kuppens et al., 2010) concern affective variability (i.e. affective fluctuations around the home base). Specifically, the second source is the experience of affective perturbations. A myriad of internal or external events can cause affective states to be displaced away from the individual's home base, and these displacements appear to be greater in some individuals than in others (e.g., Larsen & Ketelaar, 1991; Oerlemans & Bakker, 2014). The third source is the *attractor strength* exerted by the home base. After moving away, affective states tend to return to the individual's home base, driven by regulatory mechanisms. This return to home base, whose opposite is usually labeled *affective inertia,* has again been shown to be greater among some individuals than others (e.g., Congard, Dauvier, Antoine, & Gilles, 2011; Koval et al., 2015; Kuppens, et al., 2010; Pavani et al., 2017; Suls, Green, & Hillis, 1998).

Before we discuss the possible relationships between affective variability and neuroticism and extraversion, we briefly describe the hypothetical processual underpinnings of interindividual differences in these traits. Although these underpinnings were not directly examined in the present study, they deserve a mention here, as they formed the basis for the hypotheses we formulated on the relationships between neuroticism, extraversion, and affective variability.

1.3. Processual underpinnings of interindividual differences in affective variability

Interindividual differences in affective variability may partly reflect how individuals differ in their affective reactivity (i.e., the intensity with which their affective experience changes in reaction to affect-eliciting events). For example, neurotic individuals are known to display more variable experiences of negative affect than their less neurotic counterparts (Hepburn & Eysenck, 1989; McConville & Cooper, 1999; Murray et al., 2002), and have also been shown to react to unpleasant events (e.g., failure or the imagination of unpleasant situations) with more intense feelings of negative affect than their less neurotic peers (e.g., Larsen & Ketelaar, 1989, 1991). Interestingly, regardless of its possible physiological (e.g., Everaerd, Klumpers, van Wingen, Tendolkar, & Fernández, 2015) and/or cognitive (e.g., Robinson, 2007) determinants, affective reactivity may be only part of a longer and more complex process involved in the movement of individuals' affective experience away from their home base. More specifically, several theoreticians have argued that changes in affect cause changes in cognition and behavior (e.g., Bower, 1981; Forgas, 1995; Fredrickson, 1998; Izard, 2007;

Russell, 2003). The more intense an individual's affective reactivity (i.e., changes in initial affective experience triggered by an event), the greater the subsequent affectively determined cognitive and behavioral changes are likely to be. Importantly, these cognitive and behavioral changes have, in turn, been hypothesized (Garland et al., 2010; Izard, 2007; Lewis, 2005; Philippot, 2011) and shown (Brans, Koval, Verduyn, Lim, & Kuppens, 2013; Houben et al., 2017; Moberly & Watkins, 2008; Pavani et al., 2017) to have a rapid retroactive effect on the initial affective changes. The greater these cognitive and behavioral changes, the greater their retroactive effect on affective experience is likely to be. The resulting reciprocal influences between affect, cognition, and behavior often take the form of *positive feedback loops* (Brans et al., 2013; Burns et al., 2008; Fredrickson & Joiner, 2002; Houben et al., 2017; Moberly & Watkins, 2008; Pavani et al., 2017) that intensify the initial affective changes. One clear example of this is the generation of a panic attack, in which cognitive (i.e., catastrophic misinterpretations of bodily sensations), affective (i.e., anxiety experience) and behavioral (i.e., hyperventilation) processes repetitively and rapidly reinforce each other, ultimately triggering a panic attack (Van den Hout, de Jong, Zandbergen, & Merckelbach, 1990). Several other intense affective states may be the result of these *self-perpetuating* affective loops (Garland et al., 2010), including the negative affect experienced in depression disorders (Bringmann, Lemmens, Huibers, Borsboom, & Tuerlinckx, 2015) and the positive affect experienced in mania (Johnson, Edge, Holmes, & Carver, 2012).

On the basis of this understanding of affective variability, as well as initial findings on this issue, we formulated hypotheses on how interindividual differences in affective variability may be related to interindividual differences in two broad personality traits: neuroticism and extraversion.

1.4. Neuroticism, extraversion, and affective variability

1.4.1. Neuroticism and affective variability

Neuroticism (or emotional instability) is mainly defined as a disposition to frequently and intensely experience a variety of negative affective states, including anxiety, sadness, anger, and shame (McCrae & Costa, 2005). Defined thus, the observation that neurotic individuals display a more negative affective home base than their more stable counterparts is hardly surprising (e.g., Aldinger et al., 2014; David, Green, Martin, & Suls, 1997; Eid & Diener, 1999; Hepburn & Eysenck, 1989; Howarth & Zumbo, 1989; McCrae & Costa, 1991; Rusting & Larsen, 1997; Watson & Clark, 1992; Williams, 1990). Some theorists attribute this to the stronger fundamental motivation to identify and avoid potential impending threats (i.e., the so-called behavioral inhibition system) that accompanies an increased level of neuroticism (Smits & De Boeck, 2006; Zelenski & Larsen, 1999; for a review, see Larsen & Augustine, 2008). Owing to interindividual differences in this basic motivational system that each person possesses, neurotic individuals appear to be more vigilant for punishment cues and negative stimuli in their environment, display more negative thoughts, inhibit their behaviors more to avoid potentially unpleasant events, and paradoxically encounter more such events than their more stable counterparts (David et al., 1997; Heller, Komar, & Lee, 2007; Latzman & Masuda, 2013; Magnus, Diener, Fujita, & Pavot, 1993; Rusting & Larsen, 1997, 1998; Tong, 2010; Williams, Matthews, & MacLeod, 1996; Zautra et al., 2005). Possibly because of this chronic mode of functioning, their affective home base is not only more negative than that of their more stable peers, but also less positive, albeit to a lesser extent (e.g., Aldinger et al., 2014; Eid & Diener, 1999; Williams, 1990; Zautra et al., 2005).

Neuroticism's roots in the basic motivational system described above are also thought to lead neurotic individuals to display more intense positive feedback loops of negative affect in reaction to unpleasant events than their more stable counterparts. This presumably manifests itself in more intense negative affective reactivity to these events (Larsen & Augustine, 2008; Smits & De Boeck, 2006; Zelenski & Larsen, 1999). For the above-mentioned reasons linking affective reactivity to affective variability, we postulated that a heightened level of neuroticism is associated with more variable experiences of negative affect. Three types of studies have already provided support for these hypotheses. The first type consists of laboratory studies in which negative affect experiences are experimentally induced (e.g., through false feedback or guided imagery). These have shown that experimental induction is more effective (i.e., produces more intense negative affect experiences) among neurotic individuals than among more stable individuals (Larsen & Ketelaar, 1989, 1991; Rusting & Larsen, 1997; Thake & Zelenski, 2013). The second type also focuses on affective reactivity, but as it naturally occurs in everyday life. Findings mirror the results obtained in the laboratory, suggesting that neurotic individuals feel more intense negative affect than their more stable counterparts in reaction to objectively unpleasant events or their appraisal (Bolger & Schilling, 1991; Bolger & Zuckerman, 1995; Mroczek & Almeida, 2004; Tong, 2010; Zautra et al., 2005). The third type is also concerned with what occurs in everyday life, but affective variability is directly measured, via the usual standard deviation of intra-individual affect scores over time. The results yielded by this third type of study are consistent with the findings of the first two. Specifically, their results converge to suggest that a heightened level of neuroticism is accompanied by more variable negative affect experiences (Eid & Diener, 1999; Hepburn & Eysenck, 1989; McConville & Cooper, 1999; Murray et al., 2002; Williams, 1990).

Other theoretical arguments suggest that neurotic individuals also display more variable positive affect experiences than their more stable peers. Specifically, it has been argued and empirically suggested that an unpleasant event temporarily increases the negative coupling (i.e., correlation) between negative and positive affect experiences (Zautra et al., 2005). Given that neurotic individuals frequently encounter such events (David et al., 1997; Heller et al., 2007; Magnus et al., 1993; Zautra et al., 2005), their positive affect feelings may covary with their negative affect experiences. As the latter appear to be more variable than those of their more stable counterparts, neurotic individuals may also have more variable positive affect experiences. This hypothesis has received only modest support, with some studies suggesting that a heightened level of neuroticism is accompanied by more variable positive affect experiences (Eid & Diener, 1999; Murray et al., 2002; Williams, 1990), and others sreporting no relationship between neuroticism and positive affect variability (Hepburn & Eysenck, 1989; McConville & Cooper, 1999). However, it is noteworthy that most of these studies examined high-activation positive affect, whereas our hypothesis concerned positive affect in general. We also hypothesized on theoretical grounds that a heightened level of neuroticism is associated with more variable activation. As in the case of panic attacks, the occurrence of positive feedback loops in highly activated states (e.g., anxiety) may be followed by deactivated resting states (Van den Hout et al., 1990).

In summary, theoretical arguments and initial empirical findings led us to hypothesize that, compared with their more stable counterparts, neurotic individuals display a more negative and less positive affective home base, as well as more variable activation, negative, and positive affective experiences.

1.4.2. Extraversion and affective variability

Extraversion is the second personality trait that has been found to contribute to aspects of affective dynamics. Extraversion encompasses many specific facets, including sociability, gregariousness, assertiveness, engagement in activity, sensation seeking and susceptibility to positive affect (McCrae & Costa, 2005). In other

words, extraverted individuals appreciate social activities more, and behave more assertively in such situations, than their more introverted counterparts. Furthermore, compared with introverted individuals, they engage more in a variety of activities, especially those that trigger activated and pleasant feelings.

The relationship between this trait and individuals' affective home base is well documented. Extraverted individuals have more intense mean experiences of positive affect, especially activated positive affect, than their more introverted peers (David et al., 1997; Eid & Diener, 1999; Hepburn & Eysenck, 1989; Howarth & Zumbo, 1989; McCrae & Costa, 1991; Smillie et al., 2015; Watson & Clark, 1992; Williams, 1990; Zautra et al., 2005). Like neuroticism, extraversion is thought to be rooted in a fundamental motivational system (i.e., behavioral activation system). This system is responsible for identifying and pursuing potentially pleasant stimuli, especially rewards (Smits & De Boeck, 2006; Zelenski & Larsen, 1999; for a review, see Larsen & Augustine, 2008). Interindividual differences in this system are assumed to explain why, compared with their introverted counterparts, extraverted individuals are more disposed to encounter objectively pleasant events, display more positive thoughts, and behave more frequently in a fashion that triggers pleasant feelings (Heller et al., 2007; Magnus et al., 1993; Rusting & Larsen, 1997, 1998; Zautra et al., 2005). These chronic differences in functioning between extraverts and introverts are behind the differences observed in individuals' affective home base in terms of positive affect and activation.

The relationship between this trait and affective variability is not yet clearly understood. Some theoretical arguments suggest that a heightened level of extraversion is associated with more variable positive affect experiences. Specifically, extraversion could be related to affective variability via its purported roots in the basic motivational system responsible for the identification and pursuit of pleasant stimuli. Owing to the heightened sensitivity of this basic motivational system among extraverted individuals, the latter presumably experience more intense positive feedback loops of positive affect in reaction to pleasant events, especially rewarding situations, than their more introverted peers, leading them to react to such events with more intense positive affect feelings (Larsen & Augustine, 2008; Smits & De Boeck, 2006; Zelenski & Larsen, 1999). Like the hypothesis on the relationship between neuroticism and negative affect reactivity, this hypothesis has already been supported by several studies (Larsen & Ketelaar, 1989, 1991; Rusting & Larsen, 1997; Smillie, Cooper, Wilt, & Revelle, 2012; Smillie, Geaney, Wilt, Cooper, & Revelle, 2013), including more ecologically valid intensive longitudinal studies (Oerlemans & Bakker, 2014). As might be expected, results indicate that extraverted individuals react to rewarding situations with more intense positive affect in general, or more intense activated positive affect, than introverted individuals. By contrast, studies directly examining affective variability via the usual standard deviation of affective scores have not generally supported the hypothesis that extraverts' positive affect experiences are more variable than those of introverts. Only Hepburn and Eysenck (1989)'s study yielded findings consistent with this hypothesis, with other studies failing to find a relationship between extraversion and the variability of positive affect (Eid & Diener, 1999; McConville & Cooper, 1999; Murray et al., 2002; Williams, 1990).

In summary, theoretical arguments and initial empirical findings led us to hypothesize that, compared with their more introverted counterparts, extraverted individuals have a more positive and activated affective home base, as well as more variable positive and activation experiences.

1.4.3. Interaction between extraversion and neuroticism and affective dynamics

Eysenck and Eysenck (1985) were among the first authors to consider how neuroticism and extraversion might combine and interact to predict certain aspects of affective dynamics. On the basis of their observation that neuroticism is associated with affective fluctuations ranging from neutral to negative, whereas extraversion is associated with affective fluctuations ranging from neutral to positive, they formulated the following hypotheses.

Individuals scoring high on neuroticism but low on extraversion (i.e., neurotic introverts; NIs) are characterized by affective fluctuations ranging only from neutral to negative. In other words, their negative affect experiences are highly variable, in contrast to their positive affect experiences. According to Eysenck and Eysenck (1985), NIs' affective home base is therefore close to the negative pole of a single bipolar dimension extending from negative to positive with a neutral midpoint. Conversely, individuals scoring low on neuroticism but high on extraversion (i.e., stable extraverts; SEs) are characterized by affective fluctuations ranging only from neutral to positive. Their positive affect experiences are thus highly variable, but not their negative affect feelings, leading SEs to have a positive affective home base. Individuals scoring high on both neuroticism and extraversion (i.e., neurotic extraverts; NEs) are characterized by wide affective fluctuations ranging from negative to positive. Their positive and negative affect experiences are both very variable, leading NEs to have a neutral affective home base. Finally, individuals scoring low on both neuroticism and extraversion (stable introverts; SIs) also have a neutral affective home base, not because their affective experiences fluctuate widely from negative to positive, as with NEs, but because these experiences undergo only small fluctuations.

Albeit interesting, shortly after their formulation, these hypotheses were questioned on theoretical grounds (e.g., Williams, 1990, 1993). In particular, critics doubted whether positive affect and negative affect variabilities are so symmetrical that they can be summed to yield a single indicator of affective variability. A similar criticism concerned the validity of locating individuals' affective home base on a single dimension (i.e., valence). The concept of a *neutral midpoint* has also been questioned (e.g., Williams, 1993), as it is unclear whether this neutral midpoint refers to the individuals' mean valence level, or a specific affective state consisting of nonvalenced feelings. These unanswered questions and uncertainties made it difficult to precisely test Eysenck and Eysenck (1985)'s hypotheses. Nevertheless, their pioneering work on this issue laid the foundations for future investigations.

On the basis of the theoretical arguments and empirical findings on the relationship between neuroticism, extraversion, and the variability of positive affect, negative affect and activation set out above, we formulated four hypotheses in the present study. First, we hypothesized that SIs are the least variable individuals. The variability of their positive affect, negative affect, and activation experiences is low. Second, SEs display more variable positive affect and activation experiences. In addition to the more positive affective home base that accompanies extraversion, this variability may lead SEs to differ from other individuals, insofar as their affective experiences are more frequently characterized by very high positive affect and activation. It is also conceivable that SEs have slightly more variable negative affect experiences than SIs, as certain findings suggest that extraverted individuals engage more in risky activities than introverted individuals and suffer the consequences (Nettle, 2005). Third, starting from the same point of comparison, we also hypothesized that, relative to SIs, NIs display much more variable negative affect experiences, as well as more variable activation experiences. When combined with the disposition to experience deactivated affect that characterizes introversion, this heightened variability in negative affect and activation feelings may lead NIs to differ from other individuals, insofar as their affective feelings are more frequently characterized by both low activation and intense negativity. Moreover, owing to the increased coupling between negative affect and positive affect that is sup-

posed to accompany a heightened level of neuroticism, NIs presumably have more variable positive affect experiences than SIs. Fourth and last, we hypothesized that NEs are the most variable individuals, as their positive affect, negative affect, and activation experiences exhibit considerable variability. NEs differ from NIs mainly in the variability of their positive affect feelings. Owing to the effect of extraversion, the positive affect experienced by NEs may be more variable than that experienced by NIs. When combined with the disposition to experience activated affect that characterizes extraversion, the affective variability profile of NEs may cause them to differ from other individuals, insofar as their affective experiences are more frequently characterized by both activation and negative affect. Furthermore, owing to their increased likelihood not only of encountering more unpleasant events in general (related to their neuroticism) but also of engaging in risky activities (related to their extraversion), NEs may be the individuals who most frequently encounter unpleasant events. Consequently, their positive and negative affect experiences may frequently be closely coupled, influencing their affective home base. Specifically, although a heightened level of extraversion is generally related to a more positive affective home base, this is less likely to be the case when it is combined with a high level of neuroticism, a trait characterized by a strong relationship with negative affect experiences, as well as a close coupling of positive and negative affect. NEs may even have an affective home base whose low position on the PA dimension is symmetrical to its high position on the NA dimension.

1.5. The present study

The primary purpose of this study was to understand more fully how personality is related to affective variability. To this end, we attempted to show how neuroticism, extraversion, and the interaction between the two predict the location of the affective home base and the variability of the affective states experienced by individuals in the course of their daily lives. We believed that the original data analysis strategy we used would provide a more accurate and finely tuned understanding of these effects. First, we set out to analyze the relationship between neuroticism, extraversion, and the variability of affective experience in every direction within a three-dimensional affective space whose axes correspond to the usual three dimensions: positive affect, negative affect, and activation. To the best of our knowledge, this had never before been attempted. Second, we analyzed the interaction between neuroticism and extraversion without transforming these continuous variables into categorical ones-a strategy that has not always been adopted (Hepburn & Eysenck, 1989; Murray et al., 2002; Williams, 1990). Third, we used a measure of affective variability based on quantile regression models (Koenker & Bassett, 1978) that is supposed to address the limitations of the usual standard deviation of intra-individual scores over time. Using the latter to capture the general movement of affective experience away from the home base is a questionable method, as the distribution of affects is known to be asymmetrical, especially for negative affect. By computing extreme quantiles (e.g., 95th) using quantile regression models, we hoped to take better account of these asymmetries. Moreover, computing extreme quantiles in every direction within the affective state space using quantile regression with mixed models allowed us to delimit zones of affective variation for each personality profile within a three-dimensional variability ellipsoid that also provided the main direction of the variability. Our analyses were performed on data collected using an ESM (Hektner, Schmidt, & Csikszentmihalyi, 2006) that involved five daily assessments over a 2-week period. Because there were such short intervals between the assessments, we were able to capture the short-term dynamics of affective experience. Our hypotheses are summarized in Table 1.

Table 1
Hypotheses formulated in the present study.

Profile	Direction of positive feedback loop	Variability	Home base
SI	None	Low in all directions	Moderate positive affect Low negative affect
SE	Activated positive affect	High for positive affect and activation	High positive affect Low negative affect
NI	Deactivated negative affect	High for negative affect	Moderate positive affect High negative affect
NE	Activated negative affect	High for negative affect and activation	Moderate positive affect High negative affect

Note. SI = stable introvert; SE = stable extravert; NI = neurotic introvert; NE = neurotic extravert.

2. Method

2.1. Participants

The sample consisted of 191 nonclinical individuals (64% female), aged 13–80 years (M = 38.5, SD = 17.4). Participants were recruited from the experimenters' social networks, and came from various regions of France. Potential participants were not retained if they exhibited alexithymia, as measured by the French version of the Bermond–Vorst Alexithymia Questionnaire-20 (Vorst & Bermond, 2001), validated in French by Zech, Luminet, Rimé, and Wagner (1999).

2.2. Procedure

An initial interview was conducted with each participant, either face to face or over the phone, depending on his or her preference. During this interview, after obtaining informed consent and basic sociodemographic information, the experimenter and participant collaboratively fixed the times at which the daily assessments would take place throughout the experience sampling period. The experimenter proposed five consecutive assessments 3 h apart over the course of the day (typically 9 am, 12 pm, 3 pm, 6 pm and 9 pm), but each of these initial propositions could be changed by up to 15 min, according to the participant's schedule (e.g., 8.45 am, 12.15 pm, etc.). More importantly, this interview served to determine the wording of the items on which each participant would be assessed. To take account of the substantial interindividual differences in labeling affective experience, the experimenter followed a strategy based on Nesselroade, Gerstorf, Hardy, and Ram (2007)'s study. More specifically, for each of the 12 affects analyzed in the present study, the experimenter read out a list of statements describing this affect to each of the participants, before asking them to provide the adjective that best summarized it in their opinion (e.g., *enthusiastic*, *angry*, *serene*). Participants were then asked to express the meaning they assigned to each of the 12 items (i.e., adjectives) they had provided, to avoid any misunderstanding. Each participant was given a card on which these 12 items were printed, enabling them to respond to the assessments throughout the whole experience sampling phase.

Next, each participant was invited to complete questionnaires on the Internet (including one that measured their levels of extraversion and neuroticism) a week before the beginning of the experience sampling phase. The latter lasted 14 consecutive days. Five times a day, participants received a text message on their personal mobile phone, sent by a web server. They were asked to respond to each message within 30 min, to ensure that the assessments were neither too close nor too far apart. On each occasion,

participants were assessed on their current affective experience through the set of adjectives printed on their card. On average, participants responded to 86% of the 70 text messages they were sent during the experience sampling phase.

2.3. Materials

2.3.1. Affective experiences

We assessed the affective experience of our participants with the 12 types of affect featured in the 12-point affect circumplex model (Yik et al., 2011). This model distinguishes between five types of positive affect: *pleasant deactivation* (e.g., *tranquil*), *deactivated pleasure* (e.g., *serene*), *pleasure* (e.g., *satisfied*), *activated pleasure* (e.g., *enthusiastic*), and *pleasant activation* (e.g., *excited*). These mainly differ from each other on activation level: very low activation, low activation, activation that is neither low nor high, high activation, and very high activation. In a similar manner, this model distinguishes between five types of negative affect: *unpleasant deactivation* (e.g., *tired*), *deactivated displeasure* (e.g., *sad*), *displeasure* (e.g., *unhappy*), *activated displeasure* (e.g., *upset*), and *unpleasant activation* (e.g., *frenzied*). Finally, it also contains two neutrally valenced affects, one with very high activation (*activation;* e.g., *aroused*), and one with very low activation (*deactivation*; e.g., *still*). On each assessment occasion, participants were asked to rate the intensity with which they currently felt each type of affect, on a Likert scale ranging from 1 (*Not at all*) to 5 (*A lot*).

2.3.2. Neuroticism and extraversion

We assessed neuroticism and extraversion with two 60-item subscales of a French translation of the 300-item version of the International Personality Item Pool (IPIP; Goldberg, 1999). Participants were asked to indicate the extent to which they agreed with each item on a Likert scale ranging from 1 (*Not at all*) to 5 (*A lot*). We chose the IPIP because it is based on the most consensual approach to personality in psychology research, namely the Five-Factor model. Accordingly, this questionnaire assesses neuroticism with items probing six lower order facets (i.e., anxiety, depression, anger, vulnerability to stress, social shyness, and impulsivity), and extraversion with items probing six other lower order facets (i.e., activity, assertiveness, warmth, gregariousness, positive emotions, and excitement seeking). It has good internal consistency (Cronbach's $\alpha = 0.79$ for neuroticism and 0.85 for extraversion).

3. Results

Descriptive statistics for the 12 types of affect, neuroticism, and extraversion are set out in Table 2. The types of PA we studied had higher means and standard deviations than the types of NA. Not only did deactivated displeasure and its near neighbors have the lowest means and standard deviations, but their distribution was also positively skewed, owing to a floor effect.

3.1. Affective state space

We began by attempting to reduce the number of observed affect-related variables we had to examine, and thus to define the affective state space retained for our analyses. We assumed that a space with three dimensions would capture most of the variance in affective experience and that the axes of this space could be oriented along the usual dimensions: positive affect (PA), negative affect (NA) and activation (ACT). To this end, we performed a principal component analysis (PCA) on all the data collected during the experience sampling period for the 12 types of affect. At this stage of the approach, PCA was used solely as a technique for reducing the 12-dimensional initial response space to a more manageable three-dimensional affective state space, and not to identify potential psychological dimensions. The coordinates of the points in this space were the projections (i.e., factor scores) of the responses to the initial 12 items on the first three components of the PCA.

As expected, this PCA yielded three components with an eigenvalue greater than 1, explaining 64% of the total variance. This result was supported by the scree plot, whose typical downward curve leveled off after the third component. Visual inspection of the projections of the loadings of the 12 items on these three components placed side by side revealed that the items were approximately arranged in circle, consistent with the circumplex model on which our measures of affective experience were based (Yik et al., 2011). Given this circular configuration, common rotation techniques (e.g., varimax) would not necessarily lead to the expected orientation. We therefore decided to implement an ad hoc rotation strategy to orient the three axes according to PA, NA and ACT as precisely as possible. This ad hoc rotation strategy consisted in optimizing the angles of a three-dimensional rotation matrix applied to the factor scores in order to orient the affective state space in such a way as to jointly maximize (1) the correlation between the *pleasure* item and the first axis (PA), (2) the correlation between *displeasure* and the second axis (NA), and (3) the correlation between *activation* (and the opposite of *deactivation*) and the third axis (ACT), using the optim() function in R (R Core Team, 2018). As the purpose of orienting the axes was not to reflect a latent variable framework, but instead to provide a simpler and easier way of understanding the representation of affective variability within a subspace of the initial 12-dimensional response

Table 2
Descriptive statistics for each item: loadings on the three rotated components of the principal component analysis, and correlations with extraversion and neuroticism.

	Affect/personality	Mean (*SD*)	Skewness	PA	NA	ACT
1	*Pleasant activation*	3.01 (1.15)	0.00	0.63	−0.18	0.54
2	*Activated pleasure*	2.98 (1.17)	−0.07	0.75	−0.20	0.34
3	*Pleasure*	3.23 (1.11)	−0.22	0.81	−0.28	0.12
4	*Deactivated pleasure*	3.14 (1.19)	−0.15	0.76	−0.14	−0.24
5	*Pleasant deactivation*	3.17 (1.22)	−0.21	0.73	−0.16	−0.34
6	*Deactivation*	2.14 (1.24)	0.77	−0.10	0.45	−0.56
7	*Unpleasant deactivation*	1.62 (1.01)	1.62	−0.48	0.69	−0.19
8	*Deactivated displeasure*	1.48 (0.89)	1.99	−0.55	0.77	0.15
9	*Displeasure*	1.63 (0.99)	1.62	−0.52	0.73	0.19
10	*Activated displeasure*	1.67 (1.02)	1.50	−0.54	0.71	0.34
11	*Unpleasant activation*	1.71 (1.04)	1.44	−0.48	0.69	0.39
12	*Activation*	2.11 (1.22)	0.78	0.31	0.15	0.64
	Extraversion	3.27 (0.42)	−0.03	0.18*	0.00	0.07
	Neuroticism	2.73 (0.47)	0.09	−0.37*	0.37*	0.08

Note. NA = negative affect; PA = positive affect; ACT = activation.
* $p < .05$.

space, we believed that an orthogonal rotation was more appropriate, as it preserved the geometry of the point cloud.

The loadings on the rotated components (see Table 2) enabled us to identify the first component as a broad PA dimension, as it was oriented toward the five low- to high-arousal positive affect experiences (from *pleasant activation* to *pleasant deactivation*). The second component appeared to reflect a broad NA dimension, as it was closely related to the five types of negative affect we examined. Finally, the third component emerged mainly as an activation dimension, as it was associated with *activation* and *deactivation*, even if it was slightly oriented toward high-arousal positive affect (*pleasant activation*). When component scores reflecting individuals' responses to affective items were simultaneously projected onto the PA and NA axes, the resulting scatterplot took the form of a right-angled triangle, as shown in Fig. 1. This triangular point cloud indicated that participants' daily affective experiences mostly varied between states marked by an absence of PA and NA feelings (lower lefthand corner), intense feelings of PA and an absence of NA feelings (lower righthand corner), and an absence of PA feelings and intense NA feelings (upper lefthand corner). By contrast, individuals rarely felt intense PA and NA at the same time (upper righthand corner).

To ease the graphical interpretation of the component scores, we plotted the extreme responses to a few representative items in the scatterplot shown in Fig. 1. This was done by computing the mean component scores of all the responses for a given measurement point that contained an extreme value for a given item (e.g., all the responses where *displeasure* was rated 5). The triangular shape of PA and NA could be interpreted as an asymmetrical negative relation. The negative correlation was not perfect, as there was a high likelihood of experiencing neither PA nor NA, as shown by the high density of responses in the lower lefthand corner. By contrast, although participants were most unlikely to simultaneously experience maximum levels of PA and NA, some moderate-to-high (>3) response profiles did emerge for both positive and negative items, lying along the diagonal of the scatterplot. In order to distinguish the state of low PA and low NA from the state of moderately high PA and NA, and to observe individual differences in the PA-NA correlation, we had to use two components for PA and NA, plus a third one for ACT. The top righthand and bottom panels of Fig. 1 show the scatterplots linking ACT to NA and PA. The extreme response projections indicated that *deactivation* was weakly associated with *displeasure* in the ACT-NA plot, whereas highly activated states were relatively positive in the ACT-PA plot.

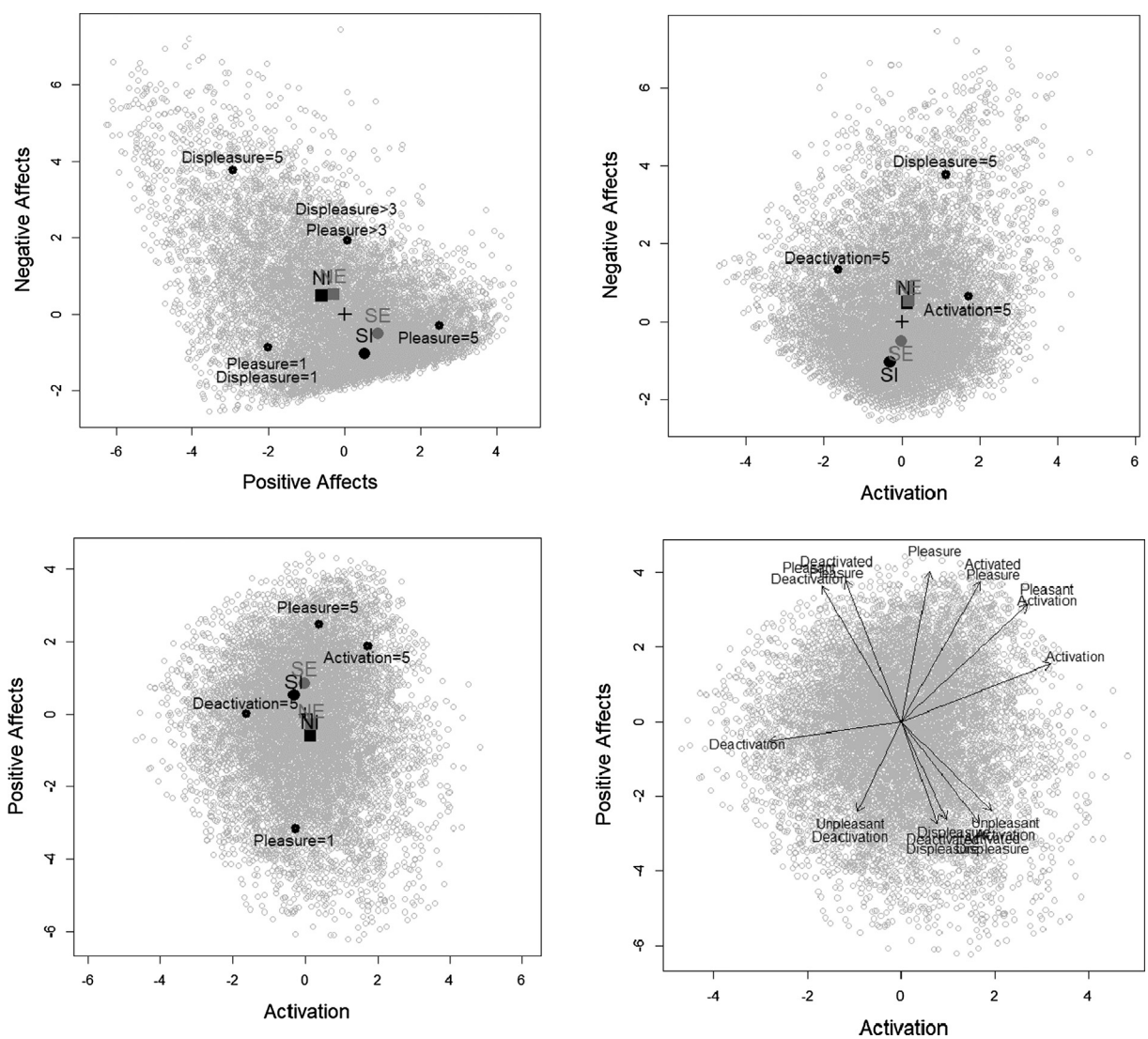

Fig. 1. Response projections in the three-dimensional affective state space with representative points, item loadings and home base position for the four personality profiles. SI = stable introvert; SE = stable extravert; NI = neurotic introvert; NE = neurotic extravert.

Table 3
Representative values of the ellipses in Fig. 3 for the four personality profiles and 12 affects.

	5th percentile – Median – 95th percentile – (Interval)			
	NEs	NIs	SEs	SIs
PA	−3.23 −0.41 1.92 (5.15)	−3.15 −0.57 1.54 (4.69)	−1.93 0.81 2.77 (4.7)	−1.61 0.47 2.08 (3.69)
NA	−0.93 0.52 3.19 (4.12)	−1 0.28 2.43 (3.43)	−1.32 −0.56 1.22 (2.54)	−1.56 −0.9 0.97 (2.53)
ACT	−1.8 0.27 2.22 (4.02)	−1.7 0.22 1.94 (3.64)	−1.98 0.05 1.95 (3.93)	−1.33 −0.11 1.41 (2.74)
*Pleasant activation**	−2.55 −0.18 1.79 (4.34)	−2.37 −0.18 1.52 (3.89)	−1.91 0.53 2.46 (4.37)	−1.22 0.44 1.61 (2.83)
*Activated pleasure***	−2.94 −0.3 1.84 (4.78)	−2.68 −0.32 1.51 (4.19)	−1.93 0.66 2.69 (4.62)	−1.32 0.56 1.85 (3.17)
*Pleasure***	−3.37 −0.41 1.85 (5.22)	−3.02 −0.44 1.53 (4.55)	−1.94 0.78 2.82 (4.76)	−1.43 0.68 2.04 (3.47)
*Deactivated pleasure**	−3.65 −0.48 1.92 (5.57)	−3.32 −0.56 1.59 (4.91)	−2.00 0.88 2.96 (4.96)	−1.57 0.69 2.22 (3.79)
*Pleasant deactivation**	−3.77 −0.51 1.92 (5.69)	−3.43 −0.6 1.59 (5.02)	−2.02 0.92 2.93 (4.95)	−1.61 0.72 2.26 (3.87)
*Deactivation**	−1.41 0.1 2.07 (3.48)	−1.55 −0.09 1.71 (3.26)	−1.51 −0.12 1.54 (3.05)	−1.33 −0.38 0.92 (2.25)
*Unpleasant deactivation***	−1.37 0.49 3.54 (4.91)	−1.32 0.37 2.89 (4.21)	−2.06 −0.77 1.68 (3.74)	−1.79 −0.92 1.2 (2.99)
*Deactivated displeasure***	−1.45 0.61 4.04 (5.49)	−1.34 0.51 3.35 (4.69)	−2.16 −0.92 1.76 (3.92)	−1.98 −1.04 1.4 (3.38)
*Displeasure***	−1.46 0.63 4.08 (5.54)	−1.33 0.52 3.4 (4.73)	−2.17 −0.93 1.78 (3.95)	−1.99 −1.05 1.42 (3.41)
*Activated displeasure**	−1.53 0.66 4.2 (5.73)	−1.36 0.56 3.53 (4.89)	−2.25 −0.98 1.85 (4.1)	−2.06 −1.05 1.5 (3.56)
*Unpleasant activation**	−1.51 0.67 4.21 (5.72)	−1.33 0.57 3.53 (4.86)	−2.15 −0.98 1.84 (3.99)	−2.04 −1.06 1.52 (3.56)
*Activation**	−1.78 0.23 2.15 (3.93)	−1.74 0.16 1.84 (3.58)	−1.97 0.12 2.02 (3.99)	−1.32 −0.07 1.4 (2.72)

Note. The asterisks indicate whether the interaction between extraversion and neuroticism improved the model's goodness of fit for each item orientation in terms of the AIC only (*) or both the AIC and the BIC (**). SIs = stable introverts; SEs = stable extraverts; NIs = neurotic introverts; NEs = neurotic extraverts.

The fourth plot in Fig. 1 illustrates the fact that each item had an orientation defined by its loadings within the affective space, thus making it possible to estimate the position of the home base and the range of variability according to the orientation of each item.

3.2. Affective home base and variability estimation using quantile regression based on linear mixed models

Affect variability can be visualized as the zone within the affective space in which affective states are more likely to occur for a given individual, while the home base can be visualized as the center of this zone. Accordingly, an individual's median affective state distribution can be used as an indicator of the home base's location, and the interval between the two extreme quantiles (i.e., 5th and 95th) as an indicator of variability. The quantile regression approach (Koenker & Bassett, 1978) provides a means of estimating the quantiles and median of a distribution as a function of predictor variables, within a multiple regression framework. It involves estimating the quantiles of the conditional distribution of the response variable given the predictor. In the multilevel context, when the predictor (e.g., personality trait) does not vary within an individual, a simple approach is possible. The idea is to use the ranks of an individual's scores to predict his or her actual scores. We applied this approach to our repeated-measures dataset using linear mixed-effects models that contained interactions between the individual's ranks and the between-participants predictor. A nonlinear transformation of the ranks (logit and polynomial) was necessary to fit the asymmetrical distributions of affects. Predictions from these models were used as estimators of the quantiles of individual distributions as a function of personality.

To estimate these quantiles in a three-dimensional framework, we began by constructing a new variable that depended on the chosen orientation within the three-dimensional affective space for which we wanted to estimate the location of the home base and the range of variability. This orientation could be that of one of the three axes, that of one of the 12 items, or any other direction. The new variable corresponded to the intra-individual rank, expressed as a percentile, of each participant's score projected onto a line aligned with the chosen orientation. For example, regarding the intra-individual rank indicator along the PA axis, the highest score of each participant on PA was scored 1, the median score was scored 0.5, and the lowest score was scored 0. These rank indicators were then logit transformed, so that they followed a more normal distribution. Finally, rank indicators were included as a predictive variable in interaction with extraversion and neuroticism in linear mixed-effects models, with the initial coordinates of each point as the response variable. The values predicted by these models enabled us to estimate, for any given level of extraversion and neuroticism, the expected location of the median and the 5th and 95th percentiles in any direction, and thus to determine the location of the home base and the limits of the affective variability zone in the three-dimensional affective state space for SIs, SEs, Nis, and NEs. To compute the ellipses in Fig. 3, we repeated the process for 90 rotations in four-degree increments around one axis-resulting in the estimation of 45 models-for each two-dimensional plane.

As mentioned above, the coordinates of the home base and the variability zone were computed for each of the four personality profiles (SI, SE, NI, NE). Results for the three main axes and 12 items are set out in Table 3 and represented in Figs. 2 and 3. Computing these predictions from a linear mixed-effects model meant we did not have to turn our continuous personality variables into categorical ones, as had been done in previous studies (Hepburn & Eysenck, 1989; Murray et al., 2002; Williams, 1990). Benchmark values were set at 1.6 standard deviations from the mean for SEs

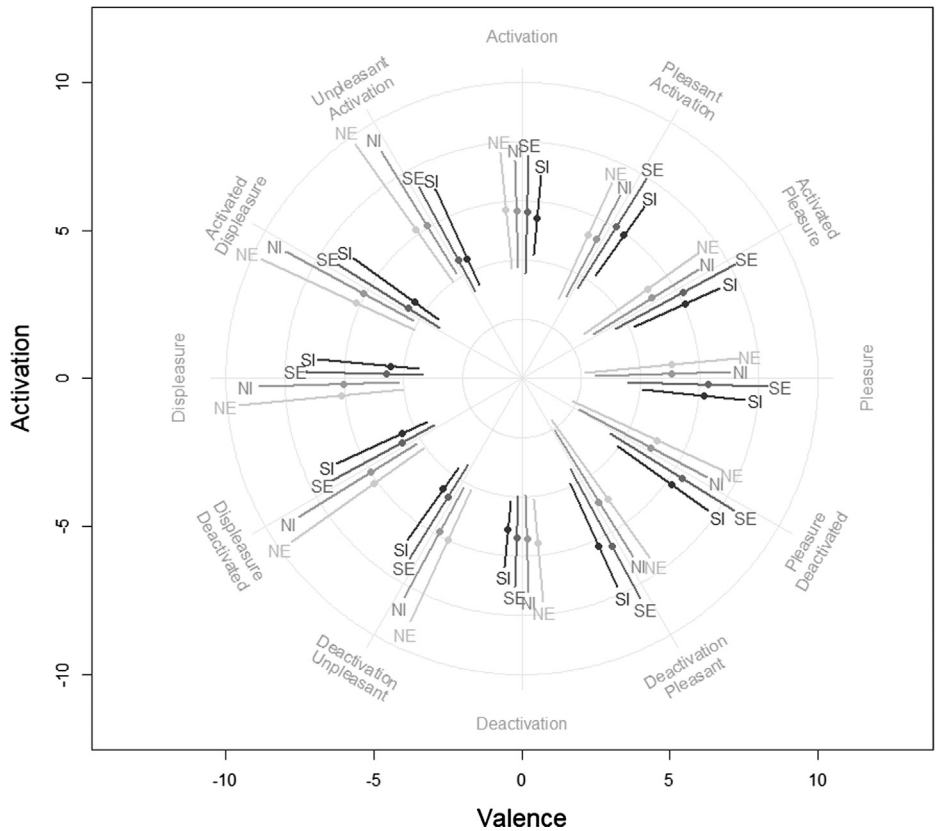

Fig. 2. Home base position and variability range (90% confidence interval) for each of the four personality profiles on each of the 12 affects. SI = stable introvert; SE = stable extravert, NI = neurotic introvert, NE = neurotic extravert.

and NIs, and 1.2 standard deviations from the mean for SIs and NEs. These values were chosen because they contrasted with each other but were still within the range of observed values, given the correlation between extraversion and neuroticism ($r = -0.36$). Moreover, using natural splines of the predictor variables lent the model greater flexibility, providing a better fit to the asymmetry of NA distribution and the nonlinear interaction between neuroticism and extraversion. We chose the degree of freedom for each natural spline transformation using a model selection approach, based on the sum of the Bayesian information criteria (BICs) of all the fitted models. Linear mixed-effects models were fitted using the lme4 package (Bates, Maechler, Bolker, & Walker, 2015) in R (R Core Team, 2018). The final formula we retained encompassed the interaction between the natural splines of the observation rank with three degrees of freedom, the natural splines of extraversion and neuroticism with two degrees of freedom, and a per participant random intercept.[2]

Table 4 provides the goodness-of-fit statistics of the models fitted along the three main axes. These models were only a subset of the fitted models, as a total of 45 models were fitted within the different two-dimensional planes, not only along the three main axes but with 45 rotations of 4-degree increments to draw the ellipsoids, plus 12 models for the different item orientations. The inclusion of both personality traits and their interactions after quadratic transformation led to the best goodness of fit, in terms of the Akaike information criterion (AIC), along the three main axes (cf. Table 4) and 12 item orientations (cf. Table 3). The interaction also improved the model fit regarding the BIC along the NA axis and along the *activated pleasure*, *pleasure*, *unpleasant deactivation*, *deactivated displeasure*, and *displeasure* orientations (cf. Table 3). We decided to use this nonlinear interaction model formulation to estimate the medians and percentiles for all the orientations, to obtain regular three-dimensional ellipsoids. Figs. 2 and 3 present the results and also provide some useful information for working out the effect sizes.

3.2.1. Affective home base according to neuroticism and extraversion

Our first goal was to determine how extraversion, neuroticism, and the interaction between the two predicted participants' affective home base. Initial information is provided in Table 2, which indicates the correlations between extraversion, neuroticism, and the means of our three indicators of affective experience for each participant. As expected, neuroticism was positively correlated with NA ($r = 0.37$, $p < .05$), and negatively correlated with PA ($r = -0.37$, $p < .05$). Extraversion was correlated with PA ($r = 0.18$, $p < .05$), but with neither NA ($r = 0$) nor ACT ($r = 0.07$, *ns*). As described in greater detail below, the upper bounds of ACT feelings were more closely correlated with extraversion than the simple mean was, underscoring the need to consider both the affective home base and affective variability. Moreover, this weak relationship between extraversion and mean PA and the absence of a correlation with NA are congruent with the hypothesis that neuroticism plays a moderating role, owing to the coupling between PA and NA that may particularly impact NEs.

More accurate information, yielded by the linear mixed-effects models that contained the interaction between extraversion and neuroticism, is provided in Fig. 1. This figure shows that, as

[2] Expressed in Wilkinson and Rogers (1973)'s notation for linear models, the formula for the retained model was: Affect ~ ns(Observation rank, 3) * ns(Extraversion, 2) * ns(Neuroticism, 2) + (1|Participant); where ns() was the natural spline function (Hastie, 1992) provided by the "splines" R library.

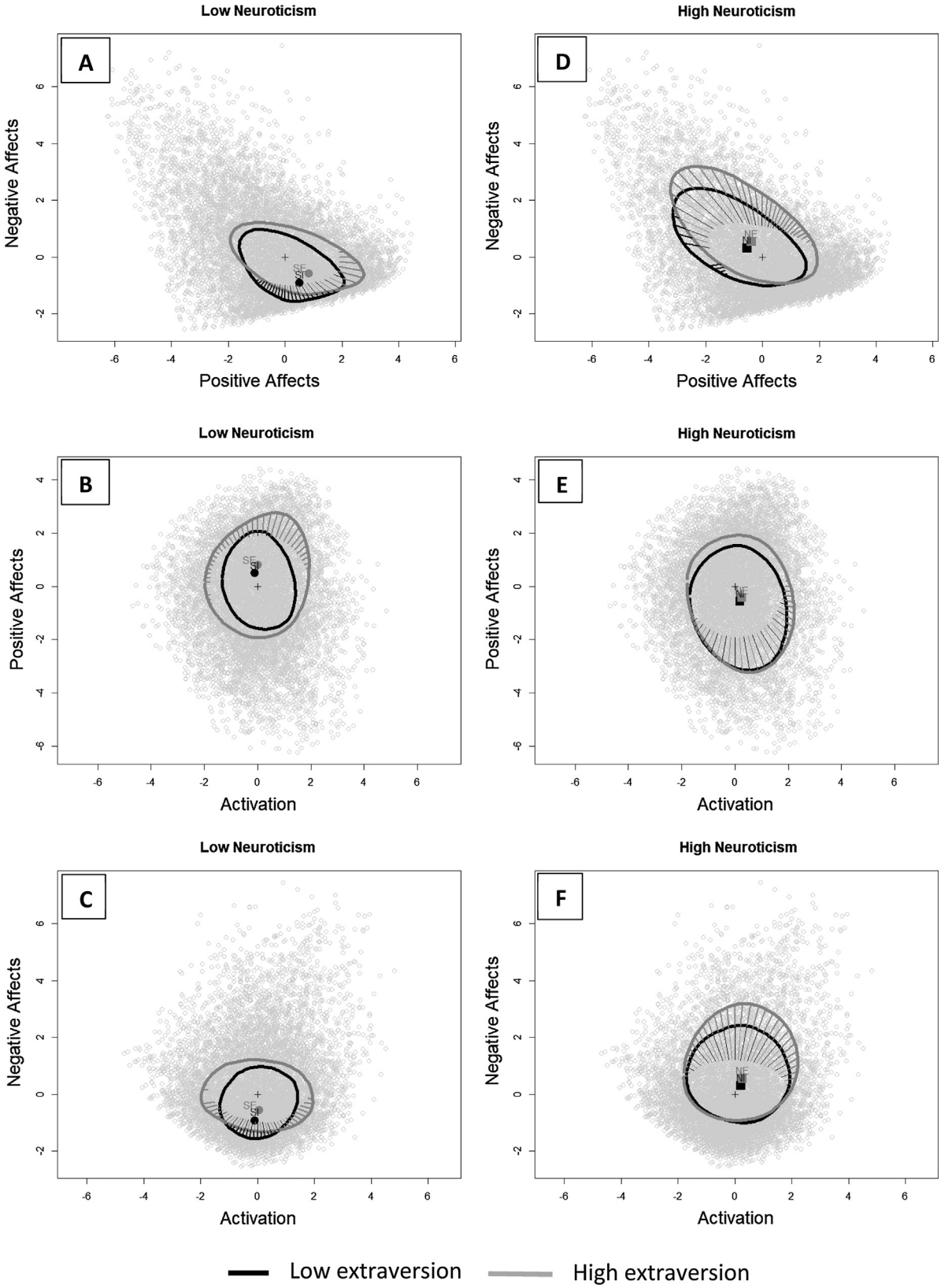

Fig. 3. Home base position and variability zone for each of the four personality profiles. SI = stable introvert; SE = stable extravert, NI = neurotic introvert, NE = neurotic extravert. Hatched areas represent zones that were only attained by the profiles represented in the panel.

expected, the home base of neurotic individuals was higher on NA than that of stable individuals. However, it also indicates that the home bases of extraverted individuals were both more positive and more negative than those of their introverted peers, reflecting more frequent experiences of mixed feelings. Interestingly, these differences between introverts and extraverts were greater for

Table 4
Goodness-of-fit statistics for the models fitted along the three main axes of the affective state space.

		PA		NA		ACT	
ns(Observation rank, 3) * (. . .)	*Df*	AIC	BIC	AIC	BIC	AIC	BIC
No effect of personality	6	35,465	**35,509**	16,538	16,582	41,530	41,574
ns(Neuroticism, 1) + ns(Extraversion, 1)	14	35,416	35,519	14,885	14,988	41,430	**41,533**
ns(Neuroticism, 1) + ns(Extraversion, 2)	18	35,422	35,554	14,761	14,893	41,430	41,562
ns(Neuroticism, 2) + ns(Extraversion, 1)	18	35,411	35,543	14,818	14,951	41,426	41,559
ns(Neuroticism, 1) * ns(Extraversion, 1)	18	35,412	35,544	14,868	15,000	41,431	41,563
ns(Neuroticism, 2) + ns(Extraversion, 2)	22	35,417	35,579	14,695	14,856	41,426	41,588
ns(Neuroticism, 1) * ns(Extraversion, 2)	26	35,422	35,613	14,667	14,858	41,431	41,623
ns(Neuroticism, 2) * ns(Extraversion, 1)	26	**35,378**	35,569	14,822	15,013	41,410	41,601
ns(Neuroticism, 2) * ns(Extraversion, 2)	38	35,382	35,661	**14,558**	**14,837**	**41,402**	41,681

Note. ns = natural spline function; PA = positive affect; NA = negative affect; ACT = activation. Lowest AIC/BIC values are in bold, indicating the best fitting model according to each criterion.

stable individuals, with SIs in particular showing the lowest median level of NA. This interaction pattern between extraversion and neuroticism also emerged for PA. As expected, SEs had a more positive home base than SIs, but NEs had a home base that was relatively similar to that of NIs on the PA axis, especially for highly activated PA. According to Table 3, NEs and NIs had similar home bases regarding *pleasant activation* and *activated pleasure*. Thus, at the median level, the expected positive relationship between extraversion and PA was observed for stable individuals, but seemed weaker for neurotic ones. Taking the four profiles one by one, SIs had a home base that was very low in NA and quite high in PA. Compared with SIs, SEs had a higher median level of not only of PA, but also of NA. The home bases of NIs and NEs were high in NA and low in PA.

3.2.2. Affective variability according to extraversion and neuroticism

Our second-and main-goal was to analyze differences in affective variability according to the four personality profiles we examined. The median and 5th and 95th percentiles computed along the three main axes, as well as in the direction of each of the 12 items for the four personality profiles within the three-dimensional affective state space, are set out in Table 3 and Fig. 2. At the item level, the effects of neuroticism clearly set the five positive items against the five negative ones. Highly neurotic participants experienced higher median and extreme levels of NA, while more emotionally stable participants had higher median and extreme states of PA for all ACT levels. Neuroticism also influenced variability, with larger variability intervals for highly neurotic individuals than for their more stable counterparts for almost all items. When we compared NIs with SIs on variability intervals (Columns 2 and 4 in Table 3), we found that NIs exhibited more variability than SIs on all items. NEs (Column 1) were also more variable than SEs (Column 3) for all but two items (*activation* and *pleasant activation*). Fig. 2 also clearly shows that a high level of extraversion was accompanied by greater variability. SEs were more variable than SIs for all items, and NEs were more variable than NIs for all items. Taken together, these different effects led the NEs to experience the highest extreme level of NA, and SEs the highest extreme level of PA.

Fig. 3 shows the ellipses in the PA-NA, ACT-PA and ACT-NA planes for stable individuals who differed on extraversion (SEs and SIs) in the lefthand panels, and for highly neurotic individuals who differed on extraversion (NEs and NIs) in the righthand panels. This representation makes it possible to consider the shape and position of the variability zone in the three-dimensional affective space and to estimate the coupling between PA and NA and their potential mixing. Home bases are also shown, and hatched areas indicate the affective states attained only by the stable individuals (lefthand panels) and only by the highly neurotic individuals (righthand panels).

In the PA-NA plane (Graphs A and D), the ellipses extended along the descending diagonal, reflecting the negative PA-NA correlation that could be numerically estimated using the 90 points constituting each ellipse. As expected, SIs exhibited by far the lowest variability in PA and NA (i.e., along this diagonal; $r_{AP\text{-}AN} = -0.61$). They also displayed the lowest variability in ACT, as shown in Graphs B and C. Furthermore, they attained the lowest NA zone with neutral PA and ACT, but never attained a very high PA zone.

Consistent with our hypotheses, SEs displayed more variable PA than SIs did. They also had a more elongated ellipse along the PA-NA diagonal (Fig. 3 Graph A; $r_{AP\text{-}AN} = -0.65$). Interestingly, they were the only individuals to attain the very high PA zone, and they also experienced higher NA and lower PA extreme states than their more introverted counterparts. Regarding ACT (Fig. 3 Graphs B and C), as predicted, SEs were once again characterized by very high variability. They were also the only ones to go from very low to very high ACT states, all the while maintaining a medium-to-high PA level, and to experience highly activated PA states (Fig. 3 Graph B). Overall, our exploration of the affective variability zone of stable individuals revealed mixed affective experiences for SEs, as they attained an extremely positive zone, but at the cost of greater variations along all three affective dimensions. By contrast, the affective experiences of SIs were not particularly variable along any of these dimensions, and SIs more frequently experienced very low levels of NA than SE did.

As regards individuals who scored high on neuroticism (NEs and NIs; righthand panels), the first interesting finding was that they attained higher NA zones than their more stable counterparts (Fig. 3 Graphs A and D), regardless of ACT levels (Fig. 3 Graphs E and F). Moreover, in line with our prediction, neurotic individuals were characterized by greater affective variability along the PA-NA diagonal, with a stronger PA-NA correlation (Fig. 3 Graph D; NI: $r_{AP\text{-}AN} = -0.73$; NE: $r_{AP\text{-}AN} = -0.77$) than emotionally stable individuals. On the ACT axis (Fig. 3. Graphs E vs. B) the variability ranges of neurotic individuals were comparable to those of SEs. Finally, when we compared NIs and NEs on affective variability, we observed that NEs were more variable along the PA-NA diagonal, with more mixed affects (Fig. 3 Graph D) and the strongest PA-NA correlation (NE: $r_{AP\text{-}AN} = -0.77$), and they were the only ones to experience highly activated NA (Fig. 3 Graph F).

4. Discussion

The primary purpose of this study was to enhance current knowledge of the relationship between personality, especially neuroticism and extraversion, and affective variability. Although robust evidence has emerged in the literature for the relationship between neuroticism and mean levels and variability of NA (e.g., Eid & Diener, 1999; Hepburn & Eysenck, 1989; McConville &

Cooper, 1999; Murray et al., 2002; Williams, 1990), as well as the relationship between extraversion and mean levels of PA (e.g., David et al., 1997; Howarth & Zumbo, 1989; McCrae & Costa, 1991; Smillie et al., 2015; Watson & Clark, 1992; Zautra et al., 2005), greater inconsistency has been reported for the relationship between the latter trait and PA variability (e.g., Hepburn & Eysenck, 1989; McConville & Cooper, 1999; Murray et al., 2002). Robust findings are also lacking as regards the relationship between neuroticism and PA and ACT variability, and between extraversion and NA and ACT variability. Furthermore, Eysenck and Eysenck (1985)'s appealing hypotheses on the possible interaction between extraversion and neuroticism have proven difficult to test. Finally, the usual measure of affective variability (i.e. standard deviation of intra-individual affect scores over time) does not allow for the simultaneous study of the amplitude and direction of individual variability within a multidimensional framework (e.g., intensity of the PA-NA coupling). The methodology adopted here, which enabled us to analyze the relationship between personality traits and the quantiles of three-dimensional distributions of affective states, seemed to yield more subtle results than in previous studies. By applying this approach to data yielded by an ESM comprising five daily assessments over a 2-week period, we were able to examine both the median level (home base) and variability in a three-dimensional affective state space of individuals who differed on their levels of extraversion and neuroticism.

Results on affective home base indicated first that, as hypothesized, neurotic individuals (NIs and NEs) had a more negative and less positive home base than their more emotionally stable counterparts (SIs and SEs). This is consistent with a number of prior findings (e.g., Aldinger et al., 2014; Williams, 1990), and can be explained by the fact that, compared with the thoughts and behaviors of emotionally stable individuals, those of neurotic individuals are more intensely governed by a motivational system that looks out for possible unpleasant and threatening stimuli, leading to sustained levels of high NA and a secondary reduction in PA (Larsen & Augustine, 2008). Interestingly, when we compared NIs with NEs, the latter's home base was only slightly more positive than that of the former, and was also more negative, with therefore a higher probability of experiencing mixed feelings. This result nuances previous findings that had suggested that extraversion is accompanied by enhanced PA (e.g., McCrae & Costa, 1991; Rusting & Larsen, 1997; Watson & Clark, 1992), as well as theoretical accounts stating that extraversion arises from a basic motivational system responsible for the identification and pursuit of pleasant stimuli (Larsen & Augustine, 2008). Even though we observed that SEs had a more positive home base than SIs, this difference appeared to be smaller among neurotic individuals, and almost nonexistent for highly activated PA. This difference was also accompanied by enhanced NA, such that both SEs and NEs had mixed feelings. We can assume that extraverts' appetite for activities eliciting arousal, the sensation-seeking facet of extraversion (Zuckerman, Bone, Neary, Mangelsdorff, & Brustman, 1972), is relevant in this context. First, these activities are often risky, with possible unpleasant consequences (Nettle, 2005). If extraverts' tendency to engage in risky activities is combined with neurotics' tendency to frequently encounter unpleasant events in general, the result may be even more frequent encounters with unpleasant events. As PA and NA appear to be strongly coupled in reactions to such events (Zautra et al., 2005), the additional PA experienced by NEs as a result of their extraversion is presumably cancelled by an increase in NA. Second, engaging in more activities is thought to trigger periods of high ACT, necessarily followed by a low-ACT resting period. Our results could therefore reflect the fact that only SEs can maintain positively valenced affects during these low-ACT periods. NEs are more likely to experience deactivated NA after engaging in activities that elicit arousal. Our four profiles differed little on the location of the home base (i.e., median) on the ACT axis, although the home base of SIs was located at a slightly lower level. The variations around the mean level appeared to be more informative.

The primary purpose of this study was to analyze affective variability. We assumed that the main process underlying affective variability is the occurrence of positive feedback loops between affective, cognitive and behavioral processes, also referred to as *self-perpetuating affective loops*. The duration of these loops, be they very rapid (i.e., completed within the space of a few milliseconds or seconds in reaction to an event and giving rise to an observable level of affective reactivity; Robinson, 2007) or rather slower (i.e., lasting for several minutes or hours; Brans et al., 2013; Houben et al., 2017; Moberly & Watkins, 2008; Pavani et al., 2017), could explain the manner in which an individual's affective experience moves away from the home base. We agree with other authors that these loops may even be responsible for the most intense affective states, such as those felt in panic attacks (Van den Hout et al., 1990), depression (Bringmann et al., 2015), and mania (Johnson et al., 2012). Those individuals most liable to frequently and/or intensely display affective feedback loops are also those most liable to exhibit variable affective experiences. Although we did not test the assumption that these loops subtend affective variability in the present study, it served as the basis for the hypotheses we formulated on the possible relationship between neuroticism, extraversion, and affective variability. A combination of theoretical arguments (Larsen & Augustine, 2008) and previous empirical findings (e.g., Bolger & Zuckerman, 1995; Oerlemans & Bakker, 2014; Rusting & Larsen, 1997; Smillie et al., 2012; Thake & Zelenski, 2013; Zautra et al., 2005) led us to predict that neurotic participants would display more variable NA than their more stable counterparts, while extraverted participants would display more variable ACT and PA than their more introverted peers. Given the stronger coupling of PA and NA that characterizes the encounter of unpleasant events (Zautra et al., 2005), we also predicted that neurotic participants would display more variable PA than their less neurotic counterparts.

Our results initially revealed a considerable difference between SIs and SEs, especially regarding PA and/or ACT variability. As expected, the affective experiences of SIs varied little in any direction of the affective space, possibly reflecting weak PA, NA, and ACT positive feedback loops. In addition, the affective feelings of SIs rarely attained the high PA-high ACT zone, unlike those of SEs, which were frequently located in this zone. Another major difference between SIs and SEs was that the latter's affective experiences varied more on PA, consistent with the hypothesis that extraverted individuals experience more intense and/or more frequent positive feedback loops of activated PA than their more introverted counterparts. Thus, the affective variability of SEs also concerned ACT, as their affective feelings attained both the very high and very low zones in this dimension, while maintaining medium-to-high PA and medium NA levels. One possible explanation is that the experience of strong positive feedback loops requires a considerable amount of energy, and therefore has to be followed by deactivated resting or recovery states. Finally, the high PA-ACT variability of SEs was accompanied by a stronger coupling of PA and NA than for SIs. This could explain their mixed affective life, which sometimes includes above-the-mean levels of NA, although they are emotionally stable individuals, as the periods of decreased ACT and PA may tend to trigger negative feelings.

Regarding neurotic individuals, as expected, NIs and NEs displayed more variable NA than their stable counterparts. Again as predicted, when we simultaneously considered PA and NA, NIs and NEs were more variable than SEs on the PA-NA diagonal axis, with a stronger correlation between PA and NA and a higher probability of mixed affective states. This is consistent with our

hypothesis that neuroticism is accompanied by a higher probability of engaging in positive feedback loops affecting NA. NEs and SEs displayed similar ranges of variability along the ACT axis, but NEs were the only ones to attain the very high NA-very high ACT zone. Finally, contrary to what we expected, NIs did not appear to reach the high NA-low ACT zone more often, which corresponds to feelings of depression. There was no evidence of a feedback loop oriented toward low ACT-NA that would primarily affect introverts.

As a whole, the pattern of results we obtained was consistent with the hypothesis that both neuroticism and extraversion favor the emergence of positive feedback loops, with extraversion triggering loops that engage ACT, and the degree of neuroticism determining the orientation of these loops in terms of valence. One possible interpretation of our results is thus that SIs rarely entered loops leading to very stable emotional experiences. SEs more often engaged in loops on the PA side, with considerable variations in their ACT level. Their affective states appeared to vary from highly activated PA to barely activated PA, while maintaining quite low NA. Because of their higher level of neuroticism, NIs were more likely to engage in loops on the NA side. These loops also triggered ACT variations, and the coupling between PA and NA resulted in both high variability and a low mean level of PA. Finally, NEs were the most liable to experience strong self-perpetuating loops on the NA side, which led them to be very variable on both NA, ACT and PA for the same reasons as NIs, but with an even higher intensity. These exacerbated dynamics also resulted in a stronger PA-NA correlation, a greater probability of experiencing mixed affect states, and the possibility of feeling very high NA with very high ACT.

Besides providing new data on the contribution of personality to affective dynamics, our results may have methodological implications. In particular, they suggest that refined methodological approaches can serve to identify more subtle phenomena in this field of research. First, the idea that the affective home base of individuals must be operationalized by mean levels may sometimes need to be challenged. Our observation that affective experience was asymmetrically distributed led us to postulate that mean outcomes can be strongly influenced by extreme scores. Moreover, our analysis based on quantiles revealed that personality traits can be closely related to these extreme scores.

By allowing for a model-based analysis of the overall distribution of responses, the quantile regression approach (Koenker & Bassett, 1978) opens up some valuable perspectives. A proper analysis of the possible interactions between selected predictors of affective dynamics may facilitate the identification of the above-mentioned subtle phenomena. For instance, we observed that a higher level of extraversion was associated with a higher median PA among emotionally stable individuals-an effect that was somewhat smaller among neurotic participants. To date, studies of the relationship between personality and affective dynamics that consider the interaction between extraversion and neuroticism have not only been few in number, but have also had methodological limitations (e.g., transforming continuous personality variables into categorical ones; Hepburn & Eysenck, 1989; Murray et al., 2002; Williams, 1990).

The identification of subtle phenomena may also be furthered by a combined examination of several outcome variables. This is particularly relevant to affective experience, as PA, NA, and/or ACT frequently seem to be coupled (Congard et al., 2011; Oerlemans & Bakker, 2014). In the present study, for instance, the affective experience of neurotic individuals differed from that of stable individuals, on account of the PA-NA home base location, variability and correlation. The latter would not have come to light had PA and NA been analyzed separately or solely on the valence dimension.

Nevertheless, further research is needed to extend our exploration of this area, while addressing some of the present study's limitations. In particular, while we were able to test specific hypotheses about the relationship between personality and affective variability, the basic overarching hypothesis about the dynamic mechanisms (i.e., positive feedback loop of PA, NA, and ACT) subtending this variability could not be tested here. Our investigation of the contribution of personality to affective dynamics should therefore be taken further by new studies using statistical approaches that are specifically designed to capture dynamic phenomena, such as damped-oscillator models (e.g., Pettersson et al., 2013). Another limitation of our study concerned the population sampling. It may be that the people who agreed to engage in an ESM, with five daily assessments over a 2-week period, were also higher than the general population on a psychological dimension such as conscientiousness, which can have implications in term of affective variability. This issue could be sidestepped in future research by shortening the ES period while increasing sample size.

To conclude, the present study confirmed the hypothesis that personality is a predictor of affective dynamics. In particular, it showed that the interaction between extraversion and neuroticism may determine the location of the affective home base and the variability of affective experience within a three-dimensional affective state space.

Footnotes

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