University of Kent
Faculty of Social Sciences
School of Psychology

PhD Thesis

Exploring the validity evidence of core affect

Ana Carla Crispim

Abstract

Core affect is an elementary affective state expressed through subjective feelings. Nonetheless, despite extensive empirical evidence in the field, researchers still disagree about its dimensionality. Thus, the present thesis aims to verify the validity evidence of existing models of core affect, overcoming the methodological issues of previous studies, and establishing the dimensionality of core affect. First, theoretical contributions are presented, and both conceptual (e.g. what is core affect?) and methodological issues (e.g. how core affect is measured?) are discussed. Following that, two empirical studies are presented. The first study explores the dimensionality of core affect and provides validity evidence of a new core affect measure. In the second study, a robust-to-biases core affect measure is developed and tested. In addition, the relationship between core affect, contextual variables (e.g. mood) and personality traits are studied in a longitudinal design. Items formats and their consequences in the measurement of core affect (e.g. rating scales, forced-choice items) are debated. Theoretical and methodological advances are discussed at last, as well as limitations and future directions.

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Exploring the validity evidence of core affect

Theoretical and empirical contributions

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Supervisor: Dr. Anna Brown

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My curiosity about core affect started when I was researching about the mental health of injured athletes. Instead of investigating psychopathologies associated to sports injuries, my Masters' supervisor and I decided to understand how athletes felt during trainings and competitions (when injuries usually happen). The concept of core affect fitted well with our purposes. However, at the time, we did not address measurement issues.

To address these issues, I wrote a PhD project for the Science without Borders program (SWB – Brazil) and talked to Anna Brown (my current supervisor) about this idea. Anna is an incredible person, and I learned a lot from her. She taught me about critical thinking in research and gave me all the support needed throughout my PhD. I can only be grateful for having her as my PhD supervisor.

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1. Introduction

Research on core affect dates back to more than a hundred years, however, doubts still exists about its conceptualisation and dimensionality. Core affect is “the most elementary consciously accessible affective feelings (and their neurophysiological counterparts) that need not to be directed at anything” (Russell & Barrett, 1999, p.806). The nature of affect is in the core of mind, and the affective experience is one of the most meaningful and relevant components (Panksepp, 2012). Therefore, it has a central role in human experience, providing the hedonic tone that colours people lives (Gray & Watson, 2007). Importantly, the affective experience only occurs as an upshot of the cognitive process; thus, core affect refers to conscious elementary processes of pleasure and activation (Russell & Barrett, 1999). Examples of affective states are pleasure, calmness, tension, energy, tiredness or displeasure (Ekkekakis, 2013).

To understand the states of core affect, Russell (1980) developed a model represented by a circumplex. In the circumplex, two dimensions of core affect are orthogonal to each other. The two dimensions are valence (with pleasure and displeasure as its poles), and activation (with activation and deactivation as its poles). Other models of core affect exist, for instance Watson, Clark and Tellegen model (1988) has positive and negative valence as separate dimensions. This model was, initially, about mood, but then was adapted to core affect, leading to the development of positive and negative affect Schedule (PANAS). Although PANAS is an internationally known measure of affect, it does not cover the totality of core affect because its items do not cover low activation aspects of pleasure and displeasure (Barrett & Russell, 1999; Ekkekakis, 2013). Other models of core affect have also been proposed, in particular, a model that includes a third dimension of dominance (Mehrabian & Russell, 1974).

Despite the seeming differences between the various models of affect, it may be argued that the models complement rather than contradict each other (Yik, Russell, & Barrett, 1999; Yik, Russell, & Steiger, 2011). Specifically, a two dimensional space was found to underlie constructs in four models (Larsen & Diener, 1992; Russell, 1980; Thayer, 1978; Watson et al., 1988), and the constructs specified under specific models could be seen as taking appropriate positions on the circumplex. Based on this research, a model of core affect represented as a 12-Point Affect Circumplex (12-PAC) has been developed (Yik et al., 2011), as well as a technique that allowed placing any related external construct into the 12-PAC (Circular Stochastic Process Model with Fourier Series; Browne, 1992).

Although resourceful, the research comparing existing models of core affect (Yik et al., 2011) had important methodological deficiencies. First, it operated at the scale level, not at the item level for model comparison. Where item responses were used, they were treated as interval scales, not as categories as they were in most measures. Second, principal components analysis was used where factor analysis would have been more appropriate. Third, Likert scales were used, which are open to numerous response biases. It has been shown that respondents use the rating options idiosyncratically (Friedman & Amoo, 1999) for instance, they may use predominantly the extreme rating categories or the central categories, or the positive categories (acquiescence). In addition, there are biases caused by the use of specific numerical or verbal anchors (e.g. Schwarz et al. 1991). Yik and colleagues (2011) attempted to control for these biases by ipsatizing the scores; this procedure leads to the data free from uniform biases but also removes the valid variance thus rendering conventional procedures such as factor analysis inappropriate. Fourth, most data collection methods relied on retrospective recollections of people’s affect at different times of the day. In assessment of transient states such as core affect, this may have serious implications on the validity of data. Fifth, some assessments involved a very large number of items (e.g. 169 items). In Classical Test Theory, longer tests are associated with better reliability indices; however, answering 169 items about how one is feeling in a particular moment can be tiresome and frustrate the participant, which could compromise the reliability as well as validity of the data.

The present work advances the existing research in several important ways. First, it uses models more appropriate for the type of data collected (multidimensional Item Response Theory or IRT models). Second, it uses alternative item formats, for example, forced-choice items to eliminate uniform response biases such as acquiescence or extreme/central tendency responding. Third, it uses momentary rather than retrospective data collection methods, for example, questionnaires distributed via mobile apps to capture people's momentary affect in different types of situations. Fourth, it seeks more efficient ways of measuring core affect once the structure of it is established. If the theoretical structure is indeed a circumplex, the measurement model chosen should allow factorially complex items to be used, tapping into both dimensions of core affect. Although the affective field has many tests to measure emotions, moods and affects (Kammann & Flett, 1983; Russell, Weiss, & Mendelsohn, 1989; Watson et al., 1988), most of them present the methodological issues mentioned above. Fifth, the present work aims to contribute to our understanding how core affect influences and it is influenced by associated factors (e.g. social interactions and personality), and which of these influences are momentary and which are more stable.

To summarise, the present work aims to verify validity evidence of existing models of core affect, overcoming the methodological issues of previous studies, and to establish the dimensionality of core affect. The data are analysed using latent variable modelling with categorical variables to compare circumplex-type models to alternative models. Based on the results of this analysis, a short measure of core affect that is robust to response styles is developed. Using this measure, intensive longitudinal assessments are carried out, which establish nomological networks of relations with contextual variables and personality.

Main hypothesis

- Core affect's structure is represented by a two-dimensional complex structure such as circumplex;

Objectives

- To verify validity evidence of the existing models of core affect overcoming the methodological issues of previous studies;
- To characterise the dimensionality of core affect;
- To develop a psychometrically valid, reliable and robust-to-biases measure of core affect based on the established measurement model;
- To verify the relationship between core affect, contextual variables and personality variables.

Part I – Theoretical contributions

2. Core affect

Matt and Julie are friends and they saw each other in the street.
Matt: Hi Julie, how are you?
Julie: Not bad, can't complain.
Matt: Really? You seem a bit bummed out.
Julie: Well if I am being honest, I am actually a little tired.

To describe how one feels can be a complex task when considering their subjective feelings. In the presented dialogue, Julie firstly described her current state in a general manner, though when asked again, she defines the affective state: tiredness. Even though people have thousands of exchanges like this across their lives, sometimes it is still hard to understand and to identify what one is actually feeling. Given the complexity of this task and the many associated factors in the study of core affect, emotions, and mood, it is necessary to start by explaining the concepts that fall under the umbrella of the affective sciences.

2.1 Affective Sciences

Affective sciences is a broad term that covers the area of study of emotions, mood, and affect. Even though philosophers have studied the emotional experience of human beings for a long time, questions such as "What are emotions?" or "Do universal emotions exist?" still have no definite answer. The study of emotion can be traced back to 360 B.C., when Plato believed that the human mind was composed by reasoning, desiring, and emotive parts (de Sousa, 2014). Later, in 1897, Wundt stated that the human experience actually comprised several other components (e.g. sense perception, memories, feelings, volitional acts), and among these components, there were emotions and feelings.

Currently it is 2017 and researchers still diverge about what comprises an emotion, or which theory best describes affective phenomena empirically. The disagreements relate to theoretical approaches (e.g. Are emotions dimensional or categorical?), the conceptualisation of constructs (e.g. Are mood, core affect, and emotions the same construct?), and go as far as study methods (e.g. Are facial expressions better stimuli than words?) and measurement (e.g. How many dimensions are needed to measure core affect?). To clarify these issues, the definitions of core affect, emotion, and mood will be explored.

2.1.1 What is core affect?

> "Affect plays a central role in human experience, providing the ongoing hedonic tone that colours the everyday lives of individuals" (Gray & Watson, 2007, p. 171).

Conceptually, "core affect is a neurophysiological state consciously accessible as the simplest raw (non-reflective) feelings evident in moods and emotions" (Russell, 2003, p. 148). Prior to this concept, Russell and Barrett (1999) defined core affect as "the most elementary consciously accessible affective feelings (and their neurophysiological counterparts) that need not to be directed at anything" (p.806). Defining the feelings of core affect as "simplest raw" and "elementary" binds the two presented descriptions of Russell (2003) and Russell and Barrett (1999) with the idea that core affect is the root of the affective experience. In other words, the idea that core affect plays the role of a building block for emotions and mood (Barrett, 2006b).

For example, although emotions and moods have other associated factors, a feeling is something that is always present, and it denotes if someone's affective state is pleasant or unpleasant. These feelings can be altered by real or imaginary events, and they can be directed or not to something (Russell, 2009). Given the variability of causes and consequences, Russell (2012) described core affect as private, subjective, and conscious. The *conscious* characteristic is especially interesting because people are always aware of how they feel, even though they might not name it, as it was exemplified by Julie and Matt's exchange in the beginning of the chapter. Thus, one can assume that a person is always in a state of core affect (Russell, 2012).

The operationalisation of this concept can be achieved by tracing back to Wundt's explanation (1897) of *simple feelings*. Wundt proposed that the physical experience of the human being was composed by sensational and affective elements (*simple feelings*). According to Wundt's argument, because feelings are subjective to one's own experience, the task of naming all possible feelings is too complex. Thus, feelings are *private*, as Russell (2012) suggested. To overcome the issue, Wundt proposed to categorise feelings according to three chief polar directions: pleasurable/unpleasurable, arousing/subduing, and strain/relaxation.

Directly or indirectly, these chief directions guided the derivation of current core affect's dimensions: valence (i.e. whether a feeling is pleasant or unpleasant) and activation (i.e. whether a feeling mobilises high or low energy). From these dimensions, researchers guided their investigation to understand core affect empirically (Betella & Verschure, 2016; Kuppens, Tuerlinckx, Russell, & Barrett, 2013; Mehrabian & Russell, 1974; Russell, 1980; Scherer, Shuman, Fontaine, & Soriano, 2013; Thayer, 1986; Yik et al., 2011). The application of these dimensions can vary according to each author's work, but they tend to be closely related.

Mehrabian and Russell (1974) explain core affect with the dimensions valence, activation, and dominance. Other authors explain core affect as a two-dimensional construct, excluding the dimension of dominance and applying only valence and activation (Russell, 1980; Russell & Barrett, 1999; Russell, 2003; Yik et al., 2011). The latter approach is more common in the present day (Betella & Verschure, 2016; Kuppens et al., 2013; Russell, 1980; Russell et al., 1989; Scherer et al., 2013; Thayer, 1986; Yik et al., 2011), which conceptualises core affect as a two-dimensional construct, and the product of these two dimensions is a single feeling (Ekkekakis, 2013; Russell, 2012).

2.1.1.1 Valence

The dimension of *valence* corresponds to how pleasant or unpleasant a feeling is (Russell, 1980). According to Brosch and Moors (2009, p. 401), Edward Tolman (1886-1959) applied the term *valence* in Psychology to explain how the forces of approach and avoidance guided human behaviours. Mehrabian and Russell (1974) later revised this definition, complementing the rational by suggesting that valence can be sufficient but not a necessary condition to elicit an approach and avoidance behaviour. Hence, the same object or event can has an assortment of appraisals among different people, which will cause them to have a variety of feelings.

The valence of a feeling also helps to codify an environment, imputing a value (e.g. good or bad, helpful or harmful, rewarding or threatening) to an experience or anything related to it (Barrett, 2006a). Other covariates such as a personal background and individual differences also exert influence in the appraisal process; thus, it is not plausible to assume valence as the unique cause of an event. These conceptual contributions are coherent and they demonstrate how valence works as an affective compass that guides people's actions, but like a compass, it can only give directions, and not much more.

2.1.1.2 Activation

The dimension of *activation* (also known as *arousal*) corresponds to the experience of mobilisation or given energy (e.g. low or high) for a reported subjective feeling (Russell et al., 1989). Similar to valence, activation levels are associated with external (e.g. life event) and internal sources (e.g. level of anxiety) (Mehrabian & Russell, 1974). In behavioural terms, an organism is active when it is alert and awake, for example, while in physiological terms, an organism is active when there is an excitatory state of neurons (e.g. increase in blood flow) (Heilman, 2000). The behavioural approach is commonly applied in the study of core affect.

2.1.2 What is emotion?

Descartes (1649/2010), while believing that body and soul were independent from each other, mentioned that passions of the soul could be defined as perceptions, sensations or commotions. These passions were hypothesised to be aroused by objects that stimulated humans' senses, and they were categorised as wonder, love, hatred, desire, joy, and sadness, which unravel to other variations of passions such as contempt, hope, and jealousy.

In 1884, William James conceptualised emotions as feelings that happened concurrently with bodily changes that follow the perception of an exciting fact; thus, James assumed body and soul were dependent on each other. Similarly, in 1897, Wundt suggested that emotions were:

> *a series of feelings succeeding one another in time unite to an interconnected process which is distinguished from preceding and following processes as an individual whole, and as in general a more intense effect on the subject than a single feeling*. (p.169)

Even though Descartes, Wundt and James presented different views of the human being's emotional experience, their concept of emotions shared common features, such as the need of an antecedent stimulus and the understanding that an emotion is not a unique feeling. In essence, it can be argued that an emotion is a more elaborated system that includes feelings, and not the other way around. Kleinginna and Kleinginna (1981) analysed 92 definitions of emotion and arrived to the same conclusion that emotions are a complex set of interactions with subjective and objective features that can initiate affective experiences, cognitive processes (e.g. appraisal), physiological adjustment, and action tendency.

Recently, Frijda and Scherer (2009) detailed the emotion system by presenting its characteristics:

a) Emotions are elicited by something that the organism of the human being takes as relevant;
b) Emotions prepare the organism to deal with the occurrence of an event;
c) Emotions tend to prioritise the control of behaviour and experience, if possible;
d) Emotions engage the person to take an action, which involves the somatovisceral and the motor systems.

Considering these concepts, emotions can be empirically studied in two perspectives: as discrete constructs or as a system. The discrete approach presents each emotion as a category on its own. For example, in Izard's Natural Kind approach (2007), emotions are categorised as interest, joy/happiness, sadness, anger, disgust, and fear. In Ekman's Basic Emotions approach (1992), basic emotions are anger, fear, enjoyment, sadness, and disgust. Therefore, in the discrete approach, each category (i.e. emotion) is studied by itself and different dimensions can be derived from it.

On the other hand, the system approach (also known as dimensional approach) assumes that higher-order dimensions cause all emotions, and the emotion being felt is determined by the variation in the levels of these dimensions. Examples of these dimensions are intensity, valence, action-tendency, and bodily changes (Frijda & Scherer, 2009).

2.1.3 What is mood?

Mood can be conceptualised as a long-lasting affective reaction with low intensity (Frijda, 2009). Mood is assumed a background affective state and it is not as intense as emotion (Thayer, 1989). Given the low-intensity characteristic, mood states are constantly present in a person's daily life and the same mood can last hours or days, in the case of psychological disorders (Ekkekakis, 2013).

In general, moods can be felt because of an external or internal event that happened recently; however, someone can be in a certain mood without a specific reason (Ekkekakis, 2013). These features are directly connected to the understanding of mood as a diffuse affective state (Thayer, 1989). To exemplify the diffuseness of mood, one might ask to another person "How is your mood today?" and the other person might say "good" or "bad", without detailing any further (Kahneman, 2012).

Interestingly, mood was once conceptualised to have five dimensions: anger, depression, tension, vigor and fatigue (Mcnair & Lorr, 1964). Clearly, this theoretical model described much more negative affects than positive affects as dimensions, and this was a direct influence from the model being firstly developed for clinical contexts. Thus, outside clinical context, the model had a limited use. Later use of the construct mood and its operationalisation led to the understanding of mood as a two-dimensional phenomenon. The two dimensions were positive moods and negative moods (Lorr, Shi, & Youniss, 1989; Watson & Tellegen, 1985).

2.1.4 Why is it important to distinguish core affect, emotion, and mood?

Understanding affective constructs is of special interest of psychologists because affective states are closely related to other psychological phenomena (e.g. personality or drug abuse behaviour). If these constructs are coherently defined, researchers are able to develop reliable instruments to study these phenomena and their relationships empirically. However, the differences between the concepts of emotion, core affect, and mood are not well established, which compromises conclusions derived from studies that involve these constructs.

The task of differentiation between these phenomena is simple in theory, but in practice, these constructs have been treated as interchangeable for as long as they have been studied. Reasons for this may be reluctance to change past measurement traditions or the lack of clear empirical evidence for their distinctiveness[1].

Many researchers accept the interchangeability of the terms emotion, mood and core affect, with or without knowledge of the consequences of this assumption.

[1] To the knowledge of the author, empirical evidence has not been presented yet.

According to Ekkekakis (2013), this type of approach caused knowledge chaos in the area of affective sciences. For example, initially, Watson, Clark and Tellegen (1988) claimed that they were assessing mood, even though the measure they developed had the word *affect* in its name. Eleven years passed before the authors acknowledge the problem (Watson, Wiese, Vaidya, & Tellegen, 1999). A similar situation happened to Kammann and Flett (1983) and the Affectometer 2. The authors based their measure in the dimensions of positive and negative affect, but claimed to be measuring general happiness.

What about theoretical evidence for the distinctiveness of affect, emotion and mood? In a quick search in Google Ngram Viewer (© 2013 Google), it is possible to verify how long the terms “affect”, “emotion”, and “mood” have been used in books. The term “affect” has been present in books since 1500, while the terms “emotion” and “mood” started to be used after 1550. Because the term “core affect” is more recent, its usage in books does not appear if included in the same graph as “emotion”, “affect”, and “mood”, but if added separately, the percentage level shows an increase in citations after 1900 and a peak around 2002.

Looking at these results, one may wonder how is it possible that allegedly interchangeable psychological phenomena have been treated differently in language? Looking at some inherent in-depth characteristics of these constructs, however, do provide evidence about their dissimilarities. For example, concerning daily frequency, core affect and mood are present most of the times, while emotions occur more rarely (Ekkekakis, 2013). Regarding intensity, emotions have high intensity, while the intensity of core affect can vary and mood has low intensity (Ekkekakis, 2013; Panksepp, 2012; Thayer, 1989). Considering possible causes for an affective state, core affect does not need a stimulus; while emotions and mood are triggered by internal or external stimuli (Ekkekakis, 2013; Frijda & Scherer, 2009; Russell, 2009; Thayer, 1989). Core affect has an immediate evaluation function (i.e. is this stimulus useful, approachable, or harmful?), while mood can also trigger evaluation of possible future events. Emotions have an instinct-related function, redirecting a person's immediate attention to something in order to draw a line of action and recover the balance of the organism (Carver, 2001; Ekkekakis, 2013; Frijda & Scherer, 2009).

Moreover, core affect happens amidst the emotions processes, giving the tone of the emotional experience. Accordingly, mood cannot be the same as an emotion because there is no direct action-tendency component. In addition, moods are also different from core affect because they are more diffuse and long lasting (Ekkekakis, 2013). Thus, conceptually, it seems plausible to assume core affect, emotions and mood as distinct. However, distinguishing between these different phenomena is only the beginning of a long path in the affective sciences field, but it is an essential step in order to have reliable results and valid measures.

2.2 Core affect theoretical models

Since 1890, several models were recommended to explain the basic feelings that underpin emotions and moods. In general, core affect is either explained by two-dimensional models (Russell, 1980; Watson et al., 1988; Yik et al., 2011) or three-dimensional models (Carver & Harmon-Jones, 2009; Mehrabian & Russell, 1974; Schimmack & Grob, 2000; Thayer, 1986).

2.2.1 Two-dimensional models

Commonly, two-dimensional models include valence and activation (Russell, 1980; Yik et al., 2011) or positive and negative affect as dimensions (Diener, Larsen, Levine, & Emmons, 1985; Kammann & Flett, 1983; Watson & Tellegen, 1985).

2.2.1.1 Circumplex model

Russell (1980) discussed the idea of the circumplex to explain core affect as a two-dimensional construct. The horizontal axis (dimension) represented pleasure-displeasure, and the vertical axis (dimension) represented arousal-sleep. The dimensions are orthogonal to each other. In theory, the combination of the two dimensions results in different feelings with different levels of pleasantness/unpleasantness and activation/quietness. Russell presented eight discrete feelings arranged around a two-dimensional space, and each point represented a feeling. Together, all eight variables followed a circular pattern, which was called circumplex (Figure 1).

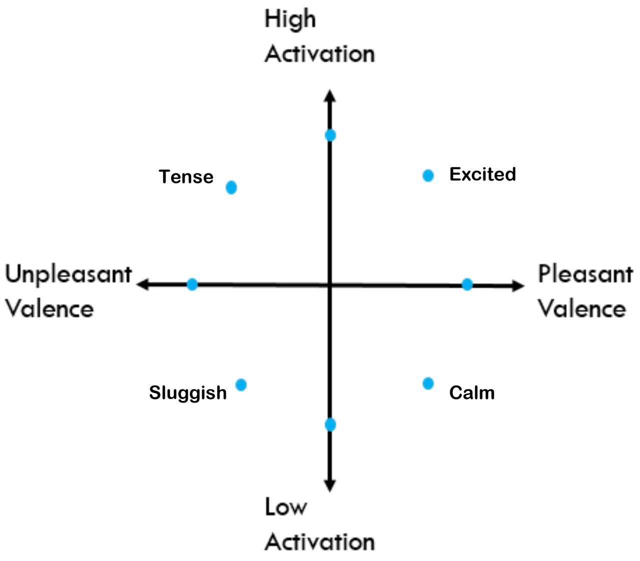


Figure 1 Circumplex two-dimensional space

The circumplex model has been tested for many years and evidence about its validity has been found (Barrett & Russell, 1998; Carroll, Yik, Russell, & Barrett, 1999; Russell, 1980; Yik et al., 2011). In the most recent circumplex model, there are 12 points spread around the two-dimensional space, which are also the products of valence and activation combinations (12-PAC model; Yik et al, 2011) (Figure 2). Feelings that are close to each other have similar levels of activation or pleasure, and feelings that are 180° distant from each other have opposite levels of activation and pleasure (Barrett & Bliss-Moreau, 2009). The complementary definition of the circumplex comes from Guttman's work on ordered structures (1954), in which he discussed that the location of the variables in the circle was a result of their correlations; therefore, strongly correlated variables would be near each other, independent variables would be 90° degrees away from each other, and bipolar variables would be 180° apart.

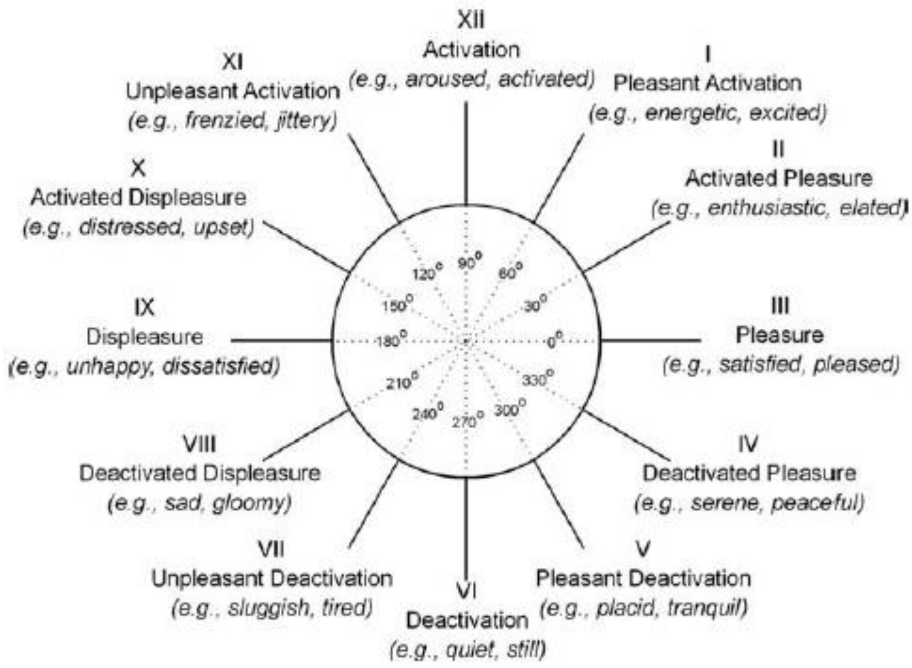


Figure 2 12-Point Affect Circumplex (12-PAC). Source: Yik et al (2011)

2.2.1.2 Positive and Negative Affect model

The second two-dimensional model is from Watson and Tellegen (1985) and has positive and negative affect as dimensions. In this model, dimensions are independent from each other and feelings are assigned to one of them. The model has influence of Bradburn's model (1969) of well-being, in which he proposes that the balance between reported positive and negative affect indicates one's current level of well-being.

While the positive and negative affect model (Watson & Tellegen, 1985) has been shown as a valid model of core affect (Watson et al., 1988), there are critiques about the levels of activation that the model covers. Specifically, there is evidence that the Positive and Negative Affect Schedule (PANAS) (Watson et al., 1988), measures high activation affects only, not allowing researchers to measure all the variations of core affect (Barrett & Russell, 1998).

There is also a two-dimensional model that proposes that positive and negative affect are underlain by intensity and frequency dimensions (Diener et al., 1985). Thus, besides dividing feelings according to positive and negative affect, the categorisation also happens according to frequency and intensity. However, if frequency and intensity are included as latent dimensions, the empirical latent model reduces to the one from Watson and Tellegen (1985).

2.2.1.3 Energetic arousal and Tense arousal model

The model from Thayer (1978) has two activation-based dimensions called energetic arousal and tense arousal. Both dimensions are hypothesised to be independent from each other. The energetic arousal relates to physiological and psychological processes, and it is represented by feelings such as energy, vigour, or peppiness. The tense arousal dimension relates to danger-related activities, and it is related to feelings such as anxiety, tension and fearfulness. Initially, the model was hypothesised to measure mood. Nowadays, the model is used in studies about core affect, given its resemblance with the dimensions valence and activation.

2.2.2 Three-dimensional models

Overall, the three-dimensional models have valence and activation as common dimensions, however, the interpretation of the third dimension varies. The development of three-dimensional models is supported by empirical evidence of core affect being better explained by three factors in real datasets (Schimmack & Grob, 2000). Some models refer to the third dimension as dominance (Mehrabian & Russell, 1974), and others present the third dimension as part of a motivational system (Carver, 2001; Carver & Harmon-Jones, 2009).

2.2.2.1 Valence, Arousal and Dominance model

Mehrabian and Russell (1974) suggested that core affect should be explained by three dimensions: valence, arousal, and dominance. According to the authors, valence refers to the continuum from displeasure to pleasure, arousal refers to the continuum from sleep to excitement, and dominance refers to feelings of control or the lack of it. Mostly, researchers that use the International Affective Picture System (Lang, Bradley, & Cuthbert, 2005) also use this model. Bakker and colleagues (2014) revisited the model to understand its connections with the ABC model of Attitudes (Affect, Cognition and Behaviour). However, recent research has adapted the model to a two-dimensional version (Betella & Verschure, 2016) without the dominance-related dimension, making it equivalent to the circumplex model.

2.2.2.2 Valence, Activation, Approach/Avoidance model

The three dimensions of this model are valence, activation, and approach/avoidance (Carver & Harmon-Jones, 2009). This model provides a functional analysis of core affect by considering approach and avoidance behaviours (Carver, 2001). Valence and activation are interpreted in the same manner as in other models. The approach/avoidance dimension relates to the motivational system; thus, bringing the functional tone that relates to appraisals (Carver, 2001; Carver & Harmon-Jones, 2009). Approach relates to reward and avoidance relates to punishment (Corr, 2013). The model is coherent theoretically but the relationship between the approach/avoidance and the other dimensions still remains unanswered.

2.3 Neural basis of core affect

> "Emotion and affect may be less than perfect, but no less essential than other forms of information processing" (Leddy, Robertson, & Schulkin, 2012, p.193).

As the introductory citation suggests, affect carries a functionality of information processing, even though this might not always be the main object of study in core affect research. How human beings appraise and process information can be studied using self-reports, where the researcher assess participants with a set of questions related to the topic, or the researcher can apply methods from the field of Neuroscience and verify neural activity patterns across the brain. Both methods may be valid and bring rich contributions to the field of affective sciences.

Given that the theories of core affect have been mainly tested with self-reports, it is also important to gather evidence from the field of Neuroscience. There is no consensus about which model best fits core affect empirically; however, the dimensions of activation and valence are presented in most models. Thus, evidence of the neural basis of core affect will be presented here according to valence and activation-related processes.

2.3.1 Valence-related processes in the brain

In general, the experience and expression of emotions are associated to the limbic region (Bear, Connors, & Paradiso, 2006). Considering the valence gives the tone of the affective experience (e.g. pleasantness/unpleasantness), there have been suggestions that valence-related processes are connected to neural activity in the limbic and paralimbic brain regions (Lindquist, Satpute, Wager, Weber, & Barrett, 2015).

More specifically, the mesolimbic pathway has been found to be a central piece for valence neural basis, given its relationship with the systems of pleasure and reward (Colibazzi et al., 2010; Longstaff, 2011; Posner, Russell, & Peterson, 2005). Because of its connection with the ventral pallidum and the nucleus accumbens (also considered the “hedonic hotspot”), the mesolimbic pathway is considered to give the hedonic tone of the human experience in the brain (Berridge & Kringelbach, 2011).

Self-reported pleasant feelings (measured with Affect Grid, a self-report measure; Russell, Weiss, & Mendelsohn, 1989) present neural activity on structures like the midbrain, the ventral striatum, and the right caudate nucleus, which are also related to reward circuits of the mesolimbic pathway (Colibazzi et al., 2010). Interestingly, unpleasant emotions tend to present more neural activity in the hippocampus, cerebellum, amygdala, left parahippocampal gyrus, occipito-temporal cortex, inferior parietal cortex, and mid cingulate cortex (Colibazzi et al., 2010; Lane et al., 1997). An example of unpleasant emotion with neural activity in these areas is fear (Bear et al., 2006). Besides the mesolimbic pathway, the actual representation of pleasure is activated by the prefrontal cortex, and more specifically, by the orbitofrontal cortex (Berridge & Kringelbach, 2013; Chikazoe, Anderson, Lee, & Kriegeskorte, 2014; Rolls, 2009).

2.3.2 Activation-related processes in the brain

Activation and arousal are often used as synonyms in the study of core affect. In neuroscience, activation is related to excitatory state of neurons in the central nervous system (Heilman, 2000). Neurologically, the activation dimension from the Affect Grid relates to processes in the midline and medial temporal lobes structures, such as the thalamus, the globus pallidus, the caudate, the amygdala, the parahippocampus, the hippocampus, and the dorsal cerebellar vermis (Colibazzi et al., 2010). Part of these structures, such as the amygdala and the hippocampus are also commonly related to the experience of emotions, which require high levels of activation (Bear et al., 2006).

Interestingly, a study with Functional Magnetic Resonance Imaging (fMRI) found significant correlations between these brain regions and scores of a self-report core affect test (Posner et al., 2009). Lindquist and colleagues (2015) corroborated partially the hypothesis with a meta-analysis, where they found increasing activation in the amygdala and the anterior insula were associated with more intense subjective experiences of activation. Another remark made by the authors is that if valence and activation are conceptualised as a circumplex (i.e. a complex structure), changes in activation and valence might be impossible to be separated empirically. This is especially true for experiments, where a stimulus will always induce some level of activation, even though it might be designed to only induce pleasantness or unpleasantness (Lindquist et al., 2015). Thus, it is possible that the complexity of core affect is also reflected in its neural basis.

2.4 The nomological network of core affect and other psychological phenomena

The affective experience is one of the most meaningful and relevant components of the human being (Panksepp, 2012). People subjectively experience affect every day in their emotions and moods (Kuppens et al., 2013). Every feeling can be continuously reinterpreted in light of distinct goals, intentions, and values of the perceiver, which contributes for the perspective that humans are the architects of their own experience (Barrett, 2013). Thus, core affect can impact various factors of one's life.

2.4.1 Cognitive appraisals and memories

The starting point to understanding how one feels could be when the affective component about an object or situation is recalled. At this moment, one asks himself "What do I think about it?", "Do I like this?", or "Do I hate this?" (Kahneman, 2012), and depending on the answer, a feeling and possibly a behaviour will be evoked, given that this process is intrinsically connected to the "reward system" in the brain (Bear et al., 2006). The recollection process of a memory happens because, when the memory is created, past feelings and experiences are considered. Consequently, when similar experiences happen in the future, the memory helps the decision-making process about a course of action, resulting in a back-and-forth influence process of core affect and cognitive appraisals on each other (Clore & Huntsinger, 2009).

Clearly, objects and events have different affective meanings for everyone, and depending on what is happening at a certain time, they can impact and change the homeostatic state of an individual (Barrett, 2006b). Evolutionarily speaking, memories and appraisals help human beings to survive and to understand their surroundings. Environmental changes prompt human beings to adapt their behaviour in the best manner they know, and remembering about how one felt in a particular situation plays an important role. Moreover, the understanding of these appraisals and memories aids understanding of internal and external events and their relationship with core affect.

2.4.2 Personality

Individual differences in personality traits are often related to how one feels across life. Evidence shows that people with higher neuroticism scores experience more negative affect, while people with higher scores on the other four personality traits of the Big Five (Extraversion, Agreeableness, Conscientiousness, and Openness) experience more positive affects (Howell & Rodzon, 2011; Komulainen et al., 2014; Letzring & Adamcik, 2015).

Longitudinally, researchers found that the tendency of having more fluctuations in core affect was also associated with higher levels of neuroticism (Kuppens, Van Mechelen, Nezlek, Dossche, & Timmermans, 2007). The authors suggested that people with higher levels of neuroticism score were more prone to displaying poor adjustment, depression, low self-esteem and negative expectations about the future, which relates to more variability in affective states across days. Agreeableness had a negative correlation with core affect variability, showing that emotionally unstable people were also less agreeable (Kuppens et al., 2007)

In addition, when the Five Factors of Personality (Costa & McCrae, 1992) were analysed together with the core affect dimensions in a circumplex, agreeableness was found very close to the valence axis (Yik et al., 2011), suggesting that agreeable people tend to relate more to positive affect feelings. In the same study, neuroticism was close to negative high activation affects and extraversion was closer to positive high activation affects, providing key insights about how personality traits are related to core affect.

2.4.3 Social interactions

Social interactions also influence one's current affective state. Socially connected individuals tend to report less negative affect states and more positive affect states when they interact with their partners (Hawkley, Preacher, & Cacioppo, 2007). In addition, Sandstrom and Dunn (2014) found that people reported greater happiness and feelings of belonging when they interacted with more classmates than usual during the day.

Furthermore, in a longitudinal study, Hawkley and colleagues (2007) showed that the quality of the social interaction at previous assessment positively predicted positive affect and negatively predicted negative affect at consequent assessment. Positive affect states had significant positive associations with the quantity of social interactions (Berry & Hansen, 1996) and with previous socialising behaviour (Watson, Clark, McIntyre, & Hamaker, 1992). Conversely, evidence from Cunningham (1988a; 1988b) showed that when affective states were manipulated, positive affect (compared to negative affect) sparked greater interest of the participants in having social interactions and conversations.

2.5 Discussion

One characteristic of core affect that is evident from the literature is its complexity. Such complexity is directly reflected in the operationalisation of the construct, which is hypothesised by some authors to be a circumplex (i.e. a complex structure). The circumplex hypothesis aligns coherently with the idea that specific feelings are products of different combinations of broader dimensions (e.g. valence and activation), and reinforces the argument about core affect's complexity, both theoretically and operationally.

Evidence from neural activity in the mesolimbic pathway, amygdala, and anterior insula and self-report measures also point to the two-dimensional explanation. Such as stated by Lindquist et al (2015), the complexity of these neural activity patterns and the difficulty in separating the processes according to activation and valence can be a consequence of understanding core affect as a circumplex. Nonetheless, results from neurological research highlights the function of core affect in the reward system. Thus, the theoretical concept of core affect's dimensions aligns coherently with neurological evidence.

An important decision to be made by every researcher that investigates core affect is what model best explains the construct. Three-dimensional models are often a result of factor analysis solutions that indicate a better goodness of fit of three factors instead of two, which some argue could be an indication of method factors in the case of core affect (Russell, 1980; Yik et al., 2011). However, authors such as Carver (2001) argue that the affective experience should be explained by taking into consideration approach and avoidance behaviours, resulting in a model with valence, activation, and approach/avoidance as dimensions.

In two-dimensional models, core affect is often explained using the dimensions of activation and valence, or the dimensions of positive and negative affect. Understanding core affect with the dimensions of positive and negative affect is convenient and widely tested with the test PANAS (Watson et al., 1988); however, the model was validated based on adjectives with higher levels of activation, thus likely not representing the whole construct of core affect.

The circumplex model (Russell, 1980; Yik et al., 2011) is well- established as a model that represents core affect in all valence and activation levels. The model from Thayer (1986) is similar to the circumplex model, however it focuses more on the activation aspect, instead of having an equal balance between valence and activation. Moreover, the three-dimensional model from Mehrabian and Russell (1974) is more often applied as a two-dimensional model without the dominance dimension, though empirical evidence for this application is not always explicit in the publications.

Thus, it is clear that valence and activation are dimensions that most often used in core affect research, independent of the model chosen. Some models emphasise more valence-related aspects of the constructs (e.g. positive and negative feelings), and some others emphasise more activation-related aspects (e.g. tense and energetic activation). It is also clear that core affect is a basic construct in the affective sciences, often complementing or being complemented by components of emotions and moods, yet being different constructs nonetheless.

This chapter provided a critical overview of common approaches in the affective sciences, including the use of different terms and conceptual models. The next chapter will focus on measuring core affect and the ramifications to the study of affective sciences derived from the psychometric methods applied.

3 Measuring core affect

"Mathematics makes the invisible visible."

Keith Devlin

When one needs to measure a certain feature of an object, including a psychological phenomenon, one needs a scale. To assign numbers to a phenomenon according to a rule of correspondence is the concept of measurement (McDonald, 2014).

In the case of core affect, different measurement models have been applied over the years (e.g. circumplex, two-factor models). These models have different implications in the interpretation of the phenomenon. Nonetheless, all models contribute to current core affect research. The next session will give a brief about measurement models.

3.1 Measurement models

The popular measurement model in psychometrics is Classical Test Theory (CTT) model, in which the observed score (O*)* is understood as a combination of the true score (T) and the error component (E): **O**bserved score = **T** + **E**. The error component is assumed to have the expectation of zero; therefore, the true score is the expected value of the observed score. In this model, the attribute relates to the true score, which relates to how the attribute is measured (Borsboom, 2005).

Another common measurement model is the latent factor model. Its main assumption is that latent factors are the common cause of variability in the observed variables. In this model, all the shared variance in the observed variables are due to the common factors. Both unidimensional and multidimensional common linear factor models can be described:

$$X_i = \mu_i + \lambda_{i1}F_1 + \cdots + \lambda_{im}F_m + E_i \quad (1).$$

In equation 1, X_i is the observed score of variable i, μ_i is the mean of variable i, λ_{i1} is the factor loading of item i on factor F_1, F_1 is the person's level in the first factor, and E_i is the unique factor of variable i. The equation also represents a regression of X_i on F_1, where λ_{i1} is the expected difference on X_i for a unit increase of F_1 in the population (McDonald, 2014).

The common linear factor model can be easily extended to item response models by applying the appropriate link functions (e.g. logistic function, normal-ogive function). By assuming each item (X_i) has an *unobserved* underlying response tendency (X_i^*) and a threshold (τ_i), it can also be assumed that if $X_i^* > \tau_i$, then X_i = 1, and if $X_i^* \leq \tau_i$, then X_i = 0:

$$P\{X_i = 1|\ F = f\} = P\ \{X_i^* >\ \tau_i|F = f\} = N(z) \quad (2)$$

The term $N(z)$ represents the normal-ogive function (i.e. cumulative normal distribution function), where

$$z = \left[\lambda_i/\sqrt{1-\lambda_i^2}\right]f - \left[1/\sqrt{1-\lambda_i^2}\right]\tau_i, \quad (3)$$

assuming that λ_i^2 is the squared factor loading and ψ_i^2 is the unique variance

$$\lambda_i^2 + \Psi_i^2 = 1 \quad (4)$$

$$\Psi_i^2 = 1 - \lambda_i^2 \quad (5)$$

Therefore, a normal-ogive multidimensional latent trait model in factor loading/threshold parameterisation is written as

$$P\{X_i = 1 | F_1 = f_1, \dots, F_m = f_m\} = N\{(\lambda_{i1}/\Psi_i)f_1 + \dots + (\lambda_{im}/\Psi_i)f_m - (\tau_i/\Psi_i)\} \quad (6)$$

Equivalently, in the intercept/slope parameterisation,

$$P\{X_i = 1 | F_1 = f_1, \dots, F_m = f_m\} = N\{b_{i1}f_1 + \dots + b_{im}f_m + a_i\} \quad (7)$$

given that

$$b_{im} = \lambda_{im}/\Psi_i \quad (8)$$

$$a_i = -\tau_i/\Psi_i \quad (9).$$

3.1.1 The circumplex

A circumplex is an order-factor type of structure. Conceptually, order-factor models consist of variables that can differ in complexity, kind, or both. For example, differences in kind may refer to different skills (e.g. Mathematics and English), while differences in complexity regard to the layers of an ability (e.g. multiplication is more complex than addition) (Guttman, 1954). A set of variables that concerns the same ability and it varies according to complexity levels of this ability (i.e. different levels of the same ability) is called a simplex. A set of variables that differs according to kind (i.e. different abilities) is called a circumplex. The set of variables that varies according to complexity levels and kinds is called a radex.

The concept of having an order-type factor structure arose from partial correlations and the role of common factors in them. In the same way that a correlation between items is explained by a factor g, Guttman (1954) hypothesised that item *z* could be the intermediate variable that explained the correlation between items i_j and i_k (ρ_{jk}), thus, excluding the necessity of one or more common factors to explain the covariance between items. In the case of circumplex, the intermediate variables are called *elementary components* (c_m). The order of variables plays a crucial role; otherwise, the meaning of the correlations is compromised.

The general idea of the circumplex can be explained considering five items (i_n) that are ordered according to five elementary components (c_m):

$$i_1 = c_1 + c_2 + c_3$$
$$i_2 = c_2 + c_3 + c_4$$
$$i_3 = c_3 + c_4 + c_5$$
$$i_4 = c_4 + c_5 + c_1$$
$$i_5 = c_5 + c_1 + c_2$$

In this representation, every item is a function of an equal number of *m* elementary components, and the elementary components have equal variance (σ^2_c). To limit the number of zero correlations, the additional constraint of $m \geq n/2$ is added, meaning that the number of elementary components influencing each item must be greater than half the number of items.

The perfect circumplex can be achieved by respecting three conditions: uniformity, equal spacing and adjacent points ("neighbouring law") (Guttman, 1954). Uniformity constrains the items to be a function of the same number of elementary components. Equal spacing among variables is a result of equal correlations in each diagonal of the correlation matrix that is parallel to the main diagonal, resulting in the equal sums in each column. Adjacent points demands items to correlate highest when they are hypothesised to be near each other around the circumference, and items correlating lowest when they are hypothesised to be far away from each other. Thus, the correlation between the variables are a function of the distance between the variables on the circle, as exemplified in Figure 3, where the two variables have a distance of 90°; resulting in a correlation of zero if $\rho_{180°}$ is –1.

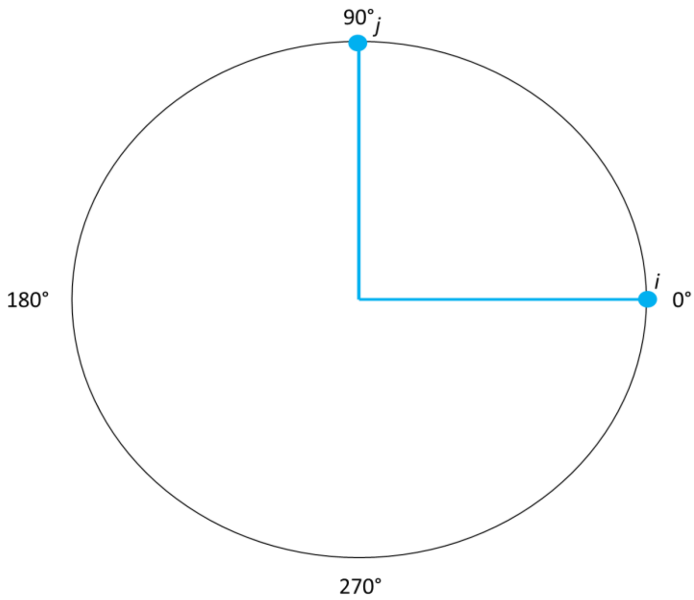


Figure 3 Representation of the correlation function of the circumplex

Together, these features lead to a correlation matrix called *circulant* (Figure 4) (Fabrigar, Visser, & Browne, 1997; Guttman, 1954).

a) Hypothetical order

ρ_1	ρ_2	ρ_3	ρ_4	ρ_3	ρ_2
ρ_2	ρ_1	ρ_2	ρ_3	ρ_4	ρ_3
ρ_3	ρ_2	ρ_1	ρ_2	ρ_3	ρ_4
ρ_4	ρ_3	ρ_2	ρ_1	ρ_2	ρ_3
ρ_3	ρ_4	ρ_3	ρ_2	ρ_1	ρ_2
ρ_2	ρ_3	ρ_4	ρ_3	ρ_2	ρ_1

b) Example of the correlation matrix fulfilling the hypothetical order

1	0.75	0.5	0.25	0.5	0.75
0.75	1	0.75	0.5	0.25	0.5
0.5	0.75	1	0.75	0.5	0.25

0.25	0.5	0.75	1	0.75	0.5
0.5	0.25	0.5	0.75	1	0.75
0.75	0.5	0.25	0.5	0.75	1

Figure 4 Circulant correlation matrix

The model presented by Guttman (1954) is called *Circular Moving Average Process model* and it was intended firstly for mental abilities. When discussing circumplexes, as well as the idea of the simplex and the radex, Guttman posited that these models are especially interesting in the area of neuroscience, considering that elementary components can be associated to neurons and the neighbouring law can be associated to neural pathways.

A disadvantage of this model is that is does not allow for negative correlations; however, several other researchers have studied solutions for this since then (Browne, 1992; Cudeck, 1986; Fabrigar et al., 1997; Jöreskog, 1978). Browne (1992) overcame the issue by assuming *Circular Stochastic Process with a Markov Property*. In his model, each observed variable (x_i) is the sum of a common part (common score; c_i) and a unique part (u_i). The common score variance is referred to be the portion of variation in the response of the participants that is common to two or more of the variables. The unique score variance is the variation of participants' response to one variable only. The circumplex correlation structure is assumed to hold for common score correlations, and not for observed variables correlations, since these present "noise" (Fabrigar et al., 1997). To represent the correlation between two common score variables (here *i* and *j*), Browne (1992) assumed the following model

$$\rho_{ij} = \rho(\theta_d) = \beta_0 + \sum_{k=1}^{m} \beta_k \cos(k\theta_d) \quad (10)$$

considering that

$$\sum_{k=0}^{m} \beta_k = 1 \quad (11)$$

where $\rho(\theta_d)$ is the continuous and monotonic ($0° \leq \theta_d \leq 180°$) correlation function with k parameters. In the model, it is assumed that the correlation is a function of the angle between the common score variables around the perimeter of the circle (Figure 3) (Browne, 1992; Fabrigar et al., 1997). In addition, the minimum correlation coefficient ($\rho_{180°}$) can be equal or greater than -1, depending on the fit of the circumplex structure to the data; thus, allowing correlations to be negative.

Instead of plotting observed scores and their correlations, the points in the circle are represented by the common scores, which are plotted according to their correlations $\rho(\theta_d)$. Accordingly, one variable is chosen as the reference, and the location of other common score variables are specified as polar angles from this reference variable. The argument in favour of this approach is that observed scores contain both common and unique variances (e.g. measurement error), which can distort the true structure of the correlations (Fabrigar et al., 1997). The advantage of Browne's model (1992) is that it does not require prior knowledge about variable's order and it can be easily applied with software such as CIRCUM and the R package "CircE" (Grassi, Luccio, & Blas, 2010).

Empirically, it can be difficult to achieve a perfect circumplex; thus, one should be aware of the possibility of quasi-circumplex structures (Guttman, 1954), where one or more criteria of a perfect circumplex are not met, and this can be achieved by applying an unconstrained circumplex model (i.e. no constraints for equal spacing, uniformity or adjacent points). In other words, a quasi-circumplex is a circumplex structure with deviations, or "noise".

Guttman (1954) warned that order-type structures were especially designed for mental test data, and may be unsuitable for non-cognitive constructs such as attitudes. The use of alternative approaches with circumplex structures will be discussed next.

3.1.2 Alternatives to the elementary components approach

Even though circumplexes were hypothesised to be high-dimensionality structures because of their elementary components, there are researchers who test order-factor structures with factor analysis (FA), exploratory and confirmatory. The use of factor analysis is especially interesting, considering that circumplex correlation matrices often yield two-factor solutions (Acton & Revelle, 2004).

For example, because of the neighbouring law, the correlation matrix of a circumplex has a particular "wave" pattern (Guttman, 1954; Jöreskog, 1978). In such a correlation matrix, one will find strong correlations near the main diagonal. As the correlations get away from the main diagonal, they get weaker, until they reach a minimum and start to rise again. In a confirmatory factor model, the researcher can check both sample- and model-based correlation matrices to verify the "wave" pattern of the data and of the model applied. The procedure is facilitated by the procedure called "heat map" (similar to Figure 4). In the heat map, different colours are applied to positive and negative correlations, while zero and near-zero correlations are usually white (Acton & Revelle, 2004); thus, it is possible to easily identify where the stronger and weaker correlations are. This strategy is useful when the order of the variables is known a priori.

In the case of an exploratory study, information about the order of the variables can be inspected with factor loadings plot. If a construct is two-dimensional, the loadings plot can give information about a possible order of the variables, given that it possibly will yield a circle-type of pattern (Figure 5).

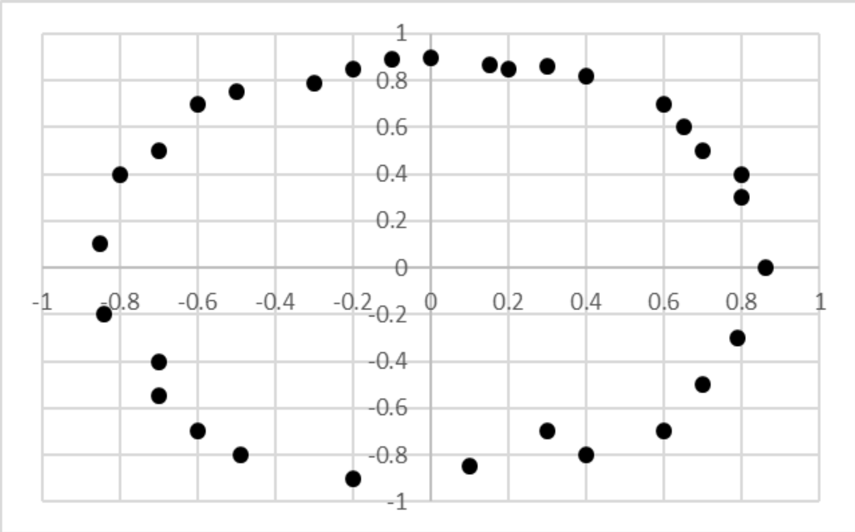


Figure 5 Hypothetical circumplex loadings plot

Importantly, Guttman (1954) offered the perspective of order-type factor models as an alternative way to understand psychological phenomena. When discussing simplexes, he suggested that variables could be considered as intermediated by a single factor called complexity (or factor *g*), or the researcher could explain the interrelations between variables by considering the order of variables and possible intermediate variables. To explain order-factor structures with or without underlying latent variables can be a decision made based on the construct of choice and the approach that the researcher finds more coherent.

3.2 Core affect measures

A review of psychometric instruments measuring core affect is presented next. The information is divided in Tables 1 and 2.

Table 1 *Core affect measures and their characteristics*

Year	Authors	Dimensions	Scale points	Item format	Stimuli	Item stem	N items
1974	Mehrabian & Russell	Valence, Arousal and Dominance	9	Semantical differential	Scenarios	Adjectives	18
1978	Thayer	Energetic arousal and Tense arousal	4	Rating scale	Momentary feelings	Adjectives	20
1978	Thayer	Energetic arousal and Tense arousal	4	Rating scale	Momentary feelings	Adjectives	50
1979	Sjöberg et al	Activation, Social Orientation, Control, Valence	4	Rating scale	Momentary feelings	Adjectives	89
1979	Sjöberg et al	Activation, Social Orientation, Control, Valence	4	Rating scale	Momentary feelings	Adjectives	148
1980	Russell	Valence and activation	8	Rating scale	Momentary feelings	Adjectives	28
1983	Zuckerman et al	Anxiety, Depression, Hostility, Positive Affect, Sensation Seeking	2	Rating scale	Momentary feelings	Adjectives	132
1985	Diener et al	Positive Affect, Negative Affect, Intensity, Frequency	7	Rating scale	Average daily feeling	Adjectives	23
1988	Watson et al	Positive and Negative affect	5	Rating scale	Past and momentary feelings	Adjectives	20
1989	Russell et al	Valence and activation	9	Rating scale (Grid)	Momentary feelings	Adjectives	2
1993	Gauvin & Rejeski	Positive Engagement, Revitalization, Physical Exhaustion and Tranquillity	5	Rating scale	Momentary feelings	Adjectives	12
2000	Schimmack & Grob	Pleasure-displeasure, awake-tiredness, tension-relaxation	7/15	Rating scale (verbal and numeric anchors)	Momentary feelings	Adjectives	84
2005	Lang et al	Valence, Activation and Dominance	9	Rating scale (Pictures)	Scenarios	Adjectives	3
2011	Yik et al	Valence and activation	5/4	Rating scale	Remembered moment	Adjectives and sentences	191
2013	Scherer et al	Valence and Power	5	Rating scale (Wheel)	Momentary feelings	Adjectives	20
2016	Harmon-Jones et al	Anger, Disgust, Fear, Anxiety, Sadness, Happiness, Satisfaction, Desire	7	Rating scale	Scenarios	Adjectives	60
2016	Betella & Verschure	Valence and Arousal	0-1	Rating scale with pictures (continuous)	Scenarios	Dimensions' names	2

Table 2 *Core affect measures and internal structure validity evidence*

Year	Authors	Factor analysis	Structure type	N items	Sample size	Estimator	Rotation	Factors retained
1974	Mehrabian & Russell	Exploratory	Simple structure	18	214	PCA	Oblique	3
1978	Thayer	Exploratory	Simple structure	20	486	Principal Axis	Oblique	4
1979	Sjöberg et al	Exploratory	Circumplex	89	404	PCA	Oblimin	6
1979	Sjöberg et al	Exploratory	Circumplex	148	500	PCA	Oblimin	6
1980	Russell	Exploratory	Circumplex	28	343	PCA	Oblimin	5
1983	Zuckerman et al	Exploratory	Simple structure	132	536	Principal Axis	Varimax	5
1988	Watson et al	Exploratory	Simple structure	20	600*	PFA	Varimax	2
1993	Gauvin & Rejeski	Exploratory	Simple structure	12	256	PFA	Varimax	4
2000	Schimmack & Grob	Confirmatory	Simple structure	84	207	-	-	3
2011	Yik et al	Confirmatory	Circumplex	191	535	Maximum Likelihood	N/A	2
2013	Scherer et al	Exploratory	Circumplex	20	174**	PCA	N/A	4
2016	Harmon-Jones et al	Exploratory	Simple structure	60	439	Maximum Likelihood	Varimax	7

Note. *Watson et al (1988) sample size varied according to time instructions and it was specified by the authors that some participants answered more than one instruction. Therefore, as the authors did not provide the exact total number accounting for repetitions, the sample size for each time instruction was: 660 (moment), 657 (today), 1002 (past few days), 586 (past few weeks), 649 (year), and 663 (general). **Total sample from UK, Switzerland, Belgium, China, Germany, Estonia, Finland, Italy, Japan, and Poland.

By looking at the dimensions proposed in Table 1, it is clear that valence is present in all measures. Some researchers named it happiness (Harmon-Jones, Bastian, & Harmon-Jones, 2016), and others divide it as positive and negative affect (Diener et al., 1985; Watson et al., 1988; Zuckerman, Lubin, & Rinck, 1983). Consequently, the main differences between the instruments regard the second dimension and the possibility of a third dimension.

In general, the second dimension is activation (Betella & Verschure, 2016; Lang et al., 2005; Mehrabian & Russell, 1974; Russell, 1980; Russell et al., 1989; Sjöberg, Svensson, & Persson, 1979; Yik et al., 2011). However, some authors differ in its interpretation. Thayer (1978) presented both valence and activation as the basis, but the dimensions chosen for his measure were actually combinations of these dimensions: energetic arousal, tension arousal. Scherer and colleagues (2013) presented power as the second dimension, instead of activation, and Diener and colleagues (1985) presented a dimension called intensity.

These interpretations varied mainly because of the theory applied by the researchers and by the evidence that they collected for it. To facilitate the validity review process, the tests will be further categorised according to whether validity evidence has been presented and the number of theoretical dimensions.

3.2.1 Tests with content and external criteria validity evidence

Some core affect tests that were not validated in terms of their internal structure, instead they were validated with external criteria. These tests are the Affect Grid (Russell et al., 1989), the International Affective Picture System (IAPS) with the Self-Assessment Manikin (SAM) scales (Lang et al., 2005), the Affective Slider (Betella & Verschure, 2016), and the core affect test of Diener and colleagues (1985).

For example, the Affect Grid is a 9x9 grid with the axis of activation and valence. It was validated using external criteria: facial expressions, emotion-related words, and PANAS. Similarly, the single-stimulus sliders of valence and arousal from Betella and Verschure (2016) were validated based on its relationships with the IAPS and SAM picture-based scales of valence and arousal, which in turn were tested mainly by verifying their descriptive statistics and their content (Lang et al., 2005).

Diener and colleagues (1985) hypothesised two extra dimensions, frequency and intensity. The frequency dimension refers to the percentage of times the individual experienced positive affect over negative affect, also known as the predominance of happy days. The intensity dimension refers to how intense the dominant affect was, and this dimension is estimated by calculating the mean of positive affect items on predominantly happy days and the mean of negative affect items on predominantly unhappy days. However, they did not provide empirical evidence for this structure.

Overall, although content and criterion-validity evidence were pursued in the above measures, it is unsafe to conclude that these tests measure core affect, since the external criteria validity evidence were based on tests that did not have internal structure established.

3.2.2 Tests with two theoretical dimensions

Tests with two theoretical dimensions often have a better fit with three-factor solutions empirically. Factor analysis and PCA results from Thayer (1978), Russell (1980), Watson and colleagues (1988), and Scherer and colleagues (2013) exemplify this issue.

For example, Thayer (1978) advocates the use of his measure with two activation-related dimensions; however, the two-dimensional solution was only achieved as a second-order solution with four first-order factors. The first second-order factor includes general activation and deactivation-sleep, and the second second-order factor includes high activation and general deactivation. Similarly, Scherer and colleagues (2013) found that a four-component solution fitted better their data, but they only interpreted the first two components (valence and power), which are in accordance with the theory.

In Russell's research (1980), he expected a two-component solution, but PCA results indicated the extraction of five components, based on the criterion of eigenvalues greater than 1. Component 1 was valence and component 2 was activation, as expected. On the side of non-expected components, component 3 loaded mainly low activation items, component 4 loaded the items "angry" and "annoyed", and component 5 loaded the items "astonished", "afraid", and "bored". The author then proposed that response styles (e.g. acquiescence) were present in the data and the extra components were related to response styles.

Yik and colleagues (2011) worked with the circumplex theory (12-Point Affect Circumplex model; 12-PAC) and they performed a confirmatory analysis with the software "CIRCUM", which applies Browne's model (1992). Across their studies, the 12-PAC model yielded rather unsatisfactory RMSEA values between .08 and .11, and good CFI between .96 and .98. The authors mentioned the possibility of responses biases and a possible method factor, but no solution was proposed.

Besides response styles, tests such as PANAS present problems related to the overall representation of core affect. When PANAS was optimised from its previous version with 60 items, only 20 items were chosen, forcing an orthogonal two-factor structure in order to have a scale with 10 items for Positive Affect (PA) and 10 items for Negative Affect (NA) (Watson et al., 1988). As a result, the factor loadings matrix tends to have clear orthogonal factors. However, if each factor of PANAS represents an extreme pole of the same continuum (namely, valence), PANAS structure might be better represented by one bipolar dimension.

3.2.3 Tests with three or more theoretical dimensions

Harmon-Jones and colleagues (2016), Sjöberg and colleagues (1979), Schimmack and Grob (2000), Mehrabian and Russell (1974), and Zuckerman and colleagues (1983) proposed models with three or more dimensions. Mehrabian and Russell's model (1974) corresponds to three dimensions: valence, activation, and dominance. These dimensions were evaluated with one-dimensional semantic differential items. The factor loadings were easily interpretable and some cross-loadings existed in items that were influenced by two dimensions, even though it might not have been the intention to have multidimensional pairs (e.g. excited-soothed).

The model proposed by Schimmack and Grob (2000) showed a good fit. The authors discussed the relevance of a three-factor model based on poor fit of two-factor models in European research. The three dimensions proposed by them were similar to valence and activation, but they were named according to their polar extremes (P-A-T: Pleasure-Displeasure, Awake-Sleepiness, Tension-Relaxation). Among the models that they tested in the first study, the model with factor correlations freely estimated had the best fit (RMSEA = .05, CFI = .99). Interestingly, each dimension influenced three bipolar items (parcel items). Results were then replicated in a second study with an optimal measure (18 items).

Harmon-Jones and colleagues (2016) proposed a model with eight dimensions, but they decided to extract seven dimensions based on EFA (varimax rotation) results. The extracted factors were named happiness, fear/anxiety, sadness, desire, disgust, and relaxation. Interestingly, the first factor (namely, happiness) accounted for approximately three times the amount of variance of the remaining factors, loading positive and negative affect items in it. Other factors loaded less items with weaker factor loadings, if compared to the first factor.

Similarly, Sjöberg et al (1979) proposed four dimensions and extracted six factors in both studies presented. In both studies, the authors extracted more factors than theoretically intended. The main factors were called positive-negative appraisal (similar to valence), activation-deactivation, positive-negative social orientation, and control-lack of control. Similar to Harmon-Jones et al (2016), the first factor loaded most of the items (positively and negatively).

Lastly, Zuckerman and colleagues' test (Multiple Affect Adjective Check List; MAACL) (1983), which was originally validated with three dimensions (anxiety, hostility, and depression) in 1964, extracted five factors: anxiety, depression, hostility, positive affect, and sensation seeking. Interestingly, a factor interpreted as positive affect accounted for the largest proportion of variance in the analyses and had most of the items loaded on it. The sensation-seeking factor was the only factor with positive and negative factor loadings retained, while *anxiety*, *depression* and *hostility* included all other items that related to negative affect.

In the models described above, all presented a common factor related to valence (or positive affect), with most of the items loading positively or negatively on it. Yet, none of the authors attempted to model an explicit method factor in the factor solution (Maydeu-Olivares & Coffman, 2006). For example, in studies of Zuckerman et al (1983) and Harmon-Jones et al (2016), it could be investigated why most items were loading on the valence-related factor. In study by Sjöberg et al (1979), it could be investigated why two extra factors were needed. In study by Harmon-Jones (2016), it could be investigated why the first factor accounted for such a high proportion of variance and included most of the items, while this did not conform to the theoretical propositions.

3.3 Discussion

Noticeably, the structure of core affect is still a matter for debate. Differences between theoretical models and empirical data seem to arise in all models suggested, raising concerns about the measurement models of core affect.

A considerable number of researchers have based their models on results from PCA and interpreting them as if they were EFA results. Although results are similar in some cases, PCA is a formative model and factor analysis is a reflective model (Borsboom, 2005), and the assumptions behind each of this procedures should not be exchanged, because problems can arise when researchers try to reproduce the results.

Another issue is the use of linear common factor models. These models assume linearity and constant errors across the whole trait continuum, untenable assumptions when analysing categorical/ordinal data (McDonald, 2014). Given that core affect researchers mostly apply ordinal rating scales, the use of data analysis procedures that respect the scale properties could resolve some of the divergences found across the tests, as well as provide models that are more appropriate for the empirical data.

The important issue that is often mentioned in discussions of the papers but not tackled is response styles. Many agree that core affect should have a circumplex-type of structure and have two dimensions underlying the observed variables. However, most found that this was not easily confirmed with empirical data, often having to extract more factors than expected, or not having the circumplex model fitting property.

The problem of response styles (e.g. acquiescence, extreme response style) is not unique to core affect and can be found in all measures using Likert-type rating scales (Wetzel, Böhnke, & Brown, 2016). Nonetheless, core affect researchers have not yet confronted the issue. The response styles, however, could be the reason why researchers have problems to extract the number of dimensions they propose theoretically because response styles can lead to additional method-related factors (Maydeu-Olivares & Coffman, 2006). Therefore, hypothesising conceptual models for core affect is the first step out of many to developing appropriate measurement models and good instruments measuring core affect in practice.

Part II - Empirical studies

4 Study 1: Measuring and modelling core affect

4.1 Objectives

Theoretically, core affect is a complex construct, and every feeling is influenced at some level by two dimensions: valence and activation (Russell, 1980). Core affect has been analysed with exploratory and confirmatory procedures for at least 40 years, but questions about its dimensionality remain open. **Study 1 aims to explore the dimensional structure of core affect**, addressing the previously neglected psychometric problems, specifically response styles, and the confusion between formative and reflective measurement models (e.g. PCA results interpreted as factor analysis results). Other issues with core affect measurement are analysing ordinal scales as interval. Usually, this type of treatment tends to underestimate the strength of the variables' relationships, because the Pearson correlation is used instead of polychoric correlations, which are more appropriate for ordinal data (Olsson, 1979). In addition, previous core affect measures were developed with rating scales of five or more points, varying in the use or not verbal anchors, and which verbal anchors should be used. The excessive number of points in a scale and the variation in the use of verbal anchors are associated with response styles such as central tendency, acquiescence and subjective understanding of the scale points (Schwarz et al., 1991).

The first aim of the present investigation was to explore core affect's dimensionality by using methods that overcome the problems outlined above. Specifically, the first study aimed to explore the dimensional structure of core affect, verifying the circumplex models based on items previously used in studies from Watson & Tellegen (1988), Yik et al (2011), Mehrabian and Russell (1974), Thayer (1978), Scherer's Emotion Wheel (2013), and Barrett & Russell (1998). To this end, the literature was extensively reviewed, different measures and their items were categorised and a new measure was developed. In addition, a personality measure and emotion pictures were used in order to verify the convergent and divergent validity evidence between core affect, personality and emotions.

4.2 Method

4.2.1 Participants

The sample (N = 422) was collected online via social media (Facebook), where participants were invited to participate in the research. Participants were recruited from numerous Facebook groups. Prior authorisation of group administrators was asked before posting the invitation in the group timeline. Participants that entered the survey link had to read the information sheet and to provide their consent to participate in the research. The majority of the participants were women (74%). The age mean was 36.2 years (*SD* = 11.8 years), where the youngest participant was 18 years old and the oldest participant was 75 years old. As the questionnaire was spread via social media, there are participants from a variety of countries, but most of them are from United Kingdom (81.8%), Australia (7.8%), and United States (6.6%). Most participants answered "White" (95%) for the ethnicity question, and most participants completed a college degree (51.9%). The participants were screened to make sure they were all native English speakers.

4.2.2 Measures

Sociodemographic and emotional context questions

Participants were requested to provide information about gender, age, school level, ethnicity, marital status, where they live (country), and if English was their first language. In addition, they were asked about the situational/emotional context immediately preceding the survey: their appraisal of the day until that moment, what activity they were doing before starting the survey and if they had interacted with someone that day.

Core affect measure

The core affect measure developed for this study included 68 adjectives thought to indicate the valence and activation dimensions according to the circumplex model of Russell (Russell, 1980). Additionally, adjectives referring to the approach/avoidance dimension (Carver, 2001; Carver & Harmon-Jones, 2009) were included in order to test if a three-dimensional structure would describe core affect better. The adjectives were mapped to the dimensions based on the results of previous research (Barrett & Russell, 1998; Mehrabian & Russell, 1974; Russell et al., 1989; Scherer et al., 2013; Thayer, 1978; Thayer, 1986; Watson et al., 1988; Yik et al., 2011)[2].

A list of 345 items was created (Appendix A), and all items were allocated to the 12 anchor positions on the circumplex proposed by Yik et al. (2011) based on their activation and valence levels. Based on the coverage of the hypothesised constructs of core affect, two researchers (main researcher and supervisor) selected the 68 items to be used in the final measure (Table 3). The items were categorised as markers of the three dimensions: valence, activation, and approach/avoidance.

A rating scale was developed to be appropriate for rating the adjectives that were selected as indicators of core affect. The following questions were asked: a) do feelings described by the adjective vary in frequency (time) or intensity?; and b) how many scale points will people be able to differentiate? It was decided to use a 3-point scale with the intensity anchors "not at all", "somewhat", and "a great deal". Usually, 5-point scales

[2] The adjectives retrieved from Scherer et al. (2013) are credited to the Appendix F in the book that the author was editor (Scherer, 1988). The reference is in the *References* section of this thesis, per request of the authors.

are used to measure core affect; some of them represent agreement (Yik et al., 2011), and others intensity (Watson et al., 1988). However, too many points can cause difficulties for participants to differentiate between categories, which in turn can result in the use of extreme rating categories only, or acquiescence or central tendency (Friedman & Amoo, 1999).

Table 3 *Experimental core affect items*

Valence and Activation	Neutral	Approach	Avoidance
Pleasure (0°)	Happy, Content	Fond, Pleased	Satisfied
Activated Pleasure (30°)	Cheerful	Delighted, Hopeful, Excited	
Pleasant Activation (60°)	Euphoric	Interested, Inspired, Enthusiastic	
Activation (90°)	Aroused, Wide awake, Active	In control, Influential, Vigorous	Controlled, Influenced
Unpleasant Activation (120°)	Tense, Jittery	Angry, Irritated	Terrified, Threatened
Activated Displeasure (150°)	Anxious, Nervous	Hostile, Annoyed	Fearful, Scared, Confused, Puzzled
Displeasure (180°)	Unhappy, Miserable	Disappointed, Dissatisfied	Ashamed, Disgusted
Deactivated Displeasure (210°)	Sad, Melancholic		Hesitant, Wary, Vulnerable, Depressed
Unpleasant Deactivation (240°)	Bored, Sluggish, Tired	Anguished	Helpless, Regretful
Deactivation (270°)	Quiet, Sleepy, Still		Self-conscious
Pleasant Deactivation (300°)	Tranquil, Calm	Safe, Cared for	Relieved, Relaxed
Deactivated Pleasure (330°)	Serene, Soothed	Nostalgic	Peaceful, Humble

Note. Adjectives were categorised according to their level of valence and activation (rows) in the circumplex, and according to the Approach/Avoidance dimension (columns). In case an adjective was not assumed to be part of the Approach/Avoidance dimension, the adjective was allocated in the "Neutral" column.

NEO-PI-R

The Five Factor Model of personality (or the Big Five) has been widely used around the world (Rolland, 2002) and is often used to verify the association between core affect and personality traits (Howell & Rodzon, 2011; Kuppens et al., 2007; Letzring & Adamcik, 2015).

The personality measure adopted for this study was the NEO-PI-R (Costa & McCrae, 1992). The NEO-PI-R measures the five dimensions of personality – Extraversion, Neuroticism, Openness to Experiences, Consciousness, and Agreeableness – with 240 items and a 5-point agreement scale. The internal structure of NEO PI-R was confirmed by its authors with an exploratory analysis with principal components method and varimax rotation. The reliability of all NEO PI-R scales were assessed with the coefficient alpha, and the results varied between .56 and .81, which were considered acceptable by the authors (Costa & McCrae, 1992).

Emotions questions

To explore the emotional context, six facial expressions representing six emotions were used. The emotions questions were presented as pictures of facial expressions (Figure 6) without labels and a binary choice (Yes/No) to participants answer if they were or were not feeling the emotions presented.

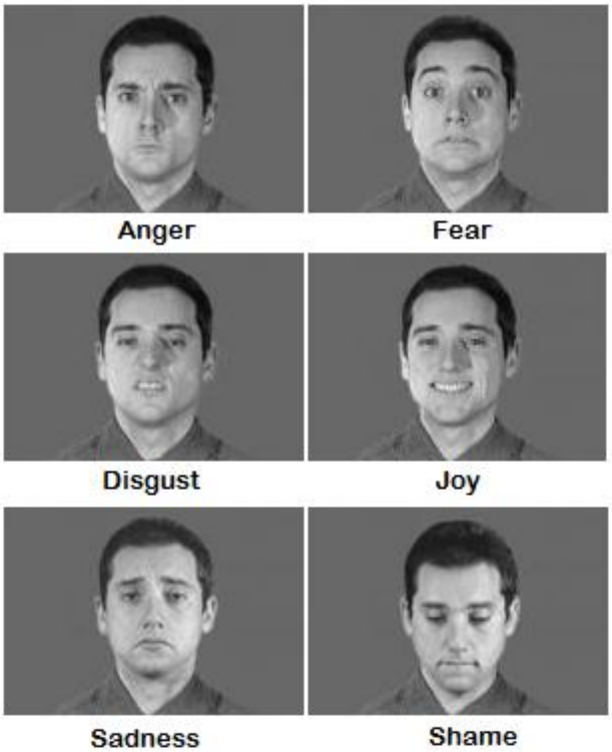


Figure 6 Facial expressions items

4.2.3 Procedures

Firstly, participants were invited to participate in the online study via social media (Facebook). Participants had to follow a survey link, and then they had to read the information sheet and provide their consent to the study. After the consent form, participants were presented with a brief instruction about the core affect measure, which read: “The next questions will be about what you are feeling and what you are doing. To answer these questions, please think about what you were doing and how you were feeling **before** you opened the questionnaire.” Following the instructions, participants were presented with the emotion’s questions, the core affect measure, the sociodemographic and momentary questions, and then the NEO-PI-R questions.

By the end of the survey, participants had access to their NEO-PI-R personality scores and then they were fully debriefed about the aim of the study. This study did not pose any significant risks, and was approved by the Ethics Committee from University of Kent.

4.2.4 Data analysis

Firstly, the data were cleaned in the SPSS software. The cleaning process involved the computation of new variables representing individual means and standard deviations. These variables were created for four sections (blocks) of the core affect measure, with 17 items each. This procedure aimed to verify data integrity (i.e. check for improbable response strings such as same response to every item, etc.). To organise the dataset, a filter variable was created in order to identify cases that would not be used in the analysis. In case a participant answered with the same category for a majority of items in more than one block, the case was then marked as invalid in the filter variable. Cases were excluded mainly because they presented higher means with lower standard deviations, or lower means with low standard deviations across all the sections, indicating the endorsement of the same response category across the items referring to very different feelings. These characteristics were verified with scatterplots of means (*x-axis)* and standard deviations (*y-axis)* and with the individual means and standard deviations section variables. Other reasons to mark participants answer as invalid involved:

- Participant did not report if he/she was a native English speaker;
- Participant presented missing data in all/most questions;
- Participant answered the questionnaire partially (e.g. personality measure was answered partially or not answered at all) in ten minutes or less;

- Participant answered the whole questionnaire (core affect measure, sociodemographic questions and personality measure) in fifteen minutes or less.

Considering these criteria, data from 14 participants was marked as invalid in the analysis of the core affect structure, resulting in a sample of 422 native English speakers. Data from 20 more participants was marked as invalid when personality variables were analysed.

The first analysis performed was an Exploratory Factor Analysis (EFA) with categorical variables based on their polychoric correlations in Mplus 7. The estimator was the Diagonally Weighted Least Squares with robust standard errors (or WLSMV in Mplus), which does not make normal distribution assumption for the observed variables and is designed for categorical data (Muthén, Du Toit, & Spisic, 1997).

The number of factors was decided based on the scree test of Cattell, RMSEA (Browne & Cudeck, 1993), CFI (Bentler, 1990) and SRMR (Hu & Bentler, 1999) results. The cut-off points applied were: RMSEA ≤ .05 for good fit, and ≤ .08 for acceptable fit (Browne & Cudeck, 1993), CFI ≥ .90 (Bentler, 1990) and SRMR ≤ .08 (Hu & Bentler, 1999). When analysing the scree plot, only the factors before the breaking point, or the so-called “elbow”, were considered.

Initially, the EFA solution was rotated with Geomin (oblique) method allowing factors to correlate with one another. If the factors are truly uncorrelated, oblique rotations reproduce this structure well (Costello & Osborne, 2005). The Geomin rotation is considered to handle data well with simple and complex factorial structures (Asparouhov & Muthén, 2009), and core affect data is known to be factorially complex.

The factor loadings were plotted in order to verify if they spread around the axes in a circle-like pattern. The loadings plot is a useful tool to verify circumplex structures in exploratory settings. Another way to understand the circumplex structure is through the correlation matrix pattern. To facilitate the verification, correlation matrices can be plotted as heat maps (Acton & Revelle, 2004). Correlations near to −1 are highlighted red, correlations near to 0 were white and correlations near to +1 are blue. For a perfect circumplex, it is expected that the blue colour is stronger near the main diagonal (corresponding to strong positive correlations between neighbouring items). Correlations are expected to fade away to white (corresponding to near-zero correlations between one-dimensional items indicating the different dimensions), until the colour turns red (corresponding to the strong negative correlations between items from the opposite sides of the circumplex). This correlation pattern is often compared to a wave. In order to use the heat maps, there must be an *a priori* assumption about where each item is located in the circumplex. As this "wave" pattern represents the adjacent points in the circumplex, the items must be organised accordingly. The core affect adjectives were organised according to Table 4.

Following the EFA, the following models were tested in order to verify the circumplex features:

a) Exploratory factor analysis with Target rotation: the EFA was performed assuming orthogonal factors and rotated to the target factor loadings presented in Table 4. To rotate to a target, a $p \times m$ target matrix with specified and non-specified elements is required (Browne, 2001), where specified elements (targets) are zero factor loadings. This essentially exploratory method has an advantage over Confirmatory Factor Analysis (CFA) in that the targets are specified to be as close to 0 as possible without being actually fixed at 0. An advantage over EFA, on the other hand, is that this rotation provides control over the final structure according to the construct's theory. The targets in this study were set to explore the content of the third factor and to confirm if the two first factors would be valence and activation. The structure was assumed orthogonal because, in theory, the circumplex axes are independent from each other.

b) Random Intercept item factor model (RI model) (Maydeu-Olivares & Coffman, 2006): this model was tested to verify if an additional factor affecting all items uniformly is present. In this model, the individual tendency to overrate is modelled by allowing the item intercept to vary between participants. This varying intercept (Random Intercept) is modelled as an additional factor affecting all items uniformly (with equal factor loadings) to the expected structure. Operationally, this model allows researchers to control for uniform biases (e.g. acquiescence, or any other method-related uniform bias). This model is a confirmatory factor model, and the Random Intercept factor is assumed uncorrelated with the rest of the factors.

Table 4 *Hypothetical core affect target structure*

Item number	Items	Valence	Activation	Approach/ Avoidance
AF1	Happy	+	0	0
AF41	Pleased	+	0	+
AF62	Relieved	+	–	–
AF23	Fond	+	0	+
AF56	Satisfied	+	0	–
AF17	Delighted	+	+	+
AF36	Interested	+	+	+
AF30	Inspired	+	+	+
AF18	Hopeful	+	+	+
AF66	Cheerful	+	+	0
AF49	Enthusiastic	+	+	+
AF25	Excited	+	+	+
AF16	Influential	0	+	+
AF5	Euphoric	+	+	0
AF13	Wide awake	0	+	0
AF57	In control	0	+	+
AF3	Influenced	0	+	–

AF32	Controlled	0	+	–
AF45	Active	0	+	0
AF39	Vigorous	0	+	+
AF52	Aroused	0	+	0
AF38	Threatened	–	+	–
AF35	Terrified	–	+	–
AF34	Scared	–	+	–
AF63	Nervous	–	+	0
AF55	Tense	–	+	0
AF19	Anxious	–	+	0
AF12	Jittery	–	+	0
AF27	Fearful	–	+	–
AF2	Angry	–	+	+
AF50	Irritated	–	+	+
AF8	Anguished	–	–	+
AF65	Hostile	–	+	+
AF15	Annoyed	–	+	+
AF26	Ashamed	–	0	–
AF67	Disgusted	–	0	–
AF33	Regretful	–	–	–
AF31	Confused	–	+	–
AF7	Puzzled	0	–	+
AF21	Dissatisfied	–	0	+
AF59	Disappointed	–	0	+
AF53	Unhappy	–	0	0
AF42	Hesitant	0	–	–
AF6	Wary	0	–	–
AF51	Sad	–	–	0
AF54	Depressed	–	–	-
AF46	Helpless	–	–	–
AF61	Miserable	–	0	0
AF68	Melancholic	–	–	0
AF4	Nostalgic	+	–	+
AF47	Vulnerable	–	–	-
AF20	Bored	–	–	0
AF24	Sluggish	–	–	0
AF22	Tired	–	–	0
AF64	Sleepy	0	–	0
AF40	Self-conscious	0	–	-
AF60	Quiet	0	–	0
AF10	Still	0	–	0
AF9	Calm	+	–	0

AF44	Tranquil	+	–	0
AF43	Relaxed	+	–	-
AF28	Peaceful	+	–	-
AF14	Serene	+	–	0
AF29	Soothed	+	–	0
AF37	Safe	+	–	+
AF11	Content	+	0	0
AF48	Cared for	+	–	+
AF58	Humble	+	–	–

Empirical reliability coefficients were calculated using the estimated scores from the final factor model. Scores were derived using the Bayesian estimator *Expected a Posteriori* (EAP). To calculate the *empirical reliability* of each dimension, the variance of the EAP scores and the error variance σ^2_{error} were computed. The error variance was estimated with by averaging the squared standard errors provided by Mplus (Brown & Croudace, 2015). Additionally, the variance of the EAP scores can be calculated from the scores or taken from the Mplus output for the estimated factor scores. As suggested in Du Toit (2003), the *empirical reliability* coefficient (ρ) for Bayesian EAP scores, which are regressed estimates of latent traits, can be calculated as:

$$\rho = \frac{\bar{\sigma}^2_{EAP}}{\bar{\sigma}^2_{EAP} + \bar{\sigma}^2_{error}} \qquad (12)$$

Therefore, equation 12 assumes that reliability (ρ) is the proportion of variance in the observed score due to true score (Brown & Croudace, 2015; McDonald, 2014). It should be noted that when item response models are applied, the empirical reliability coefficient is just an approximation of the average reliability of the test, given that the reliability will vary according to different levels of error for the latent trait scores.

Lastly, convergent and discriminant validity correlations were calculated. Core affect scores used for these calculations were estimated based on the model of choice and with EAP estimator. NEO-PI-R scores were calculated as sum scores, as instructed in the manual (Costa & McCrae, 1992). Emotions scores were the participants' answers to the pictures; therefore, each emotion had a score of 0 (no) or 1 (yes). Score variables were merged in one dataset and the correlations between the constructs were calculated based on the type of data (categorical and continuous) (Table 5). To overcome the problem of having near-zero average correlations because of the positive and negative signs, absolute values were calculated in addition to the raw values.

Table 5 *Types of correlation applied in convergent and discriminant validity analysis*

Variables	Valence	Activation
Valence	-	-
Activation	Pearson	-
Neuroticism	Pearson	Pearson
Extraversion	Pearson	Pearson
Openness	Pearson	Pearson
Agreeableness	Pearson	Pearson
Consciousness	Pearson	Pearson
Anger	Biserial	Biserial
Happiness	Biserial	Biserial
Sadness	Biserial	Biserial
Shame	Biserial	Biserial
Fear	Biserial	Biserial
Disgust	Biserial	Biserial

4.3 Results

4.3.1 Construct validity

4.3.1.1 Exploratory Factor Analysis

The scree plot in Figure 7 suggested two major factors and possibly a third factor underlying the 68 adjectives.

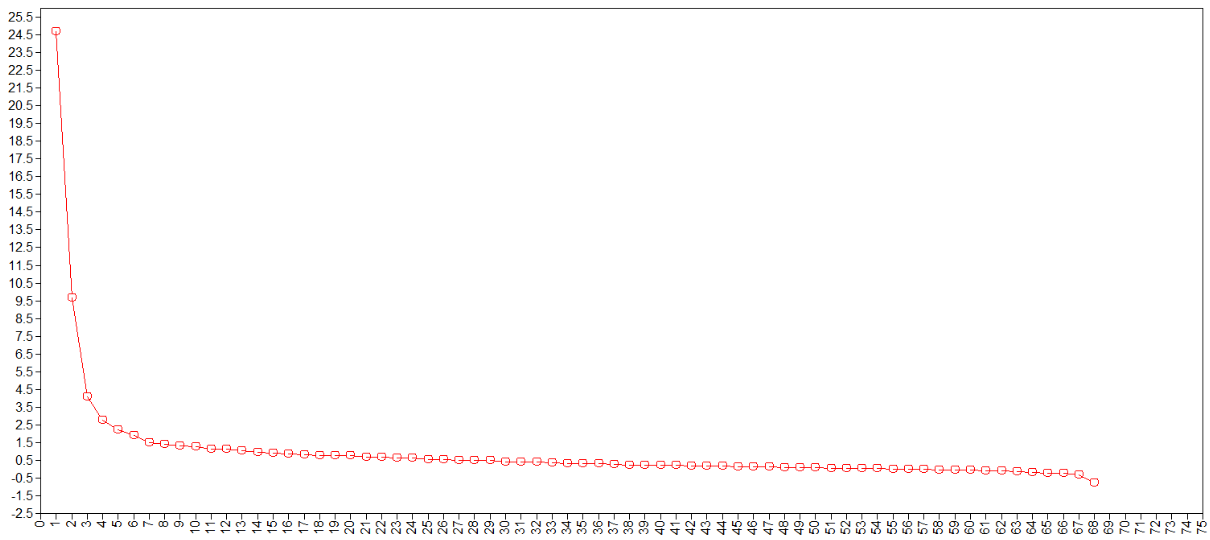


Figure 7 Study 1 - Scree plot

Goodness of fit results for models with one, two, three, and four factors are presented in Table 6.

Table 6 *Summary of model fit results*

	Models			
	1 factor	2 factor	3 factors	4 factors
Number of parameters	68	135	201	266
χ^2	7195.1	4649.56	3137.42	2703.15
Degrees of freedom	2210	2143	2077	2012
p-value	< .01	< .01	< .01	< .01
RMSEA	.073 (.0001)	.053 (.018)	.035 (1)	.029 (1)
RMSEA CI 90%	.071-.075	.051-.055	.032-.037	.026- .031
CFI	.788	.893	.955	.971
SRMR	.168	.092	.073	.063

Note. N=422.

Clearly, the one-dimensional model does not fit the data. The two-dimensional model fits better but only adequately, the three-dimensional model fits well, while the four-dimensional model is probably over-fitting. By analysing the factor loadings from the one-, two-, and three-factor models, some interesting features were noticed. Firstly, the single factor in the one-factor model is Valence, with the “marker” item (most salient) being “unhappy” (λ = .94). In the two-factor model, the first factor refers to negative affect and the second factor refers to positive affect. Factors are correlated negatively (r = − .27, p < .05). The marker items are "fearful" (λ = .94) and "enthusiastic" (λ = .84) for factor 1 and factor 2, respectively.

The three-factor model presents the same pattern as the two-factor model for the first two factors (positive and negative affect), and the third factor is characterised predominantly by items describing low activation. The marker items for the 3-factor model are "terrified" (λ = .98), "enthusiastic" (λ = .88), and "sleepy" (λ = .77), respectively. In this model, factor 1 correlates negatively with factor 2 (r = − .336, p < .05) and factor 2 correlates positively with factor 3 (r = .211, p < .05), but there is no significant correlation between factor 1 and factor 3.

Table 7 *Standardised factor loadings from EFA with GEOMIN oblique rotation*

Models	1 factor	2 factors		3 factors		
Adjectives	1	1	2	1	2	3
Happy	**-.809**	**-.411**	**.654**	**-.496**	**.549**	.105
Pleased	**-.757**	-.25	**.727**	-.315	**.671**	.05
Relieved	**-.387**	.125	**.672**	-.031	**.496**	**.378**
Fond	**-.417**	.1	**.678**	-.024	**.551**	.284
Satisfied	**-.725**	-.275	**.68**	**-.369**	**.573**	.144
Delighted	**-.721**	-.238	**.701**	-.278	**.681**	-.016
Interested	**-.49**	-.085	**.611**	-.116	**.609**	-.001
Inspired	**-.422**	.18	**.758**	.12	**.737**	.098
Hopeful	**-.335**	.176	**.671**	.121	**.652**	.102
Cheerful	**-.829**	**-.394**	**.672**	**-.441**	**.629**	-.009
Enthusiastic	**-.682**	-.034	**.845**	-.055	**.878**	-.069
Excited	**-.484**	.152	**.798**	.127	**.833**	-.014
Influential	-.298	.153	**.596**	.136	**.623**	-.003
Euphoric	**-.481**	.018	**.664**	-.003	**.686**	-.018
Wide awake	**-.384**	-.14	**.393**	-.007	**.572**	**-.39**
Active	**-.519**	-.01	**.684**	.042	.801	-.241
Vigorous	-.205	.303	**.65**	**.328**	**.749**	-.112
Aroused	-.232	.166	**.519**	.133	**.523**	.053
Threatened	**.858**	**.881**	-.001	**.944**	.152	-.082
Scared	**.8**	**.922**	.195	**.965**	**.36**	-.071
Terrified	**.935**	**.88**	-.194	**.982**	.024	-.198
Nervous	**.768**	**.85**	.083	**.916**	.26	-.114

Tense	**.794**	**.864**	.018	**.888**	.114	.053
Anxious	**.771**	**.886**	.123	**.913**	.237	.023
Jittery	**.665**	**.714**	-.004	**.776**	.147	-.092
Fearful	**.82**	**.937**	.205	**.98**	**.363**	-.058
Angry	**.703**	**.748**	-.011	**.721**	-.006	.171
Irritated	**.778**	**.771**	-.103	**.731**	-.119	.212
Anguished	**.785**	**.792**	-.083	**.837**	.032	-.011
Hostile	**.766**	**.729**	-.166	**.757**	-.089	.038
Annoyed	**.716**	**.707**	-.113	**.67**	-.13	.191
Ashamed	**.663**	**.797**	.188	**.788**	.238	.122
Disgusted	**.646**	**.624**	-.129	**.651**	-.061	.025
Regretful	**.725**	**.843**	.154	**.793**	.144	.244
Confused	**.691**	**.832**	.177	**.861**	.291	.01
Wary	**.496**	**.601**	.077	**.58**	.087	.139
Puzzled	**.353**	**.532**	.211	**.54**	.274	.026
Controlled	-.103	.045	.214	-.049	.088	.246
Dissatisfied	**.749**	**.785**	-.044	**.751**	-.048	.204
Self-conscious	**.422**	**.593**	.172	**.549**	.155	.195
Disappointed	**.812**	**.813**	-.079	**.79**	-.066	.17
Unhappy	**.937**	**.864**	-.218	**.834**	-.213	.198
Hesitant	**.597**	**.704**	.096	**.694**	.131	.121
Sad	**.838**	**.793**	-.174	**.764**	-.174	.196
Depressed	**.851**	**.796**	-.19	**.766**	-.192	.198
Helpless	**.797**	**.812**	-.063	**.837**	.02	.049
Influenced	-.005	**.378**	**.499**	**.352**	**.522**	.07
Miserable	**.901**	**.839**	-.211	**.832**	-.173	.142
Melancholic	**.558**	**.672**	.089	**.584**	.01	**.325**
Nostalgic	.06	**.413**	**.439**	**.337**	**.384**	.223
Vulnerable	**.714**	**.795**	.055	**.786**	.095	.136
Bored	.275	.226	-.12	.132	-.254	.297
Sluggish	**.492**	**.443**	-.167	.232	**-.399**	**.597**
Tired	**.502**	**.392**	-.258	.092	**-.539**	**.72**
Sleepy	**.453**	**.344**	-.25	.003	**-.565**	**.775**
Quiet	-.005	.083	.119	-.089	-.133	**.491**
Still	**-.427**	-.252	.318	**-.441**	-.006	**.48**
Calm	**-.676**	**-.482**	**.393**	**-.665**	.06	**.431**
Tranquil	**-.746**	**-.356**	**.63**	**-.56**	.285	**.488**
Relaxed	**-.756**	**-.47**	**.521**	**-.648**	.205	**.406**
Peaceful	**-.762**	**-.441**	**.544**	**-.634**	.213	**.434**
Serene	**-.658**	-.312	**.552**	**-.459**	**.331**	.318

Soothed	**-.591**	-.141	**.669**	-.316	**.429**	**.408**
Safe	**-.556**	-.309	**.428**	**-.433**	.244	.256
Content	**-.716**	**-.481**	**.445**	**-.598**	.259	.216
Cared for	**-.389**	-.014	**.522**	-.133	**.381**	.267
In control	**-.628**	**-.337**	**.504**	**-.403**	**.421**	.08
Humble	-.16	.274	**.568**	.108	**.368**	.456

Note. Factor loadings equal or greater than .32 are in boldface. N=422.

The preliminary interpretation of factor loadings shows that, overall, the factor structure resembles core affect's dimensions: valence and activation. In all factor solutions, adjectives load in each factor mainly according to their valence. In the two-factor solution, factors resemble positive and negative affect. The three-factor solution has a similar pattern for the first and second factor; however, the third factor has low-activation adjectives loading in it.

Because the three-factor model fits well and is substantially better than the two-factor model according to all fit indices, there may be an approach/avoidance dimension as proposed by Carver (2001), or a separate factor accounting for response styles (method factor), as previously suggested in the literature (Russell, 1980; Scherer et al., 2013; Yik et al., 2011). In order to further the analyses with the three-factor model, the predominance of Valence-related items in two factors (positive and negative feelings separated) has to be considered. Two hypotheses can be tested in accordance with the three-factor structure:

a) Core affect has three substantive dimensions: valence, activation and approach/avoidance;
b) Core affect is a two-dimensional model in theory, but when measured empirically, it requires a third factor to account for some method factor (possibly related to acquiescence).

If the first hypothesis is true, the predominance of valence items across two factors can be understood as a problem of a factor rotation that is designed to find a simple structure. To overcome this problem, the application of targets according to Table 4 should clarify the underlying factor loadings structure and allow verifying if the third factor can be interpreted as approach/avoidance.

If the second hypothesis is true, the third factor should not be related to any substantive attribute (such as approach/avoidance), but to a method factor. To test this hypothesis, the Random-Intercept model can be applied to control for individual usage of the response scale (Maydeu-Olivares & Coffman, 2006). It is especially interesting to test this hypothesis because previous research has raised the issue about non-controlled variance due to responses biases (e.g. central tendency, acquiescence, social desirability) (Yik et al., 2011) but this has not been done to date or to the knowledge of the author.

4.3.1.2 Hypothesis 1: Exploratory Factor model with Target rotation

To confirm the possibility of a third factor representing the Approach/Avoidance dimension, the target rotation was performed based on targets from Table 4. The standardised factor loadings are shown in Table 8.

The marker items for factors 1, 2 and 3 are “happy” (λ= .80), “wide awake” (λ= .50) and “excited” (λ= .64), respectively. The first factor retains the stronger factor loadings and adjectives are spread according to positive and negative affect, which suggests that this is the valence-related dimension. The second factor has weaker factor loadings but resembles the activation-related dimension. The third factor has only positive factor loadings and does not resemble the Approach/Avoidance dimension.

The predominance of positive factor loadings in a factor is not expect for core affect, given the dimensions are hypothesised to be bipolar.

Table 8 *Standardised EFA with Target orthogonal rotation*

	Factors		
Adjectives	1	2	3
Happy	**.805**	.072	**.321**
Pleased	**.702**	.164	**.430**
Relieved	**.343**	-.140	**.583**
Fond	**.365**	-.046	**.568**
Satisfied	**.700**	.055	**.400**
Delighted	**.670**	.222	**.409**
Interested	**.473**	.194	**.412**
Inspired	**.329**	.170	**.635**
Hopeful	.277	.139	**.575**
Cheerful	**.795**	.191	**.327**
Enthusiastic	**.571**	**.340**	**.586**
Excited	**.373**	.291	**.640**
Influential	.241	.214	**.495**
Euphoric	**.410**	.239	**.491**
Wide awake	**.328**	**.498**	.182
Active	**.425**	**.457**	.454
Vigorous	.127	**.352**	**.578**
Aroused	.186	.136	**.455**
Threatened	**-.815**	.163	**.339**
Scared	**-.711**	.224	**.504**
Terrified	**-.933**	.215	.187
Nervous	**-.726**	.223	**.390**
Tense	**-.777**	.041	**.376**
Anxious	**-.730**	.106	**.455**
Jittery	**-.658**	.161	.280
Fearful	**-.723**	.215	**.519**
Angry	**-.683**	-.101	.310
Irritated	**-.759**	-.171	.255
Anguished	**-.781**	.062	.263
Hostile	**-.774**	-.021	.180
Annoyed	**-.708**	-.160	.217
Ashamed	**-.605**	.021	**.479**
Disgusted	**-.657**	-.006	.161
Regretful	-.66	-.107	**.485**
Confused	**-.649**	.131	**.472**

Wary	**-.495**	-.053	.318
Puzzled	**-.352**	.097	**.375**
Controlled	.111	-.169	.198
Dissatisfied	**-.735**	-.14	.308
Self-conscious	**-.422**	-.076	**.392**
Disappointed	**-.785**	-.116	.286
Unhappy	**-.913**	-.185	.207
Hesitant	**-.578**	-.018	**.372**
Sad	**-.823**	-.174	.214
Depressed	**-.836**	-.182	.203
Helpless	**-.785**	.010	.290
Influenced	-.023	.134	**.528**
Miserable	**-.89**	-.127	.203
Melancholic	**-.536**	-.226	**.375**
Nostalgic	-.082	-.034	**.515**
Vulnerable	**-.687**	-.037	**.382**
Bored	-.263	-.313	.032
Sluggish	**-.429**	**-.594**	.135
Tired	**-.373**	**-.745**	.066
Sleepy	-.301	**-.802**	.054
Quiet	.030	**-.439**	.173
Still	**.441**	**-.406**	.156
Calm	**.692**	**-.357**	.109
Tranquil	**.728**	**-.323**	**.340**
Relaxed	**.760**	-.289	.206
Peaceful	**.753**	-.308	.233
Serene	**.650**	-.168	.300
Soothed	**.577**	-.200	**.468**
Safe	**.571**	-.145	.207
Content	**.735**	-.117	.145
Cared for	**.366**	-.094	**.402**
In control	**.639**	.054	.239
Humble	.138	-.237	**.577**

Note. Factor loadings equal or greater than .32 are in boldface. N=422.

The results do not support the hypothesis that the third dimension is Approach/Avoidance. However, the factor loadings for the third factor are significant and large, which means that some significant source of variance in responses to the adjectives is not being accounted for. Considering results from this analysis and other core affect measures in the literature, the most plausible interpretation is that the third factor corresponds to individual variation due to response biases.

Since the approach/avoidance dimension could not be confirmed, the items developed specifically to indicate this dimension were excluded from further analysis. The excluded items were: *interested*, *terrified*, *threatened*, *angry*, *ashamed*, *disgusted*, *regretful*, *wary*, *puzzled*, *self-conscious*, *vulnerable*, *hesitant*, *nostalgic*, *relieved*, *cared for*, *fond*, *influenced*, *controlled*, *in control*, *humble* and *influential.*

4.3.1.3 Hypothesis 2: Random Intercept Item Factor model

Some respondents tend to endorse certain response categories, such as preferring extreme response categories (Extreme Response Style; ERS), midpoint response categories (Midpoint Response Style; MRS), or agreement response categories (Acquiescence Response Style; ARS) (Wetzel et al., 2016). These systematic response styles are shown to be remarkably stable over time, affecting mainly rating scales in both single and longitudinal assessments (Wetzel, Lüdtke, Zettler, & Böhnke, 2016). If not accounted for, response styles affect the factor structure, and consequently, the scores derived based on the factor solution. Thus, the use of the Random Intercept item factor model comes as suggestion for improvement in self-report tests and the interpretations derived from their results (Maydeu-Olivares & Coffman, 2006).

Firstly, the model with 47 items (Approach/Avoidance items excluded) was tested using the Maximum Likelihood estimator with robust standard errors (MLR in Mplus). The factor metric for valence was set by fixing the item *happy* at 1. The factor metric of activation was set by fixing the item *active* at 1. The random intercept (RI) factor had all factor loadings fixed at 1 (Maydeu-Olivares & Coffman, 2006). Factors' correlations were set at 0. Thus, all factor variances were freely estimated. This step was necessary to understand the size of the factor variances, and to verify the significance of the RI factor variance.

Valence factor had a variance of 6.897 (*SE* = 1.456, *z* = 4.737, *p* < .001). Activation factor had a variance of 3.255 (*SE* = 1.25, *z* =3.174, *p* = .002). The random intercept factor had variance of 0.871 (*SE* = .871, *z* = .104, *p* < .001). Compared to valence and activation, the variance of random intercept factor is substantially lower but still highly significant, which suggests that the third factor related to acquiescence is important.

To identify the model when applying the WLSMV estimator, further constraints were required in the factor loadings. To set the factor metrics, the valence and activation factor variances were set at 1, factors correlations were set at 0, factor loadings of *active*, *aroused*, *quiet*, and *still* were set at 0 on valence and the factor loadings of *dissatisfied*, *happy*, *pleased*, and *unhappy* were set at 0 on activation.

The RI model with WLSMV estimator (χ^2= 3072.632, *df* = 994, *p* < .001) had an acceptable fit (RMSEA = .07, CFI = .90). The random intercept factor had a variance of .296 (*SE* = .028, *z* = 10.66, *p* < .001). The standardised factor structure of this model is presented in Table 9.

Table 9 *Standardised factor loadings of Random Intercept model*

Adjectives	Valence	Activation	RI
Happy	**.811**	0	.279
Pleased	**.724**	0	.329
Satisfied	**.709**	.103	.333
Cheerful	**.816**	.181	.262

Delighted	**.693**	.287	.316
Enthusiastic	**.633**	**.394**	.319
Inspired	**.385**	**.328**	.412
Hopeful	**.318**	.305	.429
Excited	**.456**	**.431**	.372
Euphoric	**.461**	**.360**	.388
Wide awake	**.424**	**.557**	.341
Vigorous	.195	**.473**	.411
Active	0	**.474**	.421
Aroused	0	.227	.465
Jittery	**-.624**	**.398**	.321
Scared	**-.640**	**.527**	.268
Fearful	**-.661**	**.517**	.260
Anxious	**-.687**	**.400**	.290
Nervous	**-.664**	**.493**	.269
Tense	**-.756**	**.321**	.273
Irritate	**-.761**	.074	.308
Anguished	**-.759**	.294	.277
Hostile	**-.756**	.190	.299
Annoyed	**-.706**	.044	.338
Confused	**-.592**	**.384**	.338
Dissatisfied	**-.747**	0	.318
Disappointed	**-.787**	.131	.288
Unhappy	**-.935**	0	.169
Miserable	**-.904**	.122	.196
Depressed	**-.857**	.059	.245
Sad	**-.843**	.054	.256
Helpless	**-.760**	.245	.288
Melancholic	**-.553**	.033	.398
Sluggish	**-.523**	**-.452**	.345
Tired	**-.495**	**-.611**	.295
Sleepy	**-.433**	**-.682**	.282
Bored	**-.318**	**-.316**	.427
Still	0	**-.542**	.402
Quiet	0	**-.368**	.444
Safe	**.529**	-.153	.399
Soothed	**.573**	-.064	.391
Calm	**.624**	**-.425**	.313
Tranquil	**.684**	-.233	.330
Relaxed	**.708**	-.301	.305
Peaceful	**.709**	-.292	.307

Serene	**.636**	-.129	.364
Content	**.718**	-.194	.320

Note. Factor loadings equal or greater than .32 are in boldface. RI = Random-Intercept factor. N=422.

The graphical representation of these loadings (*loadings plot*) is presented in Figure 8. Considering that the RI factor loadings were all fixed 1, there is no point in plotting them. Thus, only factors loadings of valence and activation were plotted. The factor loadings spread out nicely around the two axes, resembling a circle.

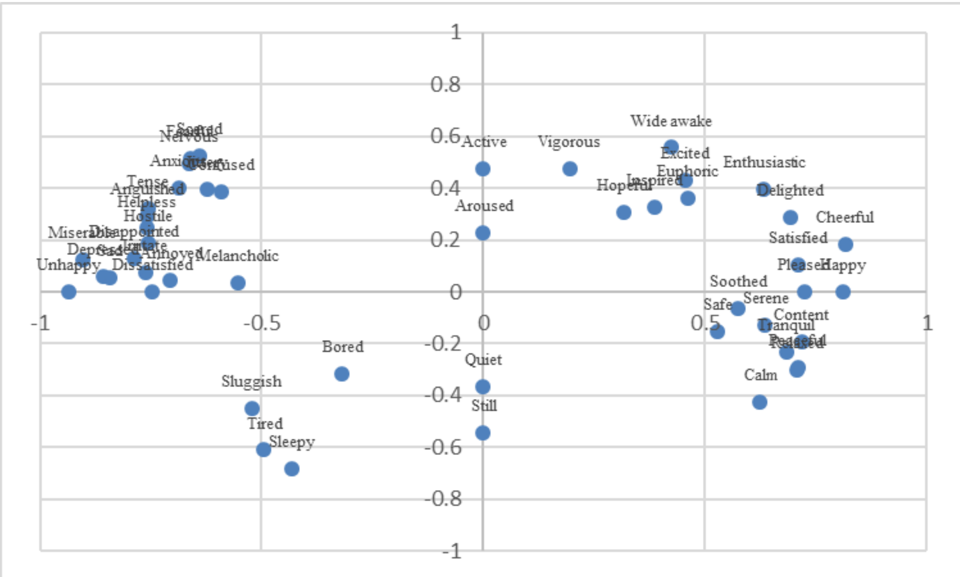


Figure 8 Loadings plot of the second RI model

4.3.1.4 Circumplexity of core affect

To verify the circumplexity of the adjective data, the sample *polychoric* correlations were plotted as a heat map. The colours in the correlation matrix help identify possible patterns in the 47x47 correlation matrix in Figure 9. The order of the adjectives in the following matrices is the same order as in Table 9.

According to Browne (1992), the true correlational structure can be a circumplex, but given the measurement error, the sample correlation matrix often resembles a *quasi*-circumplex (i.e. a circumplex with deviations). The pattern seen in Figure 9 resembles a pattern with blocks. Considering that the two first factors relate to the positive and negative poles of valence and this is possibly related to response styles, the pattern of the correlations reflect these deviations.

Considering the "block" pattern of the correlation matrix, the unconstrained circumplex model was tested; thus, allowing for quasi-circumplex structure. A polychoric correlation matrix was estimated with the package *qgraph* (function *cor.auto*). To verify the circumplexity of the data, Browne's model (1992) was tested with package *CircE*. The model uses the *Maximum Likelihood* (ML) estimator. Starting values were given using *Image Factor Analysis* (IFA). Equal spacing and equal communalities were not required. The minimum correlation coefficient ($\rho_{180°}$) was freely estimated. Model fit indices of the models and values of β_0 and β_k are presented in Table 10 and Table 11. To the knowledge of the author, there is no common understanding about the number of m elementary components to describe core affect, thus, options of $m \leq 6$ were explored.

	HAPPY	PLEASED	SATISFIE	CHEERFU	DELIGHT	ENTHUSI	INSPIRE	HOPEFU	EXCITED	EUPHOR	WIDEAW	VIGOROU	ACTIVE	AROUSE	JITTERY	SCARED	FEARFUL	ANXIOUS	NERVOU	TENSE	IRRITATE	ANGUISH	HOSTILE	ANNOYE	CONFUS	DISSATI	DISAPP	UNHAPP	MISERAB	DEPRES	SAD	HELPLES	MELANC	SLUGGIS	TIRED	SLEEPY	BORED	STILL	QUIET	SAFE	SOOTHE	CALM	TRANQU	RELAXED	PEACEFU	SERENE	CONTENT
HAPPY
PLEASED	0.735
SATISFIE	0.699	0.685
CHEERFU	0.839	0.706	0.732
DELIGHT	0.756	0.704	0.619	0.729
ENTHUSI	0.653	0.755	0.626	0.732	0.63
INSPIRE	0.425	0.505	0.43	0.434	0.482	0.651
HOPEFU	0.348	0.433	0.408	0.365	0.44	0.536	0.607
EXCITED	0.546	0.625	0.502	0.57	0.702	0.712	0.627	0.6
EUPHOR	0.489	0.537	0.499	0.584	0.701	0.569	0.447	0.467	0.609
WIDEAW	0.348	0.328	0.293	0.37	0.38	0.425	0.263	0.244	0.236	0.229
VIGOROU	0.211	0.454	0.332	0.349	0.37	0.581	0.506	0.31	0.452	0.495	0.293
ACTIVE	0.467	0.58	0.507	0.605	0.56	0.71	0.48	0.386	0.519	0.419	0.506	0.652
AROUSE	0.301	0.317	0.335	0.275	0.382	0.354	0.389	0.409	0.33	0.325	0.228	0.298	0.378
JITTERY	-0.431	-0.31	-0.305	-0.386	-0.236	-0.167	-0.047	-0.039	-0.081	-0.1	-0.158	0.15	-0.079	0.167
SCARED	-0.483	-0.312	-0.268	-0.408	-0.239	-0.109	0.069	0.184	0.16	0.047	-0.145	0.067	-0.121	0.106	0.604
FEARFUL	-0.385	-0.273	-0.287	-0.395	-0.176	-0.102	0.102	0.153	0.139	0.037	-0.147	0.09	-0.084	0.055	0.613	0.89
ANXIOUS	-0.431	-0.317	-0.232	-0.42	-0.183	-0.144	-0.003	-0.01	0.023	-0.018	-0.123	0.156	-0.097	0.047	0.747	0.76	0.818
NERVOU	-0.418	-0.325	-0.313	-0.399	-0.345	-0.151	-0.028	0.076	-0.066	-0.058	-0.127	0.11	-0.116	0.179	0.755	0.788	0.81	0.823
TENSE	-0.506	-0.402	-0.391	-0.449	-0.346	-0.224	-0.001	-0.064	0.019	-0.068	-0.186	0.147	-0.166	0.017	0.722	0.713	0.771	0.799	0.756
IRRITATE	-0.588	-0.43	-0.417	-0.52	-0.415	-0.316	-0.064	-0.111	-0.19	-0.341	-0.167	0.088	-0.223	-0.11	0.481	0.523	0.516	0.55	0.49	0.663
ANGUISH	-0.612	-0.473	-0.476	-0.504	-0.449	-0.3	-0.114	-0.032	-0.104	-0.106	-0.176	0.077	-0.197	-0.018	0.658	0.734	0.757	0.687	0.612	0.718	0.645
HOSTILE	-0.497	-0.45	-0.408	-0.482	-0.344	-0.271	-0.216	-0.312	-0.215	-0.147	-0.176	0.247	-0.275	0.021	0.428	0.455	0.54	0.582	0.552	0.696	0.733	0.608
ANNOYE	-0.49	-0.405	-0.383	-0.538	-0.32	-0.34	-0.058	-0.076	-0.108	-0.169	-0.2	0.119	-0.245	-0.015	0.271	0.386	0.391	0.47	0.363	0.539	0.858	0.497	0.741
CONFUS	-0.369	-0.247	-0.305	-0.371	-0.264	-0.122	0.044	0.042	0.095	-0.03	-0.082	0.289	0.01	0.107	0.575	0.704	0.729	0.69	0.721	0.63	0.565	0.635	0.502	0.482
DISSATI	-0.495	-0.38	-0.451	-0.538	-0.284	-0.304	-0.063	-0.03	-0.135	-0.207	-0.165	0.063	-0.252	-0.044	0.52	0.601	0.623	0.671	0.505	0.639	0.75	0.673	0.682	0.704	0.622
DISAPP	-0.551	-0.451	-0.489	-0.567	-0.468	-0.294	-0.112	-0.086	-0.144	-0.222	-0.111	0.053	-0.201	-0.014	0.412	0.575	0.592	0.662	0.528	0.692	0.763	0.713	0.701	0.682	0.613	0.761
UNHAPP	-0.649	-0.568	-0.611	-0.682	-0.536	-0.407	-0.187	-0.188	-0.27	-0.398	-0.249	-0.089	-0.349	-0.169	0.55	0.614	0.681	0.703	0.632	0.739	0.657	0.749	0.699	0.588	0.62	0.764	0.837
MISERAB	-0.634	-0.6	-0.572	-0.635	-0.489	-0.45	-0.208	-0.2	-0.251	-0.129	-0.256	0.056	-0.311	-0.266	0.528	0.581	0.653	0.688	0.661	0.752	0.63	0.723	0.696	0.554	0.652	0.668	0.757	0.923
DEPRES	-0.652	-0.628	-0.46	-0.664	-0.558	-0.457	-0.182	-0.183	-0.356	-0.221	-0.234	-0.063	-0.379	-0.143	0.534	0.607	0.633	0.69	0.647	0.728	0.619	0.677	0.64	0.499	0.568	0.613	0.739	0.853	0.873
SAD	-0.576	-0.505	-0.526	-0.637	-0.634	-0.382	-0.16	-0.041	-0.215	-0.319	-0.259	-0.139	-0.336	-0.073	0.449	0.665	0.698	0.648	0.613	0.69	0.535	0.697	0.54	0.468	0.545	0.639	0.768	0.88	0.828	0.815
HELPLES	-0.572	-0.481	-0.449	-0.454	-0.413	-0.366	-0.159	-0.091	-0.096	-0.07	-0.106	0.024	-0.256	0.042	0.494	0.712	0.712	0.703	0.632	0.682	0.643	0.729	0.684	0.497	0.664	0.666	0.736	0.795	0.782	0.767	0.74
MELANC	-0.315	-0.241	-0.265	-0.359	-0.211	-0.11	0.027	0.016	0.021	-0.095	-0.241	-0.094	-0.18	-0.011	0.429	0.544	0.502	0.533	0.488	0.612	0.468	0.517	0.426	0.388	0.311	0.552	0.497	0.68	0.657	0.653	0.643	0.515
SLUGGIS	-0.284	-0.293	-0.237	-0.335	-0.302	-0.291	-0.104	-0.136	-0.229	-0.294	-0.47	-0.119	-0.342	-0.066	0.305	0.164	0.245	0.358	0.231	0.439	0.42	0.312	0.364	0.354	0.225	0.431	0.373	0.474	0.381	0.443	0.414	0.266	0.409
TIRED	-0.291	-0.283	-0.222	-0.268	-0.201	-0.344	-0.208	-0.148	-0.169	-0.191	-0.562	-0.185	-0.37	-0.193	0.273	0.136	0.26	0.263	0.202	0.359	0.319	0.232	0.304	0.24	0.224	0.3	0.205	0.349	0.358	0.4	0.326	0.258	0.318	0.693
SLEEPY	-0.205	-0.217	-0.206	-0.239	-0.26	-0.3	-0.142	-0.122	-0.166	-0.211	-0.629	-0.203	-0.383	-0.044	0.265	0.045	0.106	0.202	0.144	0.301	0.301	0.155	0.265	0.318	0.05	0.237	0.144	0.287	0.207	0.238	0.254	0.09	0.273	0.681	0.81
BORED	-0.193	-0.21	-0.243	-0.235	-0.237	-0.253	-0.133	-0.095	-0.169	-0.181	-0.115	-0.096	-0.236	-0.079	0.028	0.174	0.123	0.203	0.009	0.059	0.294	0.18	0.249	0.324	0.25	0.344	0.352	0.274	0.173	0.226	0.206	0.177	0.222	0.391	0.296	0.224
STILL	0.312	0.26	0.263	0.179	0.182	0.171	0.249	0.185	0.059	0.097	0.063	0.065	-0.022	0.142	-0.403	-0.224	-0.226	-0.28	-0.308	-0.32	-0.22	-0.322	-0.335	-0.177	-0.25	-0.153	-0.201	-0.251	-0.358	-0.241	-0.201	-0.304	-0.056	0.047	-0.042	0.027	0.044
QUIET	0.02	-0.07	0.085	-0.086	-0.193	-0.111	0.008	0.012	-0.174	-0.072	-0.094	-0.145	-0.139	0.039	0.035	0.062	0.031	0.067	0.002	0.039	-0.026	0.094	-0.039	-0.081	-0.013	0.104	0.024	0.115	0.07	0.197	0.169	0.048	0.16	0.24	0.176	0.203	0.206	0.277
SAFE	0.432	0.399	0.537	0.468	0.309	0.4	0.256	0.287	0.215	0.196	0.25	0.063	0.351	0.138	-0.332	-0.401	-0.362	-0.348	-0.371	-0.365	-0.262	-0.38	-0.421	-0.252	-0.348	-0.293	-0.316	-0.411	-0.394	-0.336	-0.38	-0.417	-0.205	-0.159	-0.149	-0.125	-0.098	0.278	0.275
SOOTHE	0.574	0.524	0.618	0.545	0.498	0.458	0.408	0.422	0.402	0.47	0.213	0.282	0.318	0.312	-0.18	-0.221	-0.209	-0.24	-0.219	-0.241	-0.318	-0.359	-0.417	-0.346	-0.105	-0.311	-0.354	-0.431	-0.401	-0.324	-0.402	-0.236	-0.097	-0.087	-0.099	-0.059	-0.113	0.419	0.204	0.398
CALM	0.533	0.44	0.405	0.497	0.418	0.316	0.229	0.213	0.248	0.254	0.148	-0.031	0.145	0.182	-0.612	-0.387	-0.43	-0.512	-0.585	-0.577	-0.487	-0.495	-0.642	-0.428	-0.407	-0.37	-0.384	-0.458	-0.502	-0.503	-0.431	-0.405	-0.182	-0.198	-0.175	-0.127	0.1	0.632	0.262	0.446	0.525
TRANQU	0.623	0.593	0.614	0.608	0.509	0.492	0.381	0.287	0.377	0.402	0.162	0.223	0.309	0.078	-0.444	-0.386	-0.39	-0.371	-0.429	-0.464	-0.334	-0.46	-0.399	-0.366	-0.322	-0.364	-0.399	-0.523	-0.492	-0.492	-0.426	-0.44	-0.108	-0.217	-0.168	-0.117	-0.083	0.541	0.244	0.567	0.675	0.668
RELAXED	0.655	0.534	0.59	0.59	0.417	0.449	0.201	0.179	0.263	0.208	0.266	0.111	0.29	0.182	-0.563	-0.471	-0.452	-0.45	-0.537	-0.562	-0.425	-0.534	-0.528	-0.492	-0.385	-0.43	-0.469	-0.534	-0.524	-0.487	-0.508	-0.462	-0.298	-0.256	-0.227	-0.166	-0.084	0.497	0.304	0.587	0.574	0.728	0.75
PEACEFU	0.657	0.506	0.551	0.57	0.472	0.408	0.388	0.293	0.269	0.359	0.176	0.114	0.282	0.261	-0.504	-0.411	-0.486	-0.495	-0.489	-0.541	-0.465	-0.523	-0.527	-0.484	-0.412	-0.457	-0.47	-0.582	-0.548	-0.494	-0.434	-0.452	-0.21	-0.256	-0.112	-0.127	-0.153	0.535	0.238	0.467	0.629	0.64	0.771	0.736
SERENE	0.594	0.533	0.551	0.549	0.537	0.505	0.374	0.231	0.342	0.39	0.232	0.255	0.221	0.224	-0.307	-0.391	-0.349	-0.266	-0.379	-0.452	-0.361	-0.392	-0.463	-0.355	-0.277	-0.369	-0.392	-0.463	-0.458	-0.407	-0.429	-0.364	-0.151	-0.23	-0.224	-0.157	-0.136	0.442	0.164	0.406	0.603	0.56	0.677	0.612	0.652
CONTENT	0.646	0.569	0.572	0.598	0.478	0.469	0.372	0.181	0.282	0.376	0.249	0.086	0.27	0.068	-0.491	-0.424	-0.426	-0.494	-0.409	-0.548	-0.462	-0.577	-0.552	-0.449	-0.445	-0.496	-0.497	-0.644	-0.674	-0.551	-0.568	-0.555	-0.287	-0.214	-0.222	-0.139	-0.118	0.436	0.076	0.435	0.586	0.502	0.586	0.6	0.679	0.635

Figure 9 Sample-estimated polychoric correlation matrix with 47 items

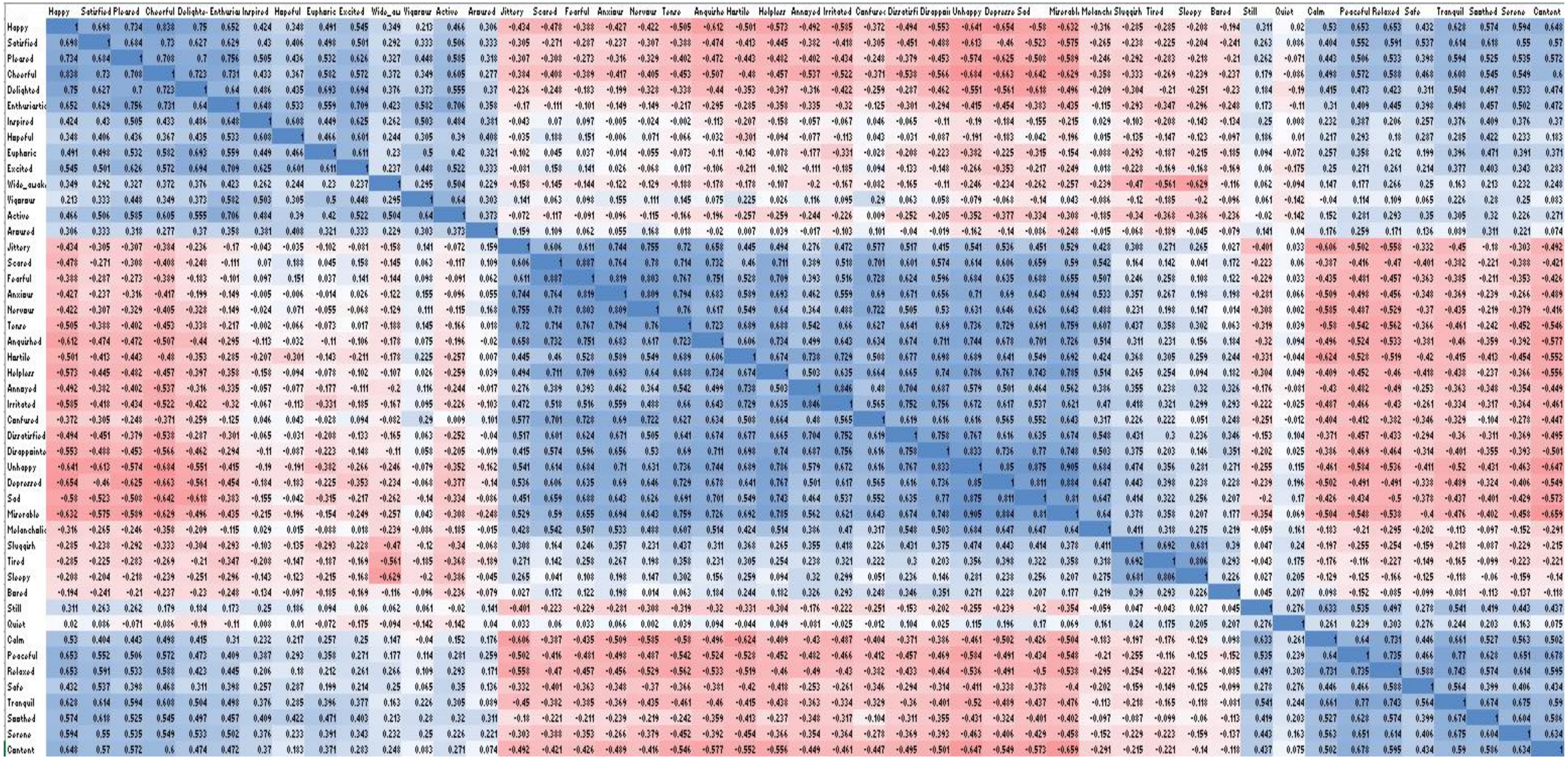
Table 10 *Circumplex model fit indices and $\rho_{180°}$ information*

Models	$\rho_{180°}$	χ^2	*df*	RMSEA	SRMR	CFI	AIC	BIC
m = 1	-.690	46930.87	987	.333	.097	.246	110.805	112.548
m = 2	-.418	46226.22	986	.330	.173	.258	109.126	107.762
m = 3	-.559	45902.77	985	.329	.223	.263	108.353	106.979
m = 4	-.456	45619.15	984	.328	.136	.268	107.675	106.291
m = 5	-.451	45477.04	983	.328	.136	.270	107.333	105.939
m = 6	-.397	45461.00	982	.328	.143	.270	107.290	105.887

Table 11 *Beta values of circumplex models with $m \leq 6$*

Models	β_0	β_1	β_2	β_3	β_4	β_5	β_6
m = 1	.155	.845					
m = 2	.160	.709	.131				
m = 3	.146	.691	.074	.088			
m = 4	.158	.625	.035	.103	.078		
m = 5	.122	.661	.075	.009	.077	.055	
m = 6	.123	.647	.079	.002	.078	.050	.021

The majority of the fit indices did not show an acceptable fit for the unconstrained circumplex model (*quasi*-circumplex). Besides the SRMR, model fit indices are likely misrepresenting the fit of the model, considering that the results are extremely low. According to AIC and BIC criteria, there is substantive improvement until the model of $m = 4$; however, the beta weights attained the lower bound of zero at β_2 and β_3 when $m \geq 4$, showing that the model with $m = 1$ is a better fit. The reproduced common score correlation matrix ($\mathbf{P}_c$) of model with $m = 1$ is presented in Figure 10, and the circular representation of the variables is presented in Figure 11.



	Happy	Satisfied	Pleased	Cheerful	Delighte	Enthusia	Inspired	Hopeful	Euphoric	Excited	Wide_aw	Vigorous	Active	Aroused	Jittery	Scared	Fearful	Anxious	Nervous	Tense	Anguishe	Hostile	Helpless	Annoyed	Irritated	Confuse	Dissatisfi	Disappoi	Unhappy	Depresse	Sad	Miserabl	Melanch	Sluggish	Tired	Sleepy	Bored	Still	Quiet	Calm	Peaceful	Relaxed	Safe	Tranquil	Soothed	Serene	Content
Happy	1	0.698	0.734	0.838	0.75	0.652	0.424	0.348	0.491	0.545	0.349	0.213	0.466	0.306	-0.434	-0.478	-0.388	-0.427	-0.422	-0.505	-0.612	-0.501	-0.573	-0.492	-0.585	-0.372	-0.494	-0.553	-0.641	-0.654	-0.58	-0.632	-0.316	-0.285	-0.285	-0.208	-0.194	0.311	0.02	0.53	0.653	0.653	0.432	0.628	0.574	0.594	0.648
Satisfied	0.698	1	0.684	0.73	0.627	0.629	0.43	0.406	0.498	0.501	0.292	0.333	0.506	0.333	-0.305	-0.271	-0.287	-0.237	-0.307	-0.388	-0.474	-0.413	-0.445	-0.382	-0.418	-0.305	-0.451	-0.488	-0.613	-0.46	-0.523	-0.575	-0.265	-0.238	-0.225	-0.204	-0.241	0.263	0.086	0.404	0.552	0.591	0.537	0.614	0.618	0.55	0.57
Pleased	0.734	0.684	1	0.708	0.7	0.756	0.505	0.436	0.532	0.626	0.327	0.448	0.585	0.318	-0.307	-0.308	-0.273	-0.316	-0.329	-0.402	-0.472	-0.443	-0.482	-0.402	-0.434	-0.248	-0.379	-0.453	-0.574	-0.625	-0.508	-0.589	-0.246	-0.292	-0.283	-0.218	-0.21	0.262	-0.071	0.443	0.506	0.533	0.398	0.594	0.525	0.535	0.572
Cheerful	0.838	0.73	0.708	1	0.723	0.731	0.433	0.367	0.582	0.572	0.372	0.349	0.605	0.277	-0.384	-0.408	-0.389	-0.417	-0.405	-0.453	-0.507	-0.48	-0.457	-0.537	-0.522	-0.371	-0.538	-0.566	-0.684	-0.663	-0.642	-0.629	-0.358	-0.333	-0.269	-0.239	-0.237	0.179	-0.086	0.498	0.572	0.588	0.468	0.608	0.545	0.549	0.6
Delighted	0.75	0.627	0.7	0.723	1	0.64	0.486	0.435	0.693	0.694	0.376	0.373	0.555	0.37	-0.236	-0.248	-0.183	-0.199	-0.328	-0.338	-0.44	-0.353	-0.397	-0.316	-0.422	-0.259	-0.287	-0.462	-0.551	-0.561	-0.618	-0.496	-0.209	-0.304	-0.21	-0.251	-0.23	0.184	-0.19	0.415	0.473	0.423	0.311	0.504	0.497	0.533	0.474
Enthusiastic	0.652	0.629	0.756	0.731	0.64	1	0.648	0.533	0.559	0.709	0.423	0.582	0.706	0.358	-0.17	-0.111	-0.101	-0.149	-0.149	-0.217	-0.295	-0.285	-0.358	-0.335	-0.32	-0.125	-0.301	-0.294	-0.415	-0.454	-0.383	-0.435	-0.115	-0.293	-0.347	-0.296	-0.248	0.173	-0.11	0.31	0.409	0.445	0.398	0.498	0.457	0.502	0.472
Inspired	0.424	0.43	0.505	0.433	0.486	0.648	1	0.608	0.449	0.625	0.262	0.503	0.484	0.381	-0.043	0.07	0.097	-0.005	-0.024	-0.002	-0.113	-0.207	-0.158	-0.057	-0.067	0.046	-0.065	-0.11	-0.19	-0.184	-0.155	-0.215	0.029	-0.103	-0.208	-0.143	-0.134	0.25	0.008	0.232	0.387	0.206	0.257	0.376	0.409	0.376	0.37
Hopeful	0.348	0.406	0.436	0.367	0.435	0.533	0.608	1	0.466	0.601	0.244	0.305	0.39	0.408	-0.035	0.188	0.151	-0.006	0.071	-0.066	-0.032	-0.301	-0.094	-0.077	-0.113	0.043	-0.031	-0.087	-0.191	-0.183	-0.042	-0.196	0.015	-0.135	-0.147	-0.123	-0.097	0.186	0.01	0.217	0.293	0.18	0.287	0.285	0.422	0.233	0.183
Euphoric	0.491	0.498	0.532	0.582	0.693	0.559	0.449	0.466	1	0.611	0.23	0.5	0.42	0.321	-0.102	0.045	0.037	-0.014	-0.055	-0.073	-0.11	-0.143	-0.078	-0.177	-0.331	-0.028	-0.208	-0.223	-0.382	-0.225	-0.315	-0.154	-0.088	-0.293	-0.187	-0.215	-0.185	0.094	-0.072	0.257	0.358	0.212	0.199	0.396	0.471	0.391	0.371
Excited	0.545	0.501	0.626	0.572	0.694	0.709	0.625	0.601	0.611	1	0.237	0.448	0.522	0.333	-0.081	0.158	0.141	0.026	-0.068	0.017	-0.106	-0.211	-0.102	-0.111	-0.185	0.094	-0.133	-0.148	-0.266	-0.353	-0.217	-0.249	0.018	-0.228	-0.169	-0.168	-0.169	0.06	-0.175	0.25	0.271	0.261	0.214	0.377	0.403	0.343	0.283
Wide_awak	0.349	0.292	0.327	0.372	0.376	0.423	0.262	0.244	0.23	0.237	1	0.295	0.504	0.229	-0.158	-0.145	-0.144	-0.122	-0.129	-0.188	-0.178	-0.178	-0.107	-0.2	-0.167	-0.082	-0.165	-0.11	-0.246	-0.234	-0.262	-0.257	-0.239	-0.47	-0.561	-0.629	-0.116	0.062	-0.094	0.147	0.177	0.266	0.25	0.163	0.213	0.232	0.248
Vigorous	0.213	0.333	0.448	0.349	0.373	0.582	0.503	0.305	0.5	0.448	0.295	1	0.64	0.303	0.141	0.063	0.098	0.155	0.111	0.145	0.075	0.225	0.026	0.116	0.095	0.29	0.063	0.058	-0.079	-0.068	-0.14	0.043	-0.086	-0.12	-0.185	-0.2	-0.096	0.061	-0.142	-0.04	0.114	0.109	0.065	0.226	0.28	0.25	0.083
Active	0.466	0.506	0.585	0.605	0.555	0.706	0.484	0.39	0.42	0.522	0.504	0.64	1	0.373	-0.072	-0.117	-0.091	-0.096	-0.115	-0.166	-0.196	-0.257	-0.259	-0.244	-0.226	0.009	-0.252	-0.205	-0.352	-0.377	-0.334	-0.308	-0.185	-0.34	-0.368	-0.386	-0.236	-0.02	-0.142	0.152	0.281	0.293	0.35	0.305	0.32	0.226	0.271
Aroused	0.306	0.333	0.318	0.277	0.37	0.358	0.381	0.408	0.321	0.333	0.229	0.303	0.373	1	0.159	0.109	0.062	0.055	0.168	0.018	-0.02	0.007	0.039	-0.017	-0.103	0.101	-0.04	-0.019	-0.162	-0.14	-0.086	-0.248	-0.015	-0.068	-0.189	-0.045	-0.079	0.141	0.04	0.176	0.259	0.171	0.136	0.089	0.311	0.221	0.074
Jittery	-0.434	-0.305	-0.307	-0.384	-0.236	-0.17	-0.043	-0.035	-0.102	-0.081	-0.158	0.141	-0.072	0.159	1	0.606	0.611	0.744	0.755	0.72	0.658	0.445	0.494	0.276	0.472	0.577	0.517	0.415	0.541	0.536	0.451	0.529	0.428	0.308	0.271	0.265	0.027	-0.401	0.033	-0.606	-0.502	-0.558	-0.332	-0.45	-0.18	-0.303	-0.492
Scared	-0.478	-0.271	-0.308	-0.408	-0.248	-0.111	0.07	0.188	0.045	0.158	-0.145	0.063	-0.117	0.109	0.606	1	0.887	0.764	0.78	0.714	0.732	0.46	0.711	0.389	0.518	0.701	0.601	0.574	0.614	0.606	0.659	0.59	0.542	0.164	0.142	0.041	0.172	-0.223	0.06	-0.387	-0.416	-0.47	-0.401	-0.382	-0.221	-0.388	-0.421
Fearful	-0.388	-0.287	-0.273	-0.389	-0.183	-0.101	0.097	0.151	0.037	0.141	-0.144	0.098	-0.091	0.062	0.611	0.887	1	0.819	0.803	0.767	0.751	0.528	0.709	0.393	0.516	0.728	0.624	0.596	0.684	0.635	0.688	0.655	0.507	0.246	0.258	0.108	0.122	-0.229	0.033	-0.435	-0.481	-0.457	-0.363	-0.385	-0.211	-0.353	-0.426
Anxious	-0.427	-0.237	-0.316	-0.417	-0.199	-0.149	-0.005	-0.006	-0.014	0.026	-0.122	0.155	-0.096	0.055	0.744	0.764	0.819	1	0.809	0.794	0.683	0.589	0.693	0.462	0.559	0.69	0.671	0.656	0.71	0.69	0.643	0.694	0.533	0.357	0.267	0.198	0.198	-0.281	0.066	-0.509	-0.498	-0.456	-0.348	-0.369	-0.239	-0.266	-0.489
Nervous	-0.422	-0.307	-0.329	-0.405	-0.328	-0.149	-0.024	0.071	-0.055	-0.068	-0.129	0.111	-0.115	0.168	0.755	0.78	0.803	0.809	1	0.76	0.617	0.549	0.64	0.364	0.488	0.722	0.505	0.53	0.631	0.646	0.626	0.643	0.488	0.231	0.198	0.147	0.014	-0.308	0.002	-0.585	-0.487	-0.529	-0.37	-0.435	-0.219	-0.379	-0.416
Tense	-0.505	-0.388	-0.402	-0.453	-0.338	-0.217	-0.002	-0.066	-0.073	0.017	-0.188	0.145	-0.166	0.018	0.72	0.714	0.767	0.794	0.76	1	0.723	0.689	0.688	0.542	0.66	0.627	0.641	0.69	0.736	0.729	0.691	0.759	0.607	0.437	0.358	0.302	0.063	-0.319	0.039	-0.58	-0.542	-0.562	-0.366	-0.461	-0.242	-0.452	-0.546
Anguished	-0.612	-0.474	-0.472	-0.507	-0.44	-0.295	-0.113	-0.032	-0.11	-0.106	-0.178	0.075	-0.196	-0.02	0.658	0.732	0.751	0.683	0.617	0.723	1	0.606	0.734	0.499	0.643	0.634	0.674	0.711	0.744	0.678	0.701	0.726	0.514	0.311	0.231	0.156	0.184	-0.32	0.094	-0.496	-0.524	-0.533	-0.381	-0.46	-0.359	-0.392	-0.577
Hostile	-0.501	-0.413	-0.443	-0.48	-0.353	-0.285	-0.207	-0.301	-0.143	-0.211	-0.178	0.225	-0.257	0.007	0.445	0.46	0.528	0.589	0.549	0.689	0.606	1	0.674	0.738	0.729	0.508	0.677	0.698	0.689	0.641	0.549	0.692	0.424	0.368	0.305	0.259	0.244	-0.331	-0.044	-0.624	-0.528	-0.519	-0.42	-0.415	-0.413	-0.454	-0.552
Helpless	-0.573	-0.445	-0.482	-0.457	-0.397	-0.358	-0.158	-0.094	-0.078	-0.102	-0.107	0.026	-0.259	0.039	0.494	0.711	0.709	0.693	0.64	0.688	0.734	0.674	1	0.503	0.635	0.664	0.665	0.74	0.786	0.767	0.743	0.785	0.514	0.265	0.254	0.094	0.182	-0.304	0.049	-0.409	-0.452	-0.46	-0.418	-0.438	-0.237	-0.366	-0.556
Annoyed	-0.492	-0.382	-0.402	-0.537	-0.316	-0.335	-0.057	-0.077	-0.177	-0.111	-0.2	0.116	-0.244	-0.017	0.276	0.389	0.393	0.462	0.364	0.542	0.499	0.738	0.503	1	0.846	0.48	0.704	0.687	0.579	0.501	0.464	0.562	0.386	0.355	0.238	0.32	0.326	-0.176	-0.081	-0.43	-0.482	-0.49	-0.253	-0.363	-0.348	-0.354	-0.449
Irritated	-0.585	-0.418	-0.434	-0.522	-0.422	-0.32	-0.067	-0.113	-0.331	-0.185	-0.167	0.095	-0.226	-0.103	0.472	0.518	0.516	0.559	0.488	0.66	0.643	0.729	0.635	0.846	1	0.565	0.752	0.756	0.672	0.617	0.537	0.621	0.47	0.418	0.321	0.299	0.293	-0.222	-0.025	-0.487	-0.466	-0.43	-0.261	-0.334	-0.317	-0.364	-0.461
Confused	-0.372	-0.305	-0.248	-0.371	-0.259	-0.125	0.046	0.043	-0.028	0.094	-0.082	0.29	0.009	0.101	0.577	0.701	0.728	0.69	0.722	0.627	0.634	0.508	0.664	0.48	0.565	1	0.619	0.616	0.616	0.565	0.552	0.643	0.317	0.226	0.222	0.051	0.248	-0.251	-0.012	-0.404	-0.412	-0.382	-0.346	-0.329	-0.104	-0.278	-0.447
Dissatisfied	-0.494	-0.451	-0.379	-0.538	-0.287	-0.301	-0.065	-0.031	-0.208	-0.133	-0.165	0.063	-0.252	-0.04	0.517	0.601	0.624	0.671	0.505	0.641	0.674	0.677	0.665	0.704	0.752	0.619	1	0.758	0.767	0.616	0.635	0.674	0.548	0.431	0.3	0.236	0.346	-0.153	0.104	-0.371	-0.457	-0.433	-0.294	-0.36	-0.311	-0.369	-0.495
Disappointed	-0.553	-0.488	-0.453	-0.566	-0.462	-0.294	-0.11	-0.087	-0.223	-0.148	-0.11	0.058	-0.205	-0.019	0.415	0.574	0.596	0.656	0.53	0.69	0.711	0.698	0.74	0.687	0.756	0.616	0.758	1	0.833	0.736	0.77	0.748	0.503	0.375	0.203	0.146	0.351	-0.202	0.025	-0.386	-0.469	-0.464	-0.314	-0.401	-0.355	-0.393	-0.501
Unhappy	-0.641	-0.613	-0.574	-0.684	-0.551	-0.415	-0.19	-0.191	-0.382	-0.266	-0.246	-0.079	-0.352	-0.162	0.541	0.614	0.684	0.71	0.631	0.736	0.744	0.689	0.786	0.579	0.672	0.616	0.767	0.833	1	0.85	0.875	0.905	0.684	0.474	0.356	0.281	0.271	-0.255	0.115	-0.461	-0.584	-0.536	-0.411	-0.52	-0.431	-0.463	-0.647
Depressed	-0.654	-0.46	-0.625	-0.663	-0.561	-0.454	-0.184	-0.183	-0.225	-0.353	-0.234	-0.068	-0.377	-0.14	0.536	0.606	0.635	0.69	0.646	0.729	0.678	0.641	0.767	0.501	0.617	0.565	0.616	0.736	0.85	1	0.811	0.884	0.647	0.443	0.398	0.238	0.228	-0.239	0.196	-0.502	-0.491	-0.491	-0.338	-0.489	-0.324	-0.406	-0.549
Sad	-0.58	-0.523	-0.508	-0.642	-0.618	-0.383	-0.155	-0.042	-0.315	-0.217	-0.262	-0.14	-0.334	-0.086	0.451	0.659	0.688	0.643	0.626	0.691	0.701	0.549	0.743	0.464	0.537	0.552	0.635	0.77	0.875	0.811	1	0.81	0.647	0.414	0.322	0.256	0.207	-0.2	0.17	-0.426	-0.434	-0.5	-0.378	-0.437	-0.401	-0.429	-0.573
Miserable	-0.632	-0.575	-0.589	-0.629	-0.496	-0.435	-0.215	-0.196	-0.154	-0.249	-0.257	0.043	-0.308	-0.248	0.529	0.59	0.655	0.694	0.643	0.759	0.726	0.692	0.785	0.562	0.621	0.643	0.674	0.748	0.905	0.884	0.81	1	0.64	0.378	0.358	0.207	0.177	-0.354	0.069	-0.504	-0.548	-0.538	-0.4	-0.476	-0.402	-0.458	-0.659
Melancholic	-0.316	-0.265	-0.246	-0.358	-0.209	-0.115	0.029	0.015	-0.088	0.018	-0.239	-0.086	-0.185	-0.015	0.428	0.542	0.507	0.533	0.488	0.607	0.514	0.424	0.514	0.386	0.47	0.317	0.548	0.503	0.684	0.647	0.647	0.64	1	0.411	0.318	0.275	0.219	-0.059	0.161	-0.183	-0.21	-0.295	-0.202	-0.113	-0.097	-0.152	-0.291
Sluggish	-0.285	-0.238	-0.292	-0.333	-0.304	-0.293	-0.103	-0.135	-0.293	-0.228	-0.47	-0.12	-0.34	-0.068	0.308	0.164	0.246	0.357	0.231	0.437	0.311	0.368	0.265	0.355	0.418	0.226	0.431	0.375	0.474	0.443	0.414	0.378	0.411	1	0.692	0.681	0.39	0.047	0.24	-0.197	-0.255	-0.254	-0.159	-0.218	-0.087	-0.229	-0.215
Tired	-0.285	-0.225	-0.283	-0.269	-0.21	-0.347	-0.208	-0.147	-0.187	-0.169	-0.561	-0.185	-0.368	-0.189	0.271	0.142	0.258	0.267	0.198	0.358	0.231	0.305	0.254	0.238	0.321	0.222	0.3	0.203	0.356	0.398	0.322	0.358	0.318	0.692	1	0.806	0.293	-0.043	0.175	-0.176	-0.116	-0.227	-0.149	-0.165	-0.099	-0.223	-0.221
Sleepy	-0.208	-0.204	-0.218	-0.239	-0.251	-0.296	-0.143	-0.123	-0.215	-0.168	-0.629	-0.2	-0.386	-0.045	0.265	0.041	0.108	0.198	0.147	0.302	0.156	0.259	0.094	0.32	0.299	0.051	0.236	0.146	0.281	0.238	0.256	0.207	0.275	0.681	0.806	1	0.226	0.027	0.205	-0.129	-0.125	-0.166	-0.125	-0.118	-0.06	-0.159	-0.14
Bored	-0.194	-0.241	-0.21	-0.237	-0.23	-0.248	-0.134	-0.097	-0.185	-0.169	-0.116	-0.096	-0.236	-0.079	0.027	0.172	0.122	0.198	0.014	0.063	0.184	0.244	0.182	0.326	0.293	0.248	0.346	0.351	0.271	0.228	0.207	0.177	0.219	0.39	0.293	0.226	1	0.045	0.207	0.098	-0.152	-0.085	-0.099	-0.081	-0.113	-0.137	-0.118
Still	0.311	0.263	0.262	0.179	0.184	0.173	0.25	0.186	0.094	0.06	0.062	0.061	-0.02	0.141	-0.401	-0.223	-0.229	-0.281	-0.308	-0.319	-0.32	-0.331	-0.304	-0.176	-0.222	-0.251	-0.153	-0.202	-0.255	-0.239	-0.2	-0.354	-0.059	0.047	-0.043	0.027	0.045	1	0.276	0.633	0.535	0.497	0.278	0.541	0.419	0.443	0.437
Quiet	0.02	0.086	-0.071	-0.086	-0.19	-0.11	0.008	0.01	-0.072	-0.175	-0.094	-0.142	-0.142	0.04	0.033	0.06	0.033	0.066	0.002	0.039	0.094	-0.044	0.049	-0.081	-0.025	-0.012	0.104	0.025	0.115	0.196	0.17	0.069	0.161	0.24	0.175	0.205	0.207	0.276	1	0.261	0.239	0.303	0.276	0.244	0.203	0.163	0.075
Calm	0.53	0.404	0.443	0.498	0.415	0.31	0.232	0.217	0.257	0.25	0.147	-0.04	0.152	0.176	-0.606	-0.387	-0.435	-0.509	-0.585	-0.58	-0.496	-0.624	-0.409	-0.43	-0.487	-0.404	-0.371	-0.386	-0.461	-0.502	-0.426	-0.504	-0.183	-0.197	-0.176	-0.129	0.098	0.633	0.261	1	0.64	0.731	0.446	0.661	0.527	0.563	0.502
Peaceful	0.653	0.552	0.506	0.572	0.473	0.409	0.387	0.293	0.358	0.271	0.177	0.114	0.281	0.259	-0.502	-0.416	-0.481	-0.498	-0.487	-0.542	-0.524	-0.528	-0.452	-0.482	-0.466	-0.412	-0.457	-0.469	-0.584	-0.491	-0.434	-0.548	-0.21	-0.255	-0.116	-0.125	-0.152	0.535	0.239	0.64	1	0.735	0.466	0.77	0.628	0.651	0.678
Relaxed	0.653	0.591	0.533	0.588	0.423	0.445	0.206	0.18	0.212	0.261	0.266	0.109	0.293	0.171	-0.558	-0.47	-0.457	-0.456	-0.529	-0.562	-0.533	-0.519	-0.46	-0.49	-0.43	-0.382	-0.433	-0.464	-0.536	-0.491	-0.5	-0.538	-0.295	-0.254	-0.227	-0.166	-0.085	0.497	0.303	0.731	0.735	1	0.588	0.743	0.574	0.614	0.595
Safe	0.432	0.537	0.398	0.468	0.311	0.398	0.257	0.287	0.199	0.214	0.25	0.065	0.35	0.136	-0.332	-0.401	-0.363	-0.348	-0.37	-0.366	-0.381	-0.42	-0.418	-0.253	-0.261	-0.346	-0.294	-0.314	-0.411	-0.338	-0.378	-0.4	-0.202	-0.159	-0.149	-0.125	-0.099	0.278	0.276	0.446	0.466	0.588	1	0.564	0.399	0.406	0.434
Tranquil	0.628	0.614	0.594	0.608	0.504	0.498	0.376	0.285	0.396	0.377	0.163	0.226	0.305	0.089	-0.45	-0.382	-0.385	-0.369	-0.435	-0.461	-0.46	-0.415	-0.438	-0.363	-0.334	-0.329	-0.36	-0.401	-0.52	-0.489	-0.437	-0.476	-0.113	-0.218	-0.165	-0.118	-0.081	0.541	0.244	0.661	0.77	0.743	0.564	1	0.674	0.675	0.59
Soothed	0.574	0.618	0.525	0.545	0.497	0.457	0.409	0.422	0.471	0.403	0.213	0.28	0.32	0.311	-0.18	-0.221	-0.211	-0.239	-0.219	-0.242	-0.359	-0.413	-0.237	-0.348	-0.317	-0.104	-0.311	-0.355	-0.431	-0.324	-0.401	-0.402	-0.097	-0.087	-0.099	-0.06	-0.113	0.419	0.203	0.527	0.628	0.574	0.399	0.674	1	0.604	0.586
Serene	0.594	0.55	0.535	0.549	0.533	0.502	0.376	0.233	0.391	0.343	0.232	0.25	0.226	0.221	-0.303	-0.388	-0.353	-0.266	-0.379	-0.452	-0.392	-0.454	-0.366	-0.354	-0.364	-0.278	-0.369	-0.393	-0.463	-0.406	-0.429	-0.458	-0.152	-0.229	-0.223	-0.159	-0.137	0.443	0.163	0.563	0.651	0.614	0.406	0.675	0.604	1	0.634
Content	0.648	0.57	0.572	0.6	0.474	0.472	0.37	0.183	0.371	0.283	0.248	0.083	0.271	0.074	-0.492	-0.421	-0.426	-0.489	-0.416	-0.546	-0.577	-0.552	-0.556	-0.449	-0.461	-0.447	-0.495	-0.501	-0.647	-0.549	-0.573	-0.659	-0.291	-0.215	-0.221	-0.14	-0.118	0.437	0.075	0.502	0.678	0.595	0.434	0.59	0.586	0.634	1

Figure 10 Heat map of unconstrained circumplex model m =1

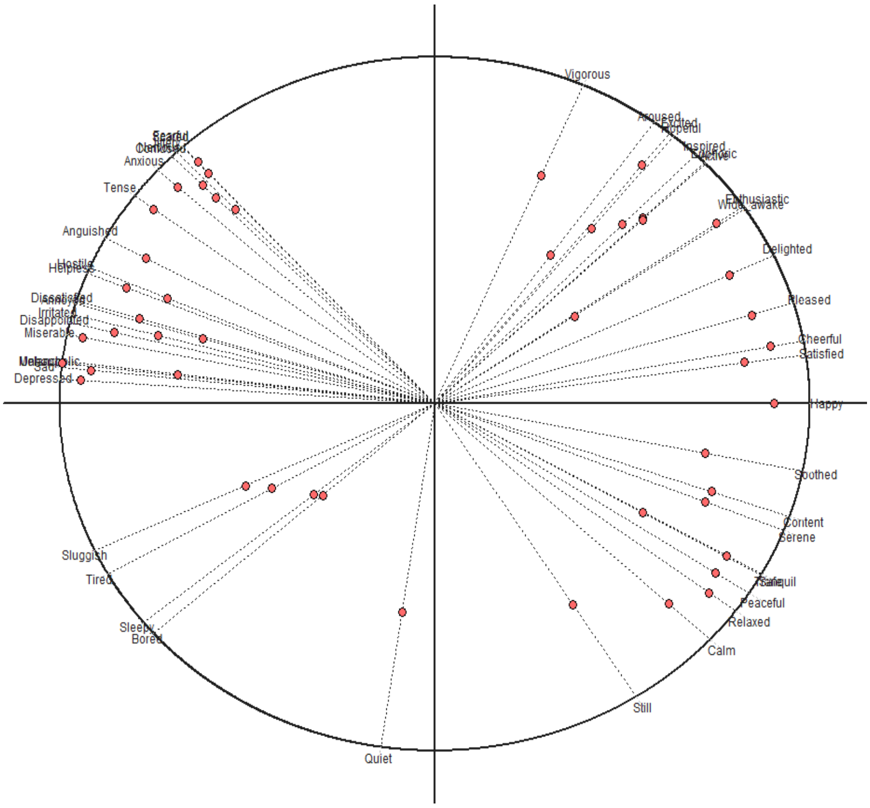


Figure 11 Circular representation of core affect m = 1

Considering the untrustworthy model fit results, unconstrained and constrained circumplex model were tested with Pearson and polychoric correlations with empirical and circumplex-simulated datasets results (Appendix B). Results from the study in Appendix B show that model fit indices from models estimated with polychoric correlations are considerably discrepant from Pearson correlations, even though polychoric correlations are stronger.

Most likely, core affect is not a perfect circumplex, but it is a *quasi*-circumplex. However, this hypothesis cannot be confirmed with Browne's model (1992) because the model fit indices are not to be trusted with polychoric correlations.

4.3.1.5 The measure of core affect based on the RI model

To develop a measure of core affect utilising the best items according to the previous analyses to be used in the Ecological Momentary Assessment (EMA) study (Study 2 of this thesis), a RI model with 28 items was estimated. To avoid large standard errors when estimating the item thresholds for the infrequently endorsed top category (*a great deal*), the response category 3 (*a great deal*) was merged with the category 2 (*somewhat*). Thus, the item became binary and the correlations were tetrachoric. The model had an acceptable fit (χ^2= 1256.077, *df* = 329, *p* < .001; RMSEA= .08, CFI= .89), and the random intercept factor had a significant variance of .487 (*SE* = .04, *z* = 10.98, *p* < .001). The standardised factor loadings are presented in Table 12 and Figure 12.

Table 12 *Standardised factor loadings of Random Intercept model with 28 items*

Adjectives	Valence	Activation	RI
Happy	**.806**	0	.338
Pleased	**.698**	0	.410
Cheerful	**.752**	.246	.350
Delighted	**.611**	**.334**	.411
Enthusiast	**.566**	**.383**	.418
Excited	**.351**	**.392**	.486
Wide awake	**.370**	**.636**	.387
Vigorous	.070	**.570**	.468
Active	0	**.649**	.435
Aroused	0	.263	.552
Jittery	**-.772**	.249	.335
Nervous	**-.769**	.258	.334
Tense	**-.857**	.055	.293
Dissatisfied	**-.788**	0	.352
Unhappy	**-.944**	0	.189
Sad	**-.866**	-.265	.242
Melancholic	**-.602**	-.215	.440
Sluggish	**-.488**	**-.579**	.374
Tired	**-.365**	**-.767**	.302
Sleepy	-.312	**-.812**	.283
Still	0	-.149	.566
Quiet	0	**-.384**	.528
Calm	**.686**	-.238	.394
Tranquil	**.742**	-.103	.379
Relaxed	**.780**	-.085	.355
Peaceful	**.747**	-.127	.373
Serene	**.647**	-.033	.436

Content	**.745**	-.033	.381

Note. Factor loadings equal or greater than .32 are in boldface. N=422.

The factor loadings from this model spread around the axes nicely (Figure 12), resembling a circle as expected. The factor loadings are easily interpretable. There are some meaningful changes in factor loadings in comparison to the loadings from the previous analyses. For example, the activation factor is more easily interpretable when compared to previous models.

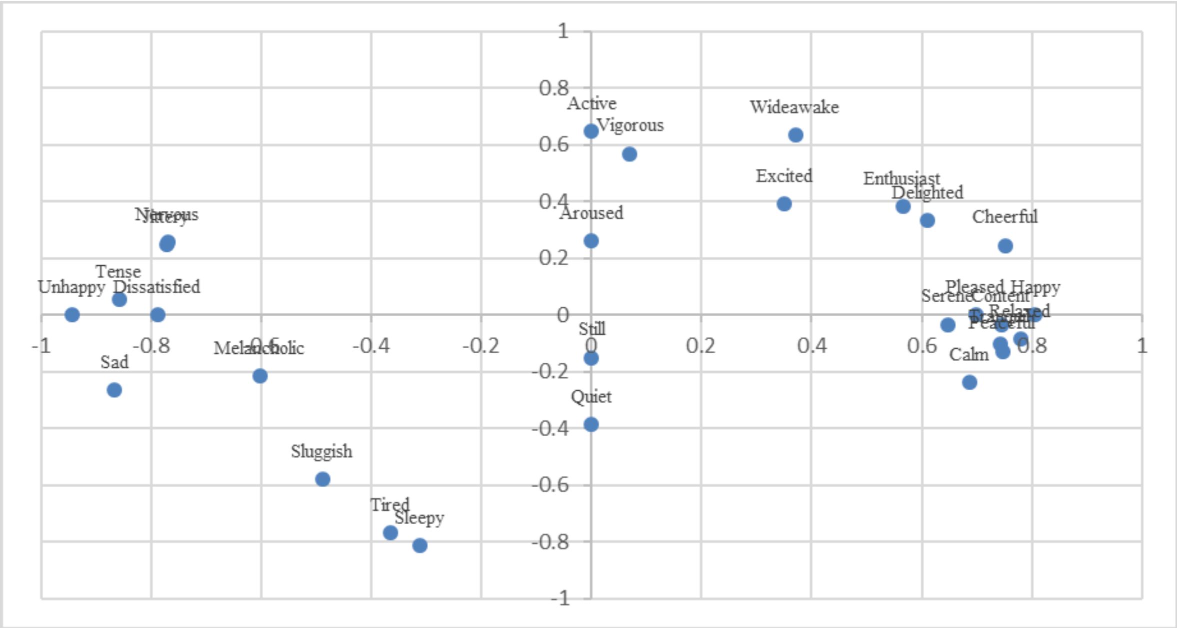


Figure 12 Loadings plot of Random Intercept model with 28 items

4.3.2 Reliability

Empirical reliability coefficients for valence and activation scores of the model with 47 items are presented in Table 13.

Table 13 *Empirical reliability coefficients*

	Valence	Activation
Error variance	.059	.192
EAP score variance	.945	.810
Reliability (ρ)	.941	.808

Reliability coefficients are acceptable, though they are only represent average reliability levels, given that item response models have different levels of measurement error for each level of latent trait (Brown & Croudace, 2015).

4.3.3 Convergent and discriminant validity

Convergent correlations are correlations between the construct in question and similar constructs from external measures. Discriminant correlations are correlations between the construct being measured and theoretically unrelated constructs. A measure has convergent validity if it correlates highly with other similar measures (similar in terms of construct, not method), and a measure has discriminant validity if it correlates low with distinct measures (distinct in terms of construct) (Campbell & Fiske, 1959). Two external measures were used to test convergent and discriminant validity of core affect (model with 47 items): personality (NEO-PI-R) (Costa & McCrae, 1992) and emotions (emotions pictures). The hypotheses for convergent and discriminant correlations are listed in Table 14. All hypotheses are based on previous research with these constructs (Costa & McCrae, 1992; Howell & Rodzon, 2011; Komulainen et al., 2014; Letzring & Adamcik, 2015; Yik et al., 2011).

Table 14 *Hypothetical convergent and discriminant correlations*

External measures	Valence	Activation
Neuroticism	Convergent	Discriminant
Extraversion	Convergent	Convergent
Openness	Discriminant	Discriminant
Agreeableness	Convergent	Discriminant
Conscientiousness	Discriminant	Discriminant
Anger	Convergent	Convergent
Joy	Convergent	Discriminant
Sadness	Convergent	Discriminant
Shame	Convergent	Convergent
Fear	Convergent	Convergent
Disgust	Convergent	Discriminant

The resulting correlations are presented in Table 15, with average convergent and discriminant values summarised at the bottom of the table.

Table 15 *Convergent and discriminant correlations results*

External measures	Valence	Activation
Neuroticism	-.448**	-.085
Extraversion	.301**	.171*
Openness	.143**	.012
Agreeableness	.086	-.007
Conscientiousness	.130*	.003
Anger	-.366**	-.057
Joy	.741**	.227**
Sadness	-.701**	-.034
Shame	-.455**	-.304**
Fear	-.226**	.333**
Disgust	-.327**	-.030
Avg. convergent validity (raw)	- .155	.036
Avg. discriminant validity (raw)	.137	.012
Avg. convergent validity (absolute)	.406	.216
Avg. discriminant validity (absolute)	-	.057

Note. N = 402.
*Correlation is significant at .001 level (2-tailed). **Correlation is significant at .0001 level (2-tailed).

For valence, the convergent correlations averaged to .406 (absolute). Divergent correlations averaged to .137 (raw). Convergent values were substantially higher when compared to discriminant values, except for Agreeableness that did not had a moderate/strong significant correlation with valence as expected. Overall, the convergent and divergent validity for valence are acceptable.

For activation, the average convergent correlation is .216 (absolute). The hypothesised convergent correlations appeared as expected, with exception of fear that did not correlated strongly (only moderately). The average divergent correlation value is r=.057 (absolute), which is substantially lower than the convergent average value. Overall, the hypothesised discriminant correlations for personality and emotions are not significantly different from zero, as expected. Unexpected convergent and discriminant results are discussed next.

Valence and Personality traits

Previous studies found correlations with magnitude between − .12 to .16[3] with Valence-related dimensions and Agreeableness. The correlation is 0.02 for the NEO-PI-R and .16 for the Five-Factor markers (Yik et al., 2011). When the dimensions of positive and negative affect are used, Agreeableness (NEO-PI) correlated .15 ($p < .01$) with Positive Affect and − .12 ($p < .05$) with Negative Affect (McCrae & Costa, 1991). Similarly, in another study with Big Five Inventory (BFI), Agreeableness correlated .08 with positive affect and − .17 ($p < .01$) with negative affect (Letzring & Adamcik, 2015). Literature results about core affect and agreeableness are somewhat contradictory; however, the low correlation found in this study is in accordance with previous results.

Openness to new experiences was expected to correlate with valence, and of the correlation established in previous research was $r = .14$ ($p < .0001$) (Yik et al., 2011). One reason for the significant correlation found in this study ($r = .143$, p < .0001) is that Openness includes a facet about feelings. In this facet, high scorers tend to feel pleasant and unpleasant feelings more intensely (Costa & McCrae, 1992).

Conscientiousness correlated weakly with Valence ($r = .13$, $p < .001$). According to Costa and McCrae (1992), more diligent and organised people tend to achieve their

[3]Note: Agreeableness (Five-Factor markers and NEO-PI-R, 60-item version, respectively) correlated .16 and .02 with the estimated angle of 348° in the circumplex (Yik et al., 2011). Note that Yik and colleagues (2011) applied the *r-max* coefficient to measure the magnitude of the correlations between the external variables (e.g. personality traits) and the vectors of the estimated angles for each of these external variables in the circumplex.

goals, allowing them to experience more feelings associated with happiness. Thus, a significant correlation is coherent with the theory.

To summarise, Conscientiousness, Agreeableness, and Openness correlate somewhat weakly but significantly with Valence. Given that valence is a dimension about pleasant and unpleasant feelings, it is reasonable to assume pleasant feelings co-vary positively with personality traits that are about positive characteristics of the human being.

Activation and Emotions

The emotion joy correlated significantly with activation (r = .227, p < .0001), even though they were hypothesised unrelated. Commonly, joy is commonly associated with happiness, which is an adjective influenced purely by valence, not activation. However, if joy includes elation or amusement (Fredrickson, 2009), the concept is broadened to be relevant to activation levels.

Anger correlated near-zero with activation (r = − .057), despite being conceptualised as a high activation emotion, with negative valence (Kuppens, 2009). The low-intensity context of the assessment (i.e. online questionnaire) can be a reason for correlations not being significant as expected, although other emotions with high activation had significant correlations. Further studies are necessary to investigate this.

4.4 Discussion

The aim of Study 1 was to explore core affect's dimensionality with items applied in previous research, but improving the data analysis process. The EFA results are straightforward in that a three-dimensional structure is the best model for the data.

Based on the several analyses performed, the hypothesis that the additional factor represents the substantive dimension of approach/avoidance was rejected and the idea of method-related variance (attributed to acquiescence with both positive and negative feelings) became the most plausible one. This is not the first study where a three-factor structure explains core affect variables correlations better than a two-factor structure. Some authors proposed that the third factor was related to different types of activation (Schimmack & Grob, 2000; Thayer, 1978). Others explicated that response styles were a plausible reason for the extra factors (Russell, 1980; Yik et al., 2011).

Interestingly, when the method-related variance is not controlled, the core affect structure becomes similar to the positive and negative affect model from Watson and Tellegen (1985), which has one factor with positive affect adjectives and another factor with negative affect adjectives. Yet, the substantive interpretation of this model in the past research might have been affected by response styles (here, acquiescing with both positive and negative adjectives), which were controlled in the present study.

Confirming the hypothesis that the responses were influenced by the uniform bias of acquiescence, which is typical in research studies where motivation of participants may be low (Meade & Craig, 2012), the Random Intercept model had the better fit and the most easily interpretable factor solution with a valence factor and an activation factor.

The existence of idiosyncratic response-scale usage (e.g. acquiescence) is not new in circumplex research. Lenk and colleagues (2006) addressed the issue when they proposed a follow-up Bayesian model to estimate circumplexes, in which they included a subject-specific random effect to capture scale-usage effects, assuming the other two factor scores of the model were from two latent bipolar latent constructs.

Indeed, the results from the Circular Stochastic Process with Fourier Series model had a worse fit than the fit from the EFA and CFA in the present study. In addition, the sample correlation matrix did not present a perfect *circulant* pattern. Possibly, these two results are related to acquiescence response style, given that the two first factors in the structure were related to the use of positive and negative affect adjectives.

Based on the results of the present study, to improve the measurement of core affect, some control of response biases (e.g. central tendency, subjective understanding of rating scales) (Friedman & Amoo, 1999; Schwarz et al., 1991) is needed. One method of controlling for response styles is to model it after data are collected (e.g. Random-Intercept model). Another solution is to prevent the bias with the use of forced-choice items.

Thus, the reduced model with 28 items was estimated to enable the development of a forced-choice measure of core affect. With the parameters for the rating scale items known, the Thurstonian IRT model can be applied to create a forced-choice measure. The forced-choice item format has the potential to improve measurement by preventing some response biases, and it has not yet been applied to measurement of core affect. This is accomplished in a longitudinal study (Study 2 of the present thesis), which is designed to investigate transient and stable components of core affect.

Study 2 aims to develop a robust-to-biases measure of core affect, as well as to verify the relationship between core affect, contextual variables (e.g. social interactions, mood), and personality traits in a longitudinal design. Firstly, the second study will advance the discussion of response styles in core affect research with a comparison of single-stimulus (e.g. rating scales) and forced-choice response formats. Secondly, the use of Ecological Momentary Assessment (EMA) mobile applications will allow exploring the relationship between core affect and other covariates, such as personality, by collecting data on feelings as participants experience them in daily life event. Besides the ecological validity of the data (i.e. daily momentary assessments outside laboratories), this method allows to model the data within (situational level) and between (interpersonal level) levels (i.e. multilevel analysis), expanding the understanding of core affect beyond one-time assessments. Moreover, daily life assessments are expected to present more variations in affective states, which is not achievable with one-time assessments only.

5 Study 2: Pursuing ecological validity evidence for core affect

5.1 Objectives

Study 2 aims to validate the 2-factor model of core affect established in Study 1 in an ecologically-valid environment, and controlling for response styles. Specifically, this study aimed to pursue construct and ecological validity evidence of core affect structure by preventing response biases using the forced-choice response format (FC), as well as by examining the relationship of the stable components of core affect and personality.

As it was established in Study 1, self-report measures of core affect can be susceptible to systematic response biases. Depending on the context (e.g. low- or high-stakes), some kinds of biases will be more prone to happen than others. Kahneman (2012) explains the process of answering questions as a matter of *heuristics*. He defines *heuristics* as a procedure that helps to find adequate answers, which are often imperfect, to difficult questions. To base the discussion, Kahneman (2012) introduces the terms *System 1* and *System 2*. To think critically (e.g. operating self-criticism) over these processes is attributed to System 2, while thinking quickly and automatically (e.g. no effort involved) is attributed to System 1.

These systems, depending on each person's mind-set, can influence response patterns in tests (Böckenholt, 2012; Böckenholt, 2017). In addition, certain characteristics of tests play a role in exacerbating the problem (e.g. longer tests, rating scales, excessive number of categories in a scale) (Friedman & Amoo, 1999; Schwarz et al., 1991). In the case of core affect, specific sources of bias make it challenging:

a) Use of rating scales;
b) Inconsistent use of verbal and non-verbal anchors in scale points;

c) Excessive number of items;

d) Use of scenarios or remembered moments as stimuli;

e) Excessive number of points in the scales.

Thinking critically about how one answers a questionnaire, especially when a series of adjectives is presented, leads to the rationale that response styles are better prevented. An efficient solution in this case is to use the forced-choice response format, reducing the possibility of response biases by forcing respondents to choose between two stimuli that can be equally attractive to them (Brown, Inceoglu, & Lin, 2017). This solution is implemented in the current study.

The important issue is the nature of stimuli presented in a core affect measure. Even though the majority of measures (including the one in Study 1) asked respondents to answer according to their current affective state, online and laboratory settings lack ecological validity. In a laboratory or in an internet-based questionnaire, the majority of people will report low activation feelings, simply because the environment is not particularly evoking any strong feelings.

To pursue greater ecological validity, one can use Ecological Momentary Assessment (EMA) with mobile applications, assessing respondents in their own contexts. This method can overcome problems such as recall of past memories, the use of ambiguous or non-validated scenarios, and superficiality of laboratory experiments and remote online assessments. Given that EMA involves intensive repeated assessments, the results can provide insights about stable and momentary components of core affect, which would not be achievable in single-session studies (Hox, 2010).

Considering all these issues, the present study aims to compare the use of rating scales and forced-choice response formats, verifying the recovery of core affect structure and the control of response styles in online and longitudinal assessments. The study was divided in two parts: baseline and longitudinal. In the baseline, participants were invited to enter the study via online survey. After answering the baseline survey, participants were invited to continue their participation longitudinally with a mobile-based survey during 15 working days. Participants had contact with one type of item response format across the longitudinal part of the study. This assignment was randomised during the baseline part.

5.2 Method

5.2.1 Participants

In the study with forced-choice items, there were N = 371 native English speakers in the baseline part, and N = 177 native English speakers in the longitudinal part. The study with rating scale items counted with N = 350 native English speakers in the baseline part, and N = 193 native English speakers in the longitudinal part.

Participants that answered the forced-choice format test were mainly women (88.6%). The youngest participant was 18 years old, and the oldest participant was 63 years old, averaging to a mean age of 28.6 years (*SD* = 11.1 years). Most of them reside in United Kingdom (87.2%) and United States (5.1%), while 8.7% of the participants were from Australia, Austria, Belgium, Canada, Chine, Denmark, Ghana, India, Indonesia, Ireland, Kuwait, Liberia, Malaysia, Netherlands, New Zealand, Qatar, Singapore, and Switzerland. Mainly, participants completed high school (40.1%) and college (35%). A majority of participants identified themselves as “White” (85.6%) in terms of ethnicity.

In the study with rating scale items, the majority of participants were women (85.4%). The youngest participant was 18 years old, and the oldest participant was 64 years old, averaging to a mean age of 28.4 years (*SD* = 10.9 years). Most participants were from United Kingdom (85.7%) and from United States (4.9%); however, 9.4% of the participants were from a variety of other countries (Australia, Canada, China, India, Ireland, Liberia, Luxembourg, New Zealand, Norway, Qatar, Singapore, United Arab Emirates, and Zambia). Most participants completed high school (42.6%) and college (31.7%), and they recognised themselves with the ethnicity "White" (84%).

5.2.2 Measures

Sociodemographic questions and situational questions

After completing the core affect test (rating scale or forced-choice format), participants were requested to provide information about gender, age, school level, ethnicity, marital status, country of residence, and native language. In addition, they also provided information about their appraisal of the day (5-point scale: "very poor", "quite poor", "fair, "quite good", "very good"), activity they were performing prior to start the questionnaire, and with who they had interacted up to that moment (family, boyfriend/girlfriend, friends, work colleagues, nobody). If the participants chose to participate in the longitudinal part of the study, they were requested to register their email.

Core affect test

Results from the 28-item RI model of Study 1 (Section *4.3.1.5 The measure of core affect based on the RI model*) were applied to develop a short core affect measure. The measure included 24 adjectives presented in Table 16. In addition to the item content of the source questionnaire, items *distressed* and *upset* were added to represent the 10th space (X) in the circumplex. Adjectives were the same in both formats (rating scale and forced choice) of the short measure.

In the rating scale format, participants were presented with the adjectives and a 3-point rating scale (*not at all*, *somewhat*, and *a great deal*). In the forced-choice format, participants were presented with 12 pairs of adjectives presented in Table 16. The items were paired according to their locations in the circumplex, to maximise the differences of factor loadings on at least one factor, Valence or Activation (e.g. adjectives that are located furthest from each other on at least one of the axes of the circumplex) according to the recommendations published for the Thurstonian IRT model (Brown & Maydeu-Olivares, 2012). Besides their position in the circumplex, the items were also paired according to their desirability, which was assessed using the thresholds parameters from the Random-Intercept model of Study 1.

Table 16 *FC format items*

Position in the circumplex		FC pairs	
Adjective 1	Adjective 2	Adjective 1	Adjective 2
VI	XII	Quiet	Aroused
III	IX	Pleased	Dissatisfied
XII	VIII	Vigorous	Sad
I	IX	Excited	Unhappy
VII	IV	Sluggish	Content
V	XI	Tranquil	Tense
XI	VI	Nervous	Still
X	V	Distressed	Calm
VIII	I	Melancholic	Active
II	VII	Cheerful	Tired
II	IV	Enthusiastic	Serene
X	III	Upset	Happy

Personality test

Personality traits measured were, as in Study 1, the Big Five: Neuroticism, Extraversion, Openness, Agreeableness, and Conscientiousness. However, the measure chosen for this study was the Forced-choice Five Factor Markers (FCFFM) (Brown & Maydeu-Olivares, 2011a). This questionnaire contains 60 items (12 items per personality trait) that are allocated in 20 blocks of triplets (3 items each). In each block, participants have to answer which item represents them least (LEAST like me) and most like them (MOST like me).

The scores are estimated according to the Thurstonian IRT model parameters established in previous studies with a UK general population sample (Brown & Maydeu-Olivares, 2011b).

5.2.3 Procedures

Participants were invited to participate in the online study via internet (e.g. social media) and via RPS (Research Participation Scheme). Participants followed the survey link, read the information sheet and provided their consent to enter the study. After consenting, they were randomised according to the item format condition (rating scale or forced-choice format). In both cases, they instructed to answer the questionnaire according to how they were feeling right before they opened the questionnaire. Following the core affect questionnaire, they were presented with the sociodemographic and situational questions, and finished the survey by answering the personality questionnaire (FCFFM).

After answering the baseline survey, participants who agreed to participate in the longitudinal study were contacted by the researcher with the instructions to download the mobile application (Paco app). The longitudinal part of the study included a 15-working-day assessment, with two random assessments per day (from 8am to 8pm, excluding weekends). The mobile application contained the same short core affect measure assigned in the baseline survey (forced-choice or rating scale), plus two situational questions about social interactions (family, boyfriend/girlfriend, friends, work colleagues, nobody) and mood state (5-point scale: “very poor”, “quite poor”, “fair, “quite good”, and “very good”). The mobile app questionnaire was developed to take only 1 or 2 minutes, which is essential to avoid participants’ fatigue and dropout. At the end of the assessment period, participants were emailed again to inform them about the end of the study and to provide them with the debriefing sheet.

5.2.4 Data analysis

The baseline and longitudinal datasets were cleaned in SPSS software. In the baseline dataset, the cleaning process involved the computation of new variables representing individual means and standard deviations. These variables were created as two sections (blocks) of the core affect measure, with 12 items each in the rating scale and 6 items each in the forced-choice format. This procedure aimed to verify data integrity (i.e. check for improbable response strings such as same response to every item, etc.). The same procedure was applied in the personality variables, having the means and standard deviations being calculated according to three blocks.

To organise the dataset, a filter variable was created in order to identify participants who answered one or both parts of the study (e.g. participant answered only the baseline part). In case a possible outlier was identified in more than one block or the participant answered with the same category for a majority of items, the case was then marked as invalid in the filter variable. Outliers presented higher means with lower standard deviations or lower means with low standard deviations across all the sections, indicating the endorsement of the same response option across all the items. These characteristics were verified with scatterplots of means (*x-axis)* and standard deviations (*y-axis)* and with the individual means and standard deviations section variables. Other reasons to mark participants' answers as invalid in the baseline part involved:

- Participant did not report if he/she was a native English speaker;
- Participant abandoned the survey early, before finishing the core affect measure (progress variable indicated less than 18%);
- Participant answered the whole questionnaire (core affect measure, sociodemographic questions and personality measure) in five minutes or less;
- Participant answered the core affect measure in fifteen seconds or less. The average time was 25 seconds.

In the longitudinal part, reasons to mark participants' answers as invalid involved:

- Participant did not report if he/she was a native English speaker in the baseline part;
- Participant did not complete the survey at the baseline part;
- Participant did not answer any notifications (0 out of 30) in the mobile application.

In the forced-choice format core affect measure at the baseline, data from 66 participants were marked as invalid, resulting in a sample of N = 371 native English speakers. In the rating scale format at the baseline, data from 112 participants was marked as invalid, resulting in a sample of N = 350 native English speakers. In addition, the time spent answering the core affect questionnaire helped identify participants who were not giving their full attention to the survey.

Before merging the baseline and longitudinal datasets, the longitudinal datasets were cleaned and categorised with filter variables, such as assessment number and day number. These variables guided the clean-up process in case participants provided more or less answers than needed. The question about social interactions was coded into five variables per assessment. The first variable contained the number of groups with which the participant interacted. The other four binary dummy variables contained contrasts about which group the participant interacted with until that assessment. To interpret the results in the same scale, variables about mood and social interactions were grand mean centred.

Next, multilevel factor and path models were applied according to hypotheses, using the software Mplus 7.4. In the longitudinal study, all models have two levels: momentary assessments (within) and person level (between). Each participant had two assessments per day, having up to 30 assessments completed during the study. The within-level variables presented data from momentary assessments, with some missing. Participants who dropped out of the longitudinal part of the study were maintained in the dataset since their information is still used to estimate parameters for the baseline measures.

Comparing repeated measurements longitudinally allows the models to be tested with multilevel CFA. The benefits of multilevel CFA approach are many. First, it allows testing whether the covariance structure of core affect is the same in daily life (within level) as it is from person to person (between level). Constraining all measurement parameters of the core affect items the same across levels, we can evaluate and compare the variances of Valence and Activation and their covariance at the situational level as well as at the person level. For example, even if the Valence and Activation factors are orthogonal in daily experiences, they may be correlated when explaining individual differences between people in their average experiences across time (e.g. those experiencing more activation on average, may be feeling more or less positive in terms of valence).

The dependent core affect items were treated as categorical. The mood variable was treated as continuous. Multilevel models were estimated with Diagonal Weighted Least Squares with robust standard errors (WLSMV in Mplus). Specifications for each model are presented in the results section.

5.3 Results

5.3.1 Improving the measurement of core affect with the Thurstonian IRT model

5.3.1.1 Rating scale format

Baseline part

An EFA with Geomin oblique rotation was performed to explore the factor structure of the short test with single-stimulus items. As it is shown in Figure 13, the scree plot indicates that two major factors are responsible for the vast majority of variance, while a third or possibly a fourth factor cannot be ignored.

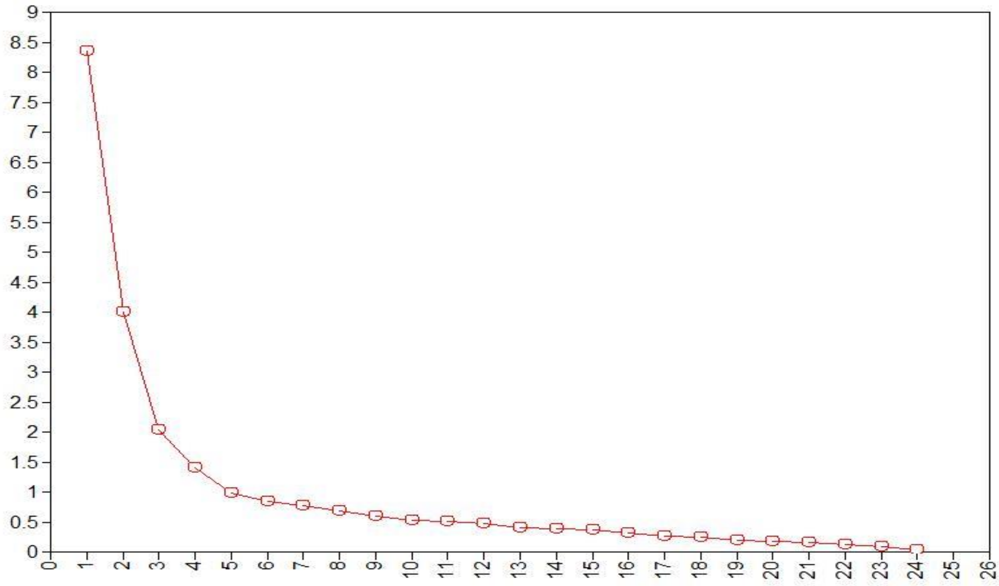


Figure 13 Scree plot of rating scale measure in the baseline part

The fit indices for the one-, two-, three-, and four-factor solution are presented in Table 17. There is a substantive drop in the χ^2 value from the one-factor solution to the two-factor solution ($\Delta\chi^2 = 489.862$, $df = 23$, $p < .001$), and from the two-factor solution to the three-factor solution ($\Delta\chi^2 = 220.554$, $df = 22$, $p < .001$). The difference between the three-factor solution to the four-factor solution is smaller but still significant ($\Delta\chi^2 = 137.626$, $df = 21$, $p < .001$).

Table 17 *EFA model fit indices of the rating scale measure in the baseline part*

	1 factor	2 factors	3 factors	4 factors
Number of parameters	24	47	69	90
χ^2	1732.112	770.786	458.158	280.342
Degrees of freedom	252	229	207	186
P-value	< .001	< .001	< .001	< .001
RMSEA	.130	.082	.059	.038
RMSEA CI 90%	.124-.135	.076-.089	.052-.066	.029-.047
CFI	.756	.911	.959	.984
SRMR	.169	.079	.055	.042

Note. N=350.

The two-dimensional model represents the constructs in theory (Valence and Activation) but it is likely distorted in the empirical data due to a method factor as was demonstrated in Study 1. To test this hypothesis, a Random Intercept item factor model was fitted to the data again (Maydeu-Olivares & Coffman, 2006). All factor loadings of the method factor were fixed at 1 and its factor variance was freely estimated. In the valence-related factor, the items *quiet* and *aroused* were used as scale anchors, having their factors loadings fixed at 0. In the activation factor, the items *unhappy* and *happy* were used as anchors. The estimator WLSMV was applied. The factor metric was set by fixing the factor variances of valence and activation at 1. All factors correlations were set at 0.

This model has a χ^2 of 719.925 for 231 degrees of freedom (p < .001). The RMSEA is .078 (acceptable), and the CFI presented a good fit (.919). Similar to the first study results, the random intercept factor variance is significant (σ^2 = .210, SE = .021, z = 9.9, p < .001). Standardised factor loadings are presented in Table 18 and Figure 14.

Table 18 *Rating scale - Standardised factor loadings of the baseline study*

	Valence		Activation	
	Factor loadings	S.E.	Factor loadings	S.E.
Quiet	0	0	**-.335**	.063
Pleased	**.619**	.039	**.433**	.050
Vigorous	.181	.069	**.630**	.052
Excited	**.446**	.051	**.620**	.042
Sluggish	**-.478**	.050	**-.368**	.064
Tranquil	**.546**	.049	-.168	.069
Nervous	**-.488**	.052	**.352**	.065
Distressed	**-.637**	.046	.213	.067
Melancholic	**-.544**	.053	-.034	.069
Cheerful	**.716**	.031	**.383**	.051
Enthusiastic	**.556**	.041	**.599**	.042
Upset	**-.709**	.038	.271	.067
Aroused	0	0	**.498**	.067
Dissatisfied	**-.737**	.035	.061	.065
Sad	**-.810**	.028	.204	.062
Unhappy	**-.881**	.024	0	0
Content	**.830**	.023	.090	.058
Tense	**-.633**	.043	**.321**	.063
Still	.138	.059	**-.345**	.066
Calm	**.685**	.039	-.268	.067
Active	**.332**	.057	**.526**	.048

Tired	**-.446**	.054	-.141	.067
Serene	**.509**	.048	-.018	.065
Happy	**.816**	.031	0	0

Note. Factor loadings equal or greater than .32 are in boldface. N=350. S.E. = Standard Error.

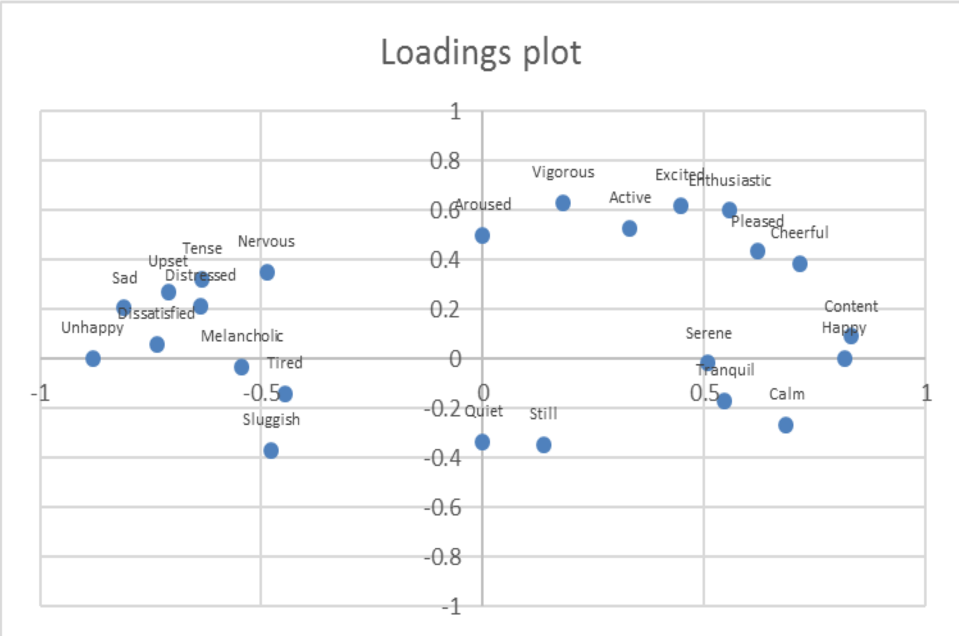


Figure 14 Rating scale - Loadings plot of the baseline study

Estimated standard errors are of the magnitude of 1/√N (1/√350= .053), indicating a well-identified model as suggested by McDonald (2014). Factor loadings have the correct sign and strength for each adjective, although they do not follow a perfect circular shape in the loadings plot (Figure 14).

Reliability and estimated scores

The reliability was estimated according to the *empirical reliability* equation 12. To obtain EAP scores, the RI model was fitted to the data with the MLR estimator and *probit* link. Reliability coefficients (ρ), error variances and latent trait variances for each factor are presented in Table 19. Valence scores varied from −2.995 to +2.36 (mean = − .003, *SD* = .9546). Activation scores varied from −2.578 to 2.306 (mean = .000, *SD*

= .860). Estimated sample scores and their standard errors are plotted together in Figure 15 and Figure 16.

Table 19 *Reliability indices information*

	Valence	Activation
Error variance	.090	.259
Latent trait variance	.911	.740
Reliability (ρ)	.910	.741

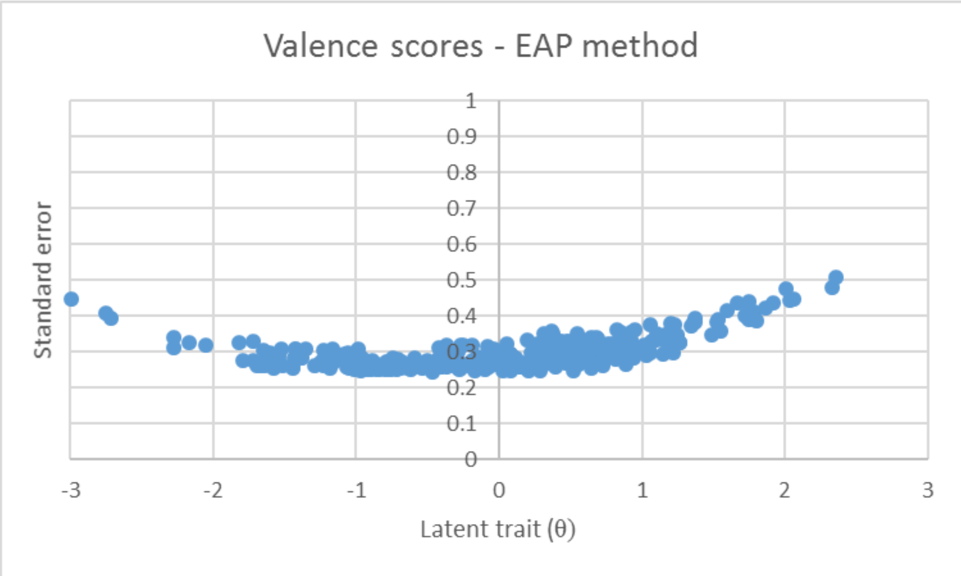


Figure 15 Standard errors of the EAP Valence scores in the RI factor model

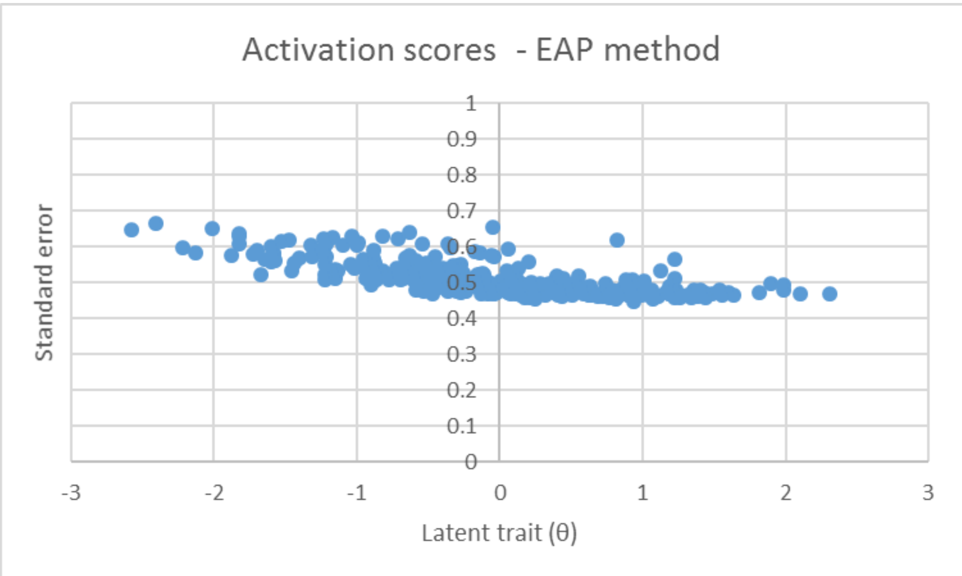


Figure 16 Standard errors of the EAP Activation scores in the RI factor model

The reliabilities coefficients are acceptable, but the reliability coefficient for activation is substantively smaller than valence's reliability coefficient. Valence EAP scores are estimated with more precision between −2 to +1, where standard errors are around .25. Activation scores are more precise between −1 to +2, where standard errors are around .45. Therefore, both scales cover a good range of latent trait levels (θ) with high precision.

Notably, EAP scores have a lower variance for activation when compared to valence. In the case of Bayesian estimators, scores are affected by the shrinkage towards the mean for the latent trait distribution. One reason for this is that the Activation scale has weaker factor loadings when compared to Valence; thus, shortening the number of items that load strongly in the factor and giving more weight to the prior distribution (Brown & Croudace, 2015).

Longitudinal part

In the rating scale condition, 193 participants (out of 350) completed (fully or partially) the longitudinal part. Participants answered an average of 22 assessments across the 15 working days (29.4% were not answered), resulting in 4183 observations at the within level in the multilevel analysis.

Modelling longitudinal core affect data

The intraclass correlations of the core affect items varied from .227 to .544, showing that a large amount of variance is explained by the grouping structure (person-level) of the data (Hox, 2010).

To continue the analysis of the rating scale measure, the dimensionality of core affect was analysed based on the longitudinal study. An EFA with Geomin oblique rotation was performed, and the scree plots in the within- and between-levels are presented in Figure 17 and Figure 18.

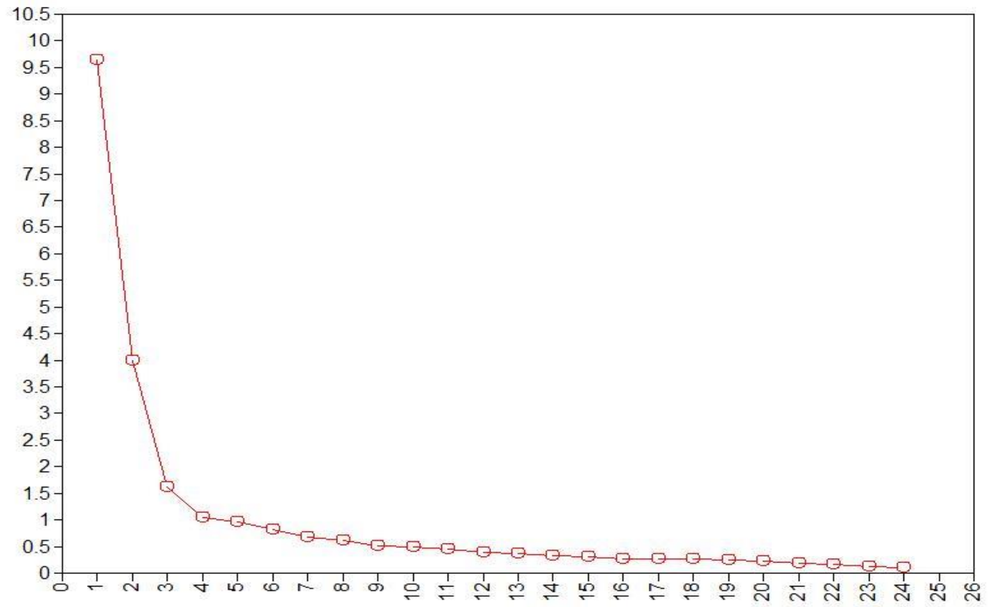


Figure 17 Rating scale - Scree plot of the within level in the longitudinal study

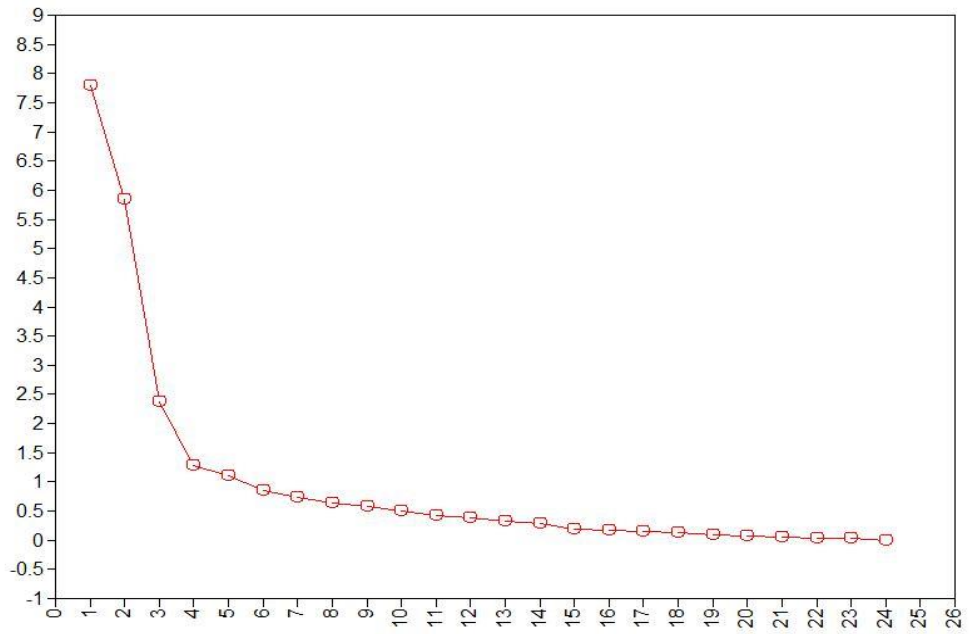


Figure 18 Rating scale - Scree plot of the between level in the longitudinal study

The scree plots suggest that solutions with two and three factors explain the majority of variance in the data. Considering the scree plot results, fit indices for EFA models with combinations of two and three factors in the within- and between-level are presented in Table 20.

Table 20 *Rating scale - Model fit indices in the longitudinal study*

	2 within, 2 between	3 within, 3 between	3 within, 2 between
N free parameters	166	210	188
χ^2	7754.823	4446.171	4106.161
Degrees of freedom	458	414	436
p-value	< .001	< .001	< .001
RMSEA	.062	.048	.045
RMSEA CI 90%	.061-.063	.047-.05	.044-.046
CFI	.925	.959	.962
SRMR within	.070	.045	.045
SRMR between	.096	.058	.096

The model with three factors at both within and between levels has better fit. Considering that the model with the random intercept factor was the better fit for the data in previous analyses, it is reasonable that the same model applies for the within and between levels. These results reinforce the idea that response styles are stable across time (Wetzel et al., 2016), considering that the method factor appears to influence the core affect structure at the between level as well.

To confirm this hypothesis, a confirmatory model was applied with 2 within and 2 between factors, and with 3 within and 3 between factors. Both models had the same constraints, except that the three-factor multilevel model had a third method factor (random intercept with factor loadings fixed at 1). It is assumed that the same constructs are measured at the within- and between-person levels; thus, factor loadings are constrained to be equal across levels. Factor variances are fixed 1 in the within-level and freely estimated in the between-level. Factor correlations are fixed at 0 in the within-level and freely estimated in the between-level. In relation to the RI factor, all factor loadings were fixed at 1 in the within- and between-levels. Its factor variances were freely estimated in both levels. The RI factor correlation with other factors was fixed at 0 in the within-level and freely estimated in the between-level. The models were estimated with WLSMV. Model fit indices are presented in Table 21.

Table 21 *Rating scale - Multilevel CFA model fit indices*

	Multilevel Factor Structure	
	2 within, 2 between	3 within, 3 between
Number of parameters	123	127
χ^2	4029.295	3506.383
Degrees of freedom	501	497
P-value	< .001	< .001
RMSEA	.041	.038
CFI	.961	.967
SRMR within	.070	.060
SRMR between	.249	.157

Clearly, the model accounting for the random intercept factor has a better fit when compared to the two-factor multilevel model. The SRMR decreases substantially in the between level from the two-factor multilevel model to the three-factor multilevel model, indicating that controlling for acquiescence is necessary. At the within level, the random intercept factor has a variance of .112 (*SE* = .004, *z* = 25.655, *p* < .001). At the between level, the random intercept factor has a variance 0.265 (*SE* = .031, *z* = 8.642, *p* < .001). Therefore, accounting for acquiescence is important at both intrapersonal and interpersonal levels. At the between level, valence had a variance of 0.401 (*SE* = .05, *z* = 8.068, *p* < .001) and activation had a variance of 0.265 (*SE* = .038, *z* = 8.642, *p* < .001).

Valence and activation do not correlate significantly at the between level (*r*= −.124, p= .173); however, the direction of the correlation indicates that in this sample, people who experienced more pleasant feelings on average had lower activation levels on average. At the between level, activation correlated significantly with the random intercept (*r* = .228, *p* = .011), indicating that participants experiencing higher activation on average, tended to acquiesce more. The factor loadings structure is presented in

Table 22 and the loading plots are presented in Figure 19 and Figure 20. The within-level structure represents the core affect structure and the factor loadings spread in a circle shape around the two axes. The circle shape is not clear in the between-level plot.

Table 22 *Rating scale - Standardised CFA factor loadings and residuals of the longitudinal study*

	Within				Between					
	Valence		Activation		Valence		Activation			
	Factor loadings	S.E.	Factor loadings	S.E.	Factor loadings	S.E.	Factor loadings	S.E.	Residuals	S.E.
Upset	**-.854**	.008	.180	.017	**-.823**	.065	.132	.019	.144	.121
Calm	**.462**	.012	**-.508**	.012	**.541**	.042	**-.453**	.043	.124	.120
Unhappy	**-.897**	.005	.117	.017	**-.860**	.054	.085	.015	.142	.085
Active	**.491**	.014	**.618**	.011	**.506**	.034	**.484**	.044	.209	.088
Tired	**-.452**	.014	**-.427**	.014	**-.460**	.036	**-.331**	.033	.450	.074
Sad	**-.829**	.007	.111	.017	**-.688**	.050	.070	.012	.391	.070
Dissatisfied	**-.748**	.009	.090	.016	**-.595**	.035	.054	.011	.478	.051
Excited	**.643**	.013	**.397**	.014	**.539**	.039	.253	.025	.437	.060
Vigorous	**.371**	.019	**.474**	.016	.228	.022	.222	.024	.724	.037
Aroused	**.324**	.024	.219	.020	.189	.023	.097	.013	.766	.035
Content	**.744**	.008	-.215	.014	**.785**	.049	-.173	.021	.071	.093
Still	0	0	**-.724**	.011	-.018	.060	**-.545**	.051	.559	.056
Serene	**.512**	.014	**-.688**	.011	**.325**	.029	**-.332**	.031	.727	.039
Tranquil	**.535**	.012	**-.719**	.009	**.338**	.029	**-.345**	.033	.721	.039
Distressed	**-.733**	.011	.261	.014	**-.632**	.044	.172	.019	.354	.074
Enthusiastic	**.726**	.010	**.381**	.012	**.599**	.035	.239	.022	.433	.037
Happy	**.856**	.005	.095	.014	**.734**	.032	.062	.011	.330	.051
Quiet	**-.376**	.012	**-.543**	.010	**-.382**	.030	**-.419**	.039	.500	.065
Sluggish	**-.562**	.013	**-.501**	.012	**-.503**	.038	**-.342**	.033	.552	.052
Pleased	**.788**	.007	0	0	**.758**	.044	.313	.072	.090	.087
Nervous	**-.430**	.016	**.333**	.015	**-.332**	.028	.196	.020	.552	.057
Tense	**-.651**	.011	**.318**	.013	**-.534**	.036	.199	.021	.435	.058
Melancholic	**-.454**	.015	-.064	.017	-.263	.025	-.028	.008	.786	.035
Cheerful	**.823**	.006	.192	.013	**.690**	.037	.122	.013	.376	.050

Note. Factor loadings equal or greater than .32 are in boldface. S.E. = Standard Error.

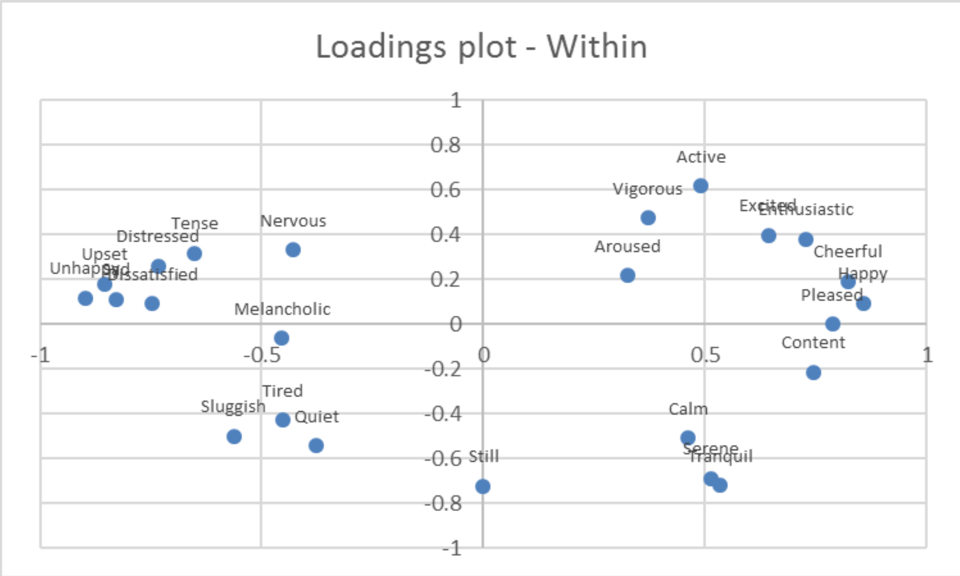


Figure 19 Rating scale - Loadings plot of the within level of the longitudinal study

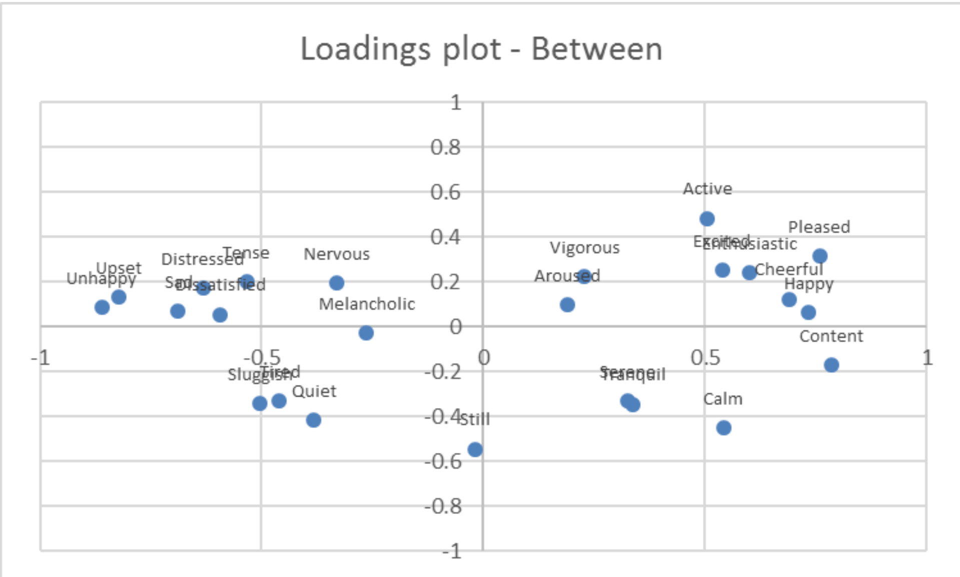


Figure 20 Rating scale - Loadings plot of the between level in the longitudinal study

5.3.1.2 Forced-choice format

Baseline part

The scree plot of the baseline adjective pairs data clearly indicated that two factors should be retained (Figure 21).

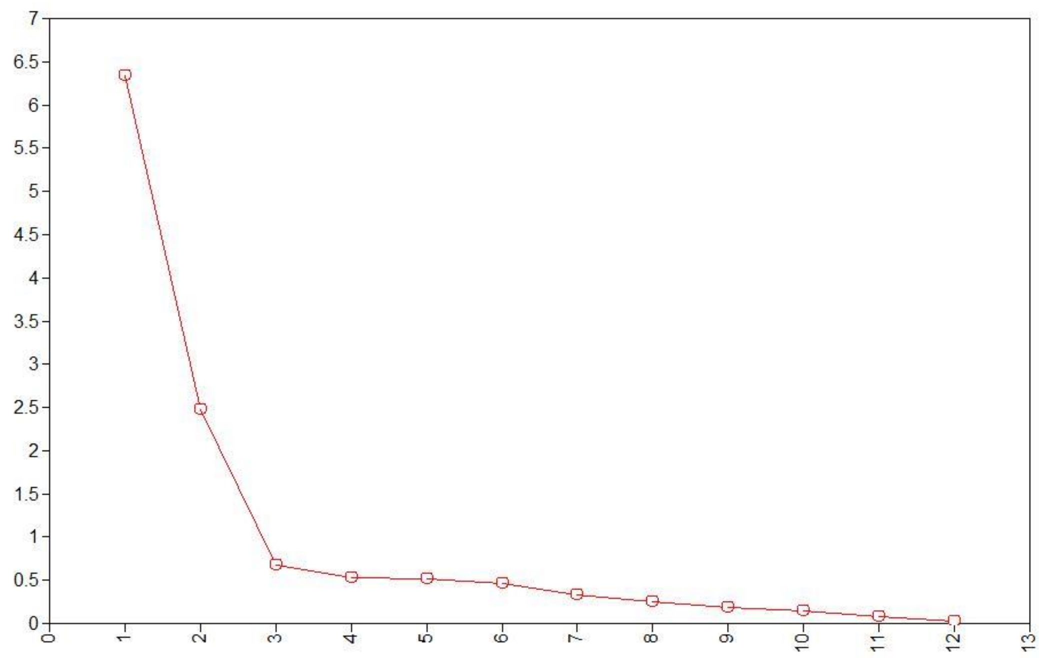


Figure 21 Scree plot of FC data in the baseline part

Comparing the χ^2 statistics yields a significant difference from the one-factor solution to the two-factor solution (χ^2=214.261, p < .001), while the comparison between the two-factor solution and the three-factor solution does not present a significant improvement (χ^2=16.417, p = .0883). It is safe to assume that the two-factor solution underlies the data. Model fit indices are presented in Table 23.

Table 23 *EFA model fit indices of the FC format measure in baseline part*

	1 factor	2 factors	3 factors
N free parameters	12	23	33
χ^2	419.398	40.118	22.021
Degrees of freedom	54	43	33
P-value	< .001	.597	.927
RMSEA	.135	< .001	< .001
RMSEA CI 90%	.123-.147	.000-.031	.000-.012
CFI	.908	1	1
SRMR	.161	.033	.026

Note. N=371.

Next, a Thurstonian IRT model (Brown & Maydeu-Olivares, 2012) was fitted to the data. Residual items variances were fixed at 1 to identify the model, factor variances were fixed at 1 and factors correlation were fixed at 0. To identify the factor loadings in this two dimensional model, as recommended by Brown and Maydeu-Olivares (2012), the loading for pair *pleased-dissatisfied* (both adjectives indicate valence) was fixed at 0 in the Activation factor. The CFA model was estimated using WLSMV estimator and theta parameterisation.

The model fitted well with RMSEA= .000, CFI = 1, χ^2 = 40.119 for *df* = 43 (*p* = .597). Factor loadings and their standard errors are presented in Table 24.

Table 24 *Standardised factor loadings of FC model at baseline study*

	Valence		Activation	
	Factor loadings	S.E.	Factor loadings	S.E.
Quiet-Aroused	-.168	.097	**-.562**	.084
Pleased-Dissatisfied	**.909**	.023	0	0
Vigorous-Sad	**.852**	.032	.214	.073
Excited-Unhappy	**.906**	.028	.292	.067
Sluggish-Content	**-.807**	.035	-.112	.068
Tranquil-Tense	**.629**	.057	**-.558**	.069
Nervous-Still	**-.492**	.072	**.695**	.065
Distressed-Calm	**-.670**	.063	**.537**	.077
Melancholic-Active	**-.635**	.054	**-.442**	.077
Cheerful-Tired	**.677**	.052	.177	.088
Enthusiastic-Serene	**.384**	.074	**.562**	.077
Upset-Happy	**-.985**	.016	.066	.062

Note. Factor loadings equal or greater than .32 are in boldface. N=371. S.E. = Standard Error.

The circular shape can be clearly seen when factor loadings are plotted (Figure 22). The solution is more elegant and simpler than the three-factor model that accounts for acquiescence with a method factor. In addition, the solution shows a better fit to the data. Therefore, it demonstrates the efficiency of the forced-choice format to overcome systematic response styles, such as acquiescence.

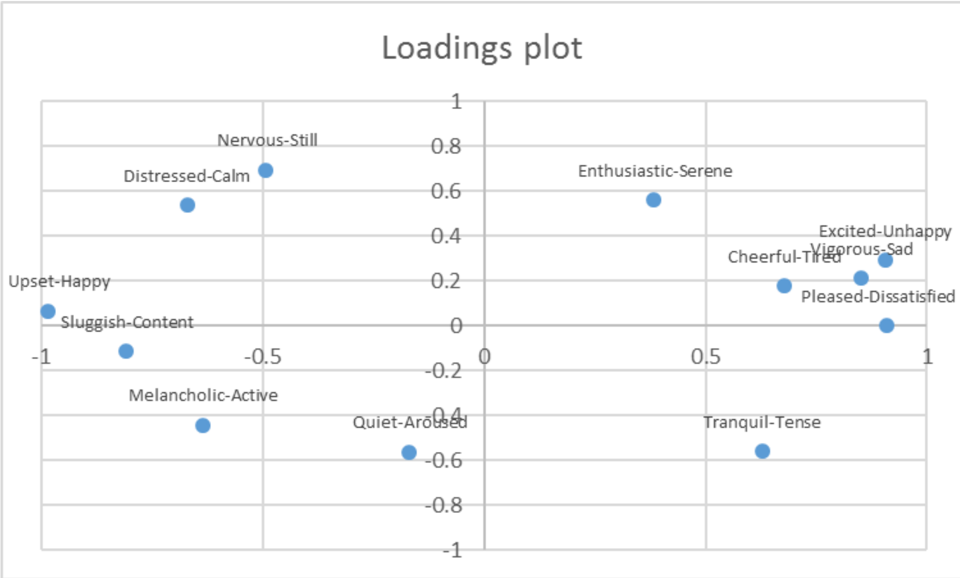


Figure 22 Loadings plot of FC format measure in the baseline study

Reliability and estimated scores

To verify the reliability of the scores, the same model was estimated with MLR estimator and *probit* link. Scores were estimated with EAP estimator and the empirical reliability was calculated based on equation 12. Error variances, latent trait variances and reliability estimates are presented in Table 25. Estimated sample scores and their standard errors are plotted together in Figure 23 and Figure 24.

Table 25 *Reliability indices information*

	Valence	Activation
Error variance	.165	.371
Latent trait variance	.835	.629
Reliability (ρ)	.835	.629

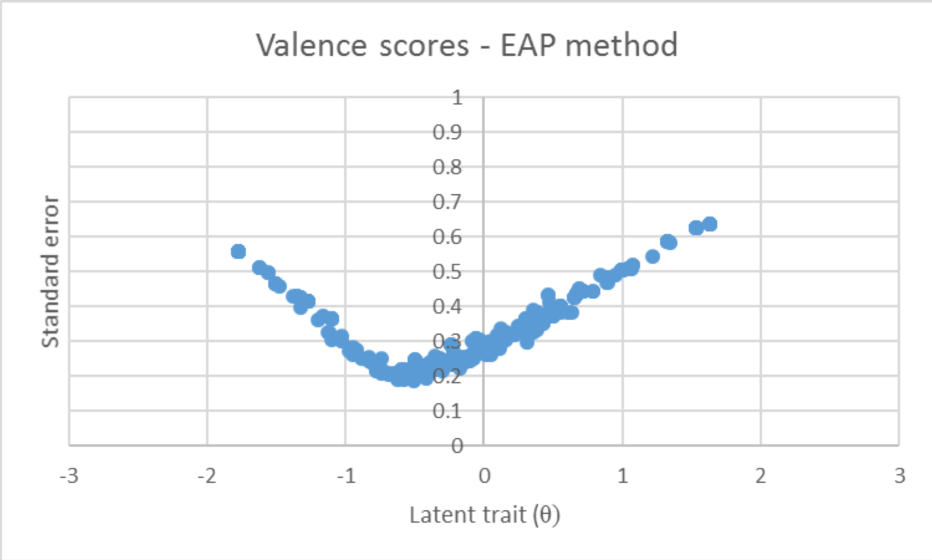


Figure 23 Standard errors of the EAP Valence scores in the FC model

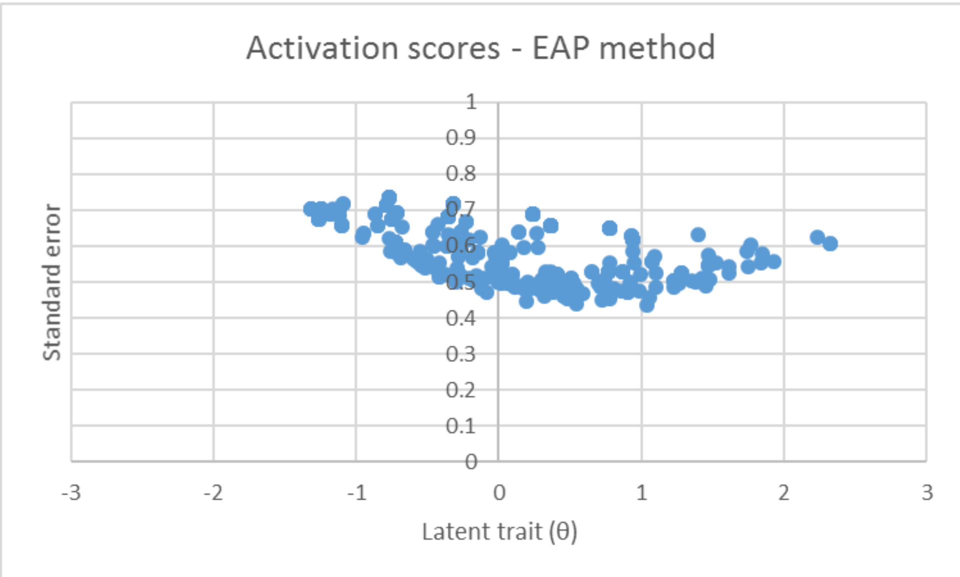


Figure 24 Standard errors of the EAP Activation scores in the FC model

EAP scores for valence varied between −1.77 and +1.632 (mean= .000, *SD* = .914). EAP activation scores varied between – 1.32 and +2.323 (mean= .000, *SD* = .793). Overall, the reliability estimate is acceptable for valence but rather low for activation. A better understanding of the scales' reliability can be achieved by looking at standard errors for each latent score (or ranges of them). For example, the lowest standard error for valence scores covers the range from −1 to 0, and its value is approximately .21. In the case of activation scores, the standard errors are lower for the range of 0 to +1, having a value of approximately .43. Considering that the forced-choice scales have 12 items and some items did not load strongly in the activation scale, it is possible that the activation construct is not as well presented in the measure as the valence construct, or perhaps it is inherently more difficult to measure in casual situations where activation levels are rather low.

Longitudinal part

In the forced-choice format condition, 177 participants (out of 371) completed (fully or partially) the study after answering the baseline questions. During the 15 working days, participants answered an average of 22 assessments (28.1% assessments were not answered), totalling to 3956 observations.

Intraclass correlations for the core affect pairs have values between .217 and .341, showing that a large amount of variance is explained by individual differnces between people rather than situational factors alone (Hox, 2010).

Modelling longitudinal core affect data

First, a multilevel EFA was performed with the longitudinal data. Both within- and between-level scree plots are similar and indicate that a two-factor solution should be retained (Figure 25 and Figure 26).

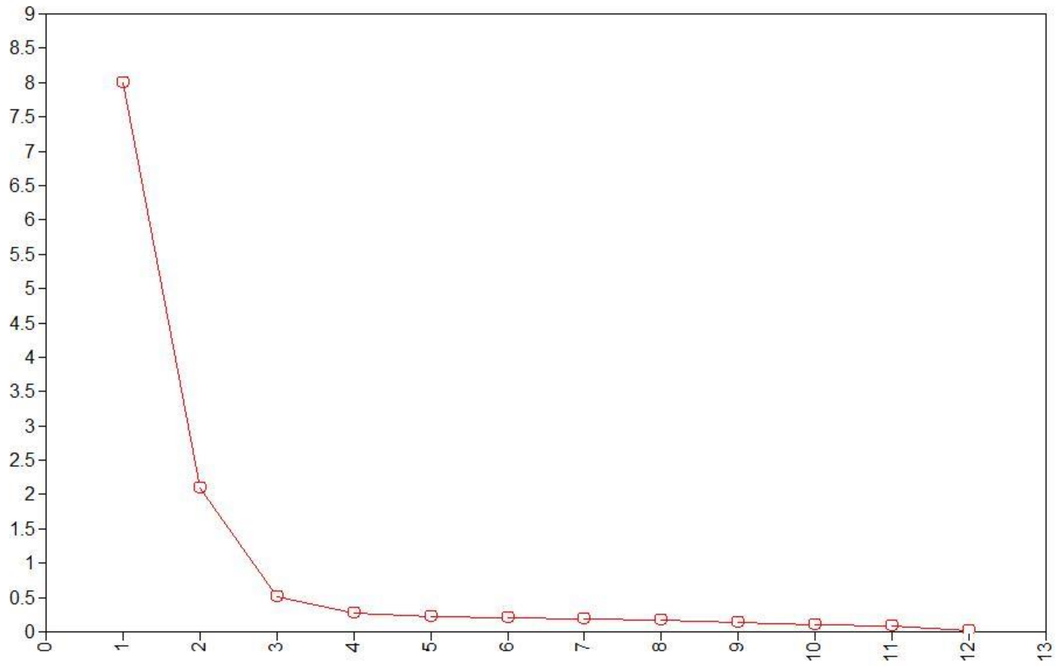


Figure 25 FC format - Scree plot of the within level in the longitudinal study

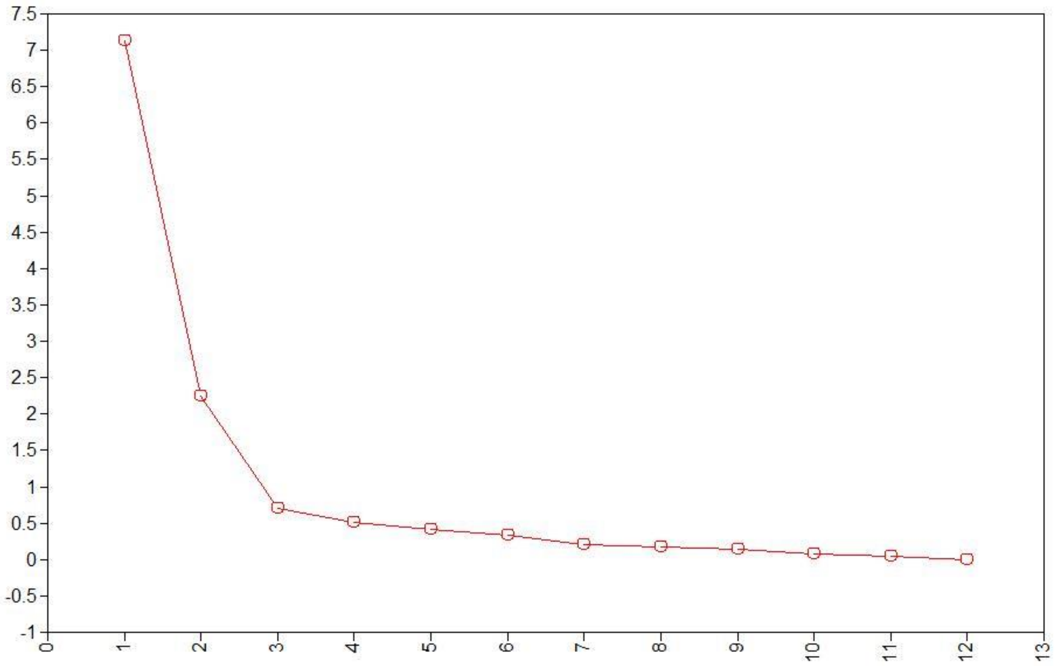


Figure 26 FC format - Scree plot of the between level in the longitudinal study

Indeed, the two-factor solution in both levels gives a χ^2 of 673.439 for 86 degrees of freedom (p < .001) (RMSEA = .042, CFI = .99, $SRMR_{within}$ = .029, $SRMR_{between}$ = .051). These model indices indicate a remarkably good fit.

The multilevel two-factor CFA model was estimated with WLSMV. Factor loadings were constrained to be equal across the levels. Factor variances were fixed at 1 in the within-level in order to set the metric of the model, and factors correlation was fixed at 0 in the within-level. In addition, the *pleased-dissatisfied* item was fixed at 0 in the activation factor (within-level) to identify the factor loadings. Factor loadings, factor variances and factors correlation were freely estimated in the between level and items residual variances were set equal in the between level to identify the model.

This model gives a χ^2 of 472.025 for 116 degrees of freedom ($p < .001$). The RMSEA is good (.028), as well as the CFI (.99) and the SRMR (within = .029 and between = .096). The factor loadings of this model is presented in Table 26.

Table 26 *FC format - Standardised factor loadings in the longitudinal study*

	Within level				Between level					
	Valence		Activation		Valence		Activation			
	Factor loadings	S.E.	Factor loadings	S.E.	Factor loadings	S.E.	Factor loadings	S.E.	Residuals	S.E.
Quiet-aroused	**-.592**	.018	**-.561**	.020	**-.533**	.035	**-.536**	.040	.514	.043
Pleased-dissatisfied	**.934**	.004	0	0	**.888**	.015	.025	.053	.218	.027
Vigorous-sad	**.868**	.008	.207	.018	**.816**	.027	.207	.025	.342	.039
Excited-unhappy	**.958**	.003	.042	.013	**.931**	.012	.043	.014	.143	.020
Sluggish-content	**-.869**	.008	-.165	.017	**-.810**	.024	-.164	.022	.356	.037
Tranquil-tense	**.731**	.014	**-.601**	.018	**.647**	.040	**-.564**	.039	.154	.027
Nervous-still	**-.529**	.019	**.635**	.017	**-.441**	.034	**.562**	.035	.415	.041
Distressed-calm	**-.796**	.013	**.479**	.019	**-.705**	.037	**.451**	.035	.204	.028
Melancholic-active	**-.817**	.010	**-.361**	.016	**-.779**	.035	**-.366**	.033	.346	.039
Cheerful-tired	**.863**	.009	.284	.017	**.827**	.031	.290	.029	.303	.036
Enthusiastic-serene	**.618**	.016	**.594**	.018	**.573**	.040	**.585**	.041	.431	.046
Upset-happy	**-.983**	.004	.019	.014	**-.967**	.009	.019	.015	.060	.016

Note. Factor loadings equal or greater than .32 are in boldface. S.E. = Standard Error.

The factor loadings spread nicely in a circle shape in the loadings plot for the within and between levels (Figure 27; Figure 28). In the between level, valence has a variance of .289 (SE = .039, z = 7.38, p < .001) and activation has a variance of .326 (SE = .054, z = 6.084, p < .001), and both are significant. Valence and activation do not correlate significantly in the between level (r = − .15, p = .117), though the direction of the correlation suggests that for participants in this sample, feelings of low activation tended to be pleasant (e.g. serene, content).

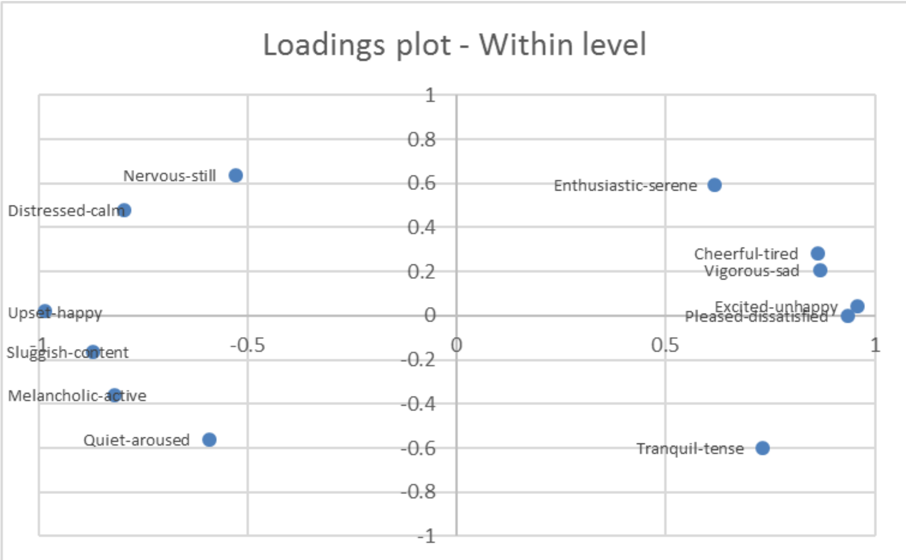


Figure 27 FC format - Loadings plot of the within level in the longitudinal study

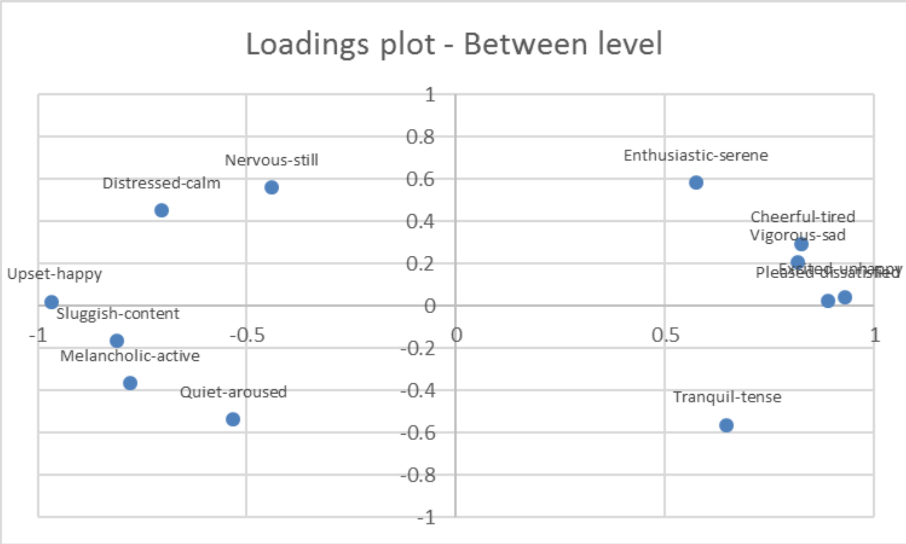


Figure 28 FC format - Loadings plot of the between -level in the longitudinal study

The complex structure of core affect was nicely recovered with the forced-choice format. In comparison to the rating scale test, the factor loadings are recovered with a more elegant solution and they resemble more a circle in the loadings plot. As seen before, although the response style of acquiescence can be controlled by the random intercept factor, it is more effective to prevent response styles from affecting the data in the first place.

5.3.2 Personality, social interactions and core affect: a longitudinal study

Considering that the forced-choice test provided a better solution for measuring core affect, the causal effects of stable and momentary components were tested with forced-choice data. Personality scores on the FCFFM measure were estimated using MAP (Maximum a Posteriori) with ULSMV estimator and theta parameterisation (Brown & Maydeu-Olivares, 2011a). The descriptive statistics of personality trait scores in both conditions are presented in Table 27.

Table 27 *Descriptive statistics about personality traits at the baseline study*

Personality traits	N	Min	Max	Mean	S.D.

Neuroticism	350	-1.206	3.290	1.25705	.969011
Extraversion	350	-3.241	1.461	-.852550	.926301
Openness	350	-2.862	1.338	-1.10243	.720731
Agreeableness	350	-2.897	1.662	-.399460	.825039
Conscientiousness	350	-3.121	1.098	-1.07296	.790567

Note. N = Sample size; Min = Minimum; Max = Maximum; S.D. = Standard Deviation.

The social interactions variable was divided into four binary variables about having or not met the participant's boyfriend/girlfriend, friends, work colleagues, and family. In the baseline study, most participants reported having had a social interaction during the day (89.9%) and they reported have been "on internet" (19.1%), "resting" (15.6%), "watching TV" (11.1%), among other activities prior to start the study. Most participants rated their day as "fair" (45.9%) and "quite good" (33.3%) until that moment.

Social interactions variables counted as assessment $t - 1$ variables because the question "Did you interact with someone today?" referred to past interactions. The mood ("How is your mood right now") question used a 5-point rating scale (very good, quite good, fair, quite poor, and very poor) and referred to assessment *t*. The causal effects tested are presented schematically in Figure 29; however, only one personality trait at a time was tested at the between level to identify individual effects of personality traits rather than effects controlled for other personality traits.

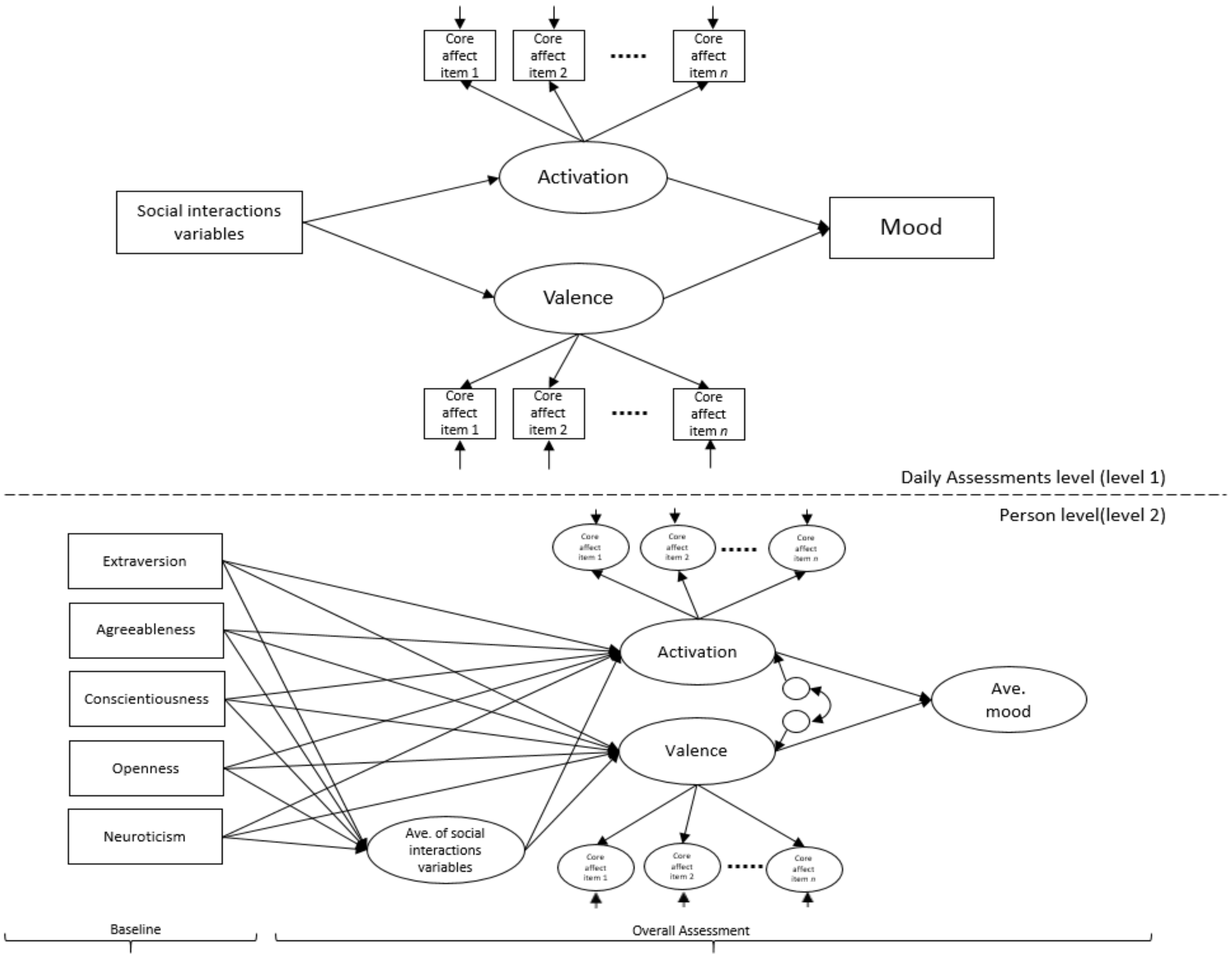


Figure 29 Longitudinal path model

In total, six multilevel models were tested. The first model did not include any baseline personality covariates at the between level; the remaining models included one personality covariate at a time. The model specifications are presented in Table 28 and models fit results are presented in Table 29. In the models with personality covariates at the baseline, there were 161 clusters with an average size of 30 data points, totalling 4830 observations. All multilevel models were tested with Diagonal Weighted Least Squares (WLSMV) estimator and theta parameterisation. Momentary assessments (two per day) were modelled in the within level and persons latent averaged scores across all assessments were modelled in the between level. Core affect item pairs were modelled with the Thurstonian IRT model specified in section 5.3.1.2.

Table 28 *Dependent variables and covariates in longitudinal models*

Models #	Variables								
	Context		Core affect		Personality				
	Social interactions	Mood	V	A	N	E	O	A	C
1	t −1	t +1	t	t	-	-	-	-	-
2	t −1	t +1	t	t	Baseline	-	-	-	-
3	t −1	t +1	t	t	-	Baseline	-	-	-
4	t −1	t +1	t	t	-	-	Baseline	-	-
5	t −1	t +1	t	t	-	-	-	Baseline	-
6	t −1	t +1	t	t	-	-	-	-	Baseline

Note. Core affect V = Valence dimension; Core affect A = Activation dimension; Personality N = Neuroticism; Personality E = Extraversion; Personality O = Openness; Personality A = Agreeableness; Personality C = Conscientiousness.

Table 29 *Summary of fit indices for longitudinal models with contextual and baseline variables*

	Models					
	1	2	3	4	5	6
# parameters	64	82	82	82	82	82
χ^2	633.329	431.058	462.211	467.384	424.220	436.712
df	224	247	247	247	247	247
p-value	< .001	< .001	< .001	< .001	< .001	< .001
RMSEA	.022	.012	.013	.014	.012	.013
CFI	.995	.997	.996	.996	.997	.997
$SRMR_{within}$	.029	.033	.290	.030	.030	.030
$SRMR_{between}$	.092	.101	.092	.095	.094	.093

Note. # parameters = Number of free parameters; *df* = degrees of freedom.

5.3.2.1 Model 1 - Contextual variables

Model 1 was designed to identify if the social interaction variables at assessment t – 1 influenced core affect dimensions, and if core affect dimensions influenced mood at t + 1. To enable Model 1, mood at assessment *t* was lagged; that is, they were moved in the dataset to the corresponding rows of assessment t. The models fit results are presented in Table 29. Standardised estimates are presented in Table 30.

Table 30 *Standardised estimates of multilevel model with contextual variables*

Level	Independent variable	Dependent variable	Estimate	S.E.	z	p
Within	Boyfriend/Girlfriend	Valence	.182	.061	2.959	.003

level	Friends	Valence	.352	.043	8.256	< .01
	Work colleagues	Valence	.002	.059	.0330	.974
	Family	Valence	.243	.045	5.450	< .01
	Boyfriend/Girlfriend	Activation	-.033	.084	- .395	.693
	Friends	Activation	.172	.053	3.249	.001
	Work colleagues	Activation	.122	.080	1.532	.125
	Family	Activation	.279	.048	5.844	< .01
	Activation	Mood t+1	-.044	.021	-2.059	.039
	Valence	Mood t+1	.156	.019	8.236	< .01
Between level	Boyfriend/Girlfriend	Valence	-.080	.234	-.343	.731
	Friends	Valence	.135	.300	.4480	.654
	Work colleagues	Valence	-.456	.353	-1.292	.196
	Family	Valence	-.258	.253	-1.022	.307
	Boyfriend/Girlfriend	Activation	.170	.267	.6360	.525
	Friends	Activation	-.212	.387	-.548	.584
	Work colleagues	Activation	.243	.403	.6020	.547
	Family	Activation	-.577	.278	-2.077	.038
	Activation	Mood	.029	.061	.4780	.633
	Valence	Mood	.900	.027	33.170	< .01

Note: S.E. = Standard Error. Significant results ($p < .05$) are highlighted.

This model shows positive significant effects of interaction with friends, family and boyfriend/girlfriend on valence, as well as a positive significant effect of friends on activation. Thus, persons that interacted with friends during the day also felt more pleasant and high activation feelings (e.g. cheerful, excited). Previous feelings significantly predicted mood at assessment *t*+1; however, this association was stronger on between level. On between level, valence strongly predicted mood ($\beta = .90$, $p < .001$), indicating that overall valence's scores predict overall mood. These findings agree with evidence from the literature (Hawkley et al., 2007; Sandstrom & Dunn, 2014; Watson et al., 1992), allowing for a chain of mediated events to be traced between personality, social interactions and core affect. Given the empirical evidence, the models with personality variables were tested with contextual variables organised according to model 1.

5.3.2.2 Model 2 - Neuroticism

The results are shown in Table 31.

Table 31 *Standardised estimates of multilevel model with Neuroticism*

Level	Independent variable	Dependent variable	Estimate	S.E.	z	p
Between level	Neuroticism	Activation	.130	.109	1.195	.232
	Neuroticism	Valence	-.523	.071	-7.376	< .01
	Neuroticism	Boyfriend/Girlfriend	.179	.100	1.779	.075
	Neuroticism	Friends	.043	.096	.4450	.656
	Neuroticism	Work colleagues	.055	.099	.5520	.581
	Neuroticism	Family	.065	.082	.7940	.427

Note: S.E. = Standard Error. Significant results ($p < .05$) are highlighted.

Neuroticism measured at baseline does not have a significant effect on between-level activation; however, it does have a significant negative effect on valence (β = -.523, $p < .001$), as expected (Komulainen et al., 2014). Persons that have a higher neuroticism level tend to feel more negative valence affects. There is also a marginal positive effect of neuroticism level on between-level interaction with boyfriends/girlfriends, which means that persons with higher levels of neuroticism tend to have more interactions with these groups of people.

Lastly, the indirect and total effects from neuroticism to valence and activation were tested. There were no significant indirect effects from neuroticism to valence or activation. The only significant effect is the unstandardised total effect of neuroticism to valence (B = − .277, *SE* = .047, z = -5.949, $p < .001$); however, this is effect is a result of the significant direct path from neuroticism to valence, showing that there is no mediation between the valence and neuroticism.

5.3.2.3 Model 3 - Extraversion

The results are shown in Table 32.

Table 32 *Standardised estimates of multilevel model with Extraversion*

Level	Independent variable	Dependent variable	Estimate	S.E.	z	p
Between level	Extraversion	Activation	.244	.115	2.114	.035
	Extraversion	Valence	.266	.099	2.679	.007
	Extraversion	Boyfriend/Girlfriend	-.141	.112	-1.265	.206
	Extraversion	Friends	.267	.100	2.66	.008
	Extraversion	Work colleagues	-.218	.093	-2.334	.020
	Extraversion	Family	.057	.100	.5720	.567

Note: S.E. = Standard Error. Significant results ($p < .05$) are highlighted.

Extraversion measured at baseline has significant positive effects on between-level activation and valence, as expected (Komulainen et al., 2014). Interestingly, extraverted persons are more prone to interact with friends and less prone to interact with work colleagues.

Indirect and total effects were calculated between extraversion and valence mediated by social interactions. No indirect effects were significant; however, the total effect of valence and extraversion was significant (B = .172, SE = .053, z = 3.233, p = .001). Given that the indirect effects are not significant, the paths between extraversion and valence and activation are not mediated by social interactions.

5.3.2.4 Model 4 - Openness

The results are shown in Table 33.

Table 33 *Standardised estimates of multilevel model with Openness*

Level	Independent variable	Dependent variable	Estimate	S.E.	z	p
Between level	Openness	Activation	.196	.225	.8710	.384
	Openness	Valence	.465	.116	3.999	0
	Openness	Boyfriend/Girlfriend	-.259	.146	-1.777	.076
	Openness	Friends	-.013	.135	-.099	.921
	Openness	Work colleagues	.077	.120	.6380	.523
	Openness	Family	.061	.129	.4720	.637

Note: S.E. = Standard Error. Significant results ($p < .05$) are highlighted.

Openness measured at baseline has no significant effects on activation. On the other hand, openness has a significant positive effect on valence (β = .465, p < .001). Thus, persons that have an open mind tend to experience more pleasant feelings, corroborating previous results in the literature (Costa & McCrae, 1992; Komulainen et al., 2014).

When indirect and total effects were calculated, there was no significant effects besides the total effect of openness on valence (B = .235, *SE* = .071, z = 3.338, p = .001). Considering the results, there is no significant mediation between openness and core affect dimensions' valence and activation.

5.3.2.5 Model 5 - Agreeableness

The results are shown in Table 34.

Table 34 *Standardised estimates of multilevel model with Agreeableness*

Level	Independent variable	Dependent variable	Estimate	S.E.	z	p
Between level	Agreeableness	Activation	.131	.125	1.049	.294
	Agreeableness	Valence	.334	.098	3.415	.001
	Agreeableness	Boyfriend/Girlfriend	-.010	.107	-.089	.929
	Agreeableness	Friends	.061	.105	.577	.564
	Agreeableness	Work colleagues	-.017	.098	-.174	.862
	Agreeableness	Family	.133	.108	1.224	.221

Note: S.E. = Standard Error. Significant results (p < .05) are highlighted.

Agreeableness measured at baseline has a significant positive effect on valence (β = .334, p = .001), but no other significant effects are seen from this personality trait. Thus, persons that are more agreeable tend to feel more pleasant feelings. This result is in accordance with previous literature (Komulainen et al., 2014).

Indirect and total effects were calculated from agreeableness to activation and valence via social interactions. There were no significant indirect effects. However, the total effect of agreeableness on valence was positive and significant (B = .195, *SE* = .064, z = 3.064, p = .002). Given these results, social interaction are not mediators of the path between agreeableness and core affect's dimensions.

5.3.2.6 Model 6 - Conscientiousness

The results are shown in Table 35.

Table 35 *Standardised estimates of Multilevel model with Conscientiousness*

Level	Independent variable	Dependent variable	Estimate	S.E.	z	p
Between level	Conscientiousness	Activation	.212	.117	1.801	.072
	Conscientiousness	Valence	.174	.106	1.631	.103
	Conscientiousness	Boyfriend/Girlfriend	-.072	.103	-.698	.485
	Conscientiousness	Friends	.007	.106	.067	.947
	Conscientiousness	Work colleagues	-.084	.099	-.845	.398
	Conscientiousness	Family	.098	.104	.937	.349

Note: S.E. = Standard Error. Significant results (p < .05) are highlighted.

There was no significant effect of Conscientiousness measured at baseline on valence or activation. Thus, this personality trait does not seem to have an influence on feelings people experience across the days.

5.3.3 Discussion

The aim of the second study was to collect ecological validity evidence for core affect. Commonly, construct validity evidence is pursued with data from online surveys or controlled laboratory settings. However, in the case of a state-related construct, such as core affect, the use of technology to investigate subjective affective experience in the daily life appears to be more appropriate. For example, in a laboratory setting, participants could be randomised into different conditions that could elicit certain feelings, but these settings could not represent the range and intensity of feelings experienced in real life.

With regard to methodological issues, in this study, the issue of response styles was dealt with in the early design stage. Instead of using rating scales, as previous studies in the literature presented in Table 2, and Study 1 of the present thesis, a measure using forced-choice pairs was developed. When compared to the rating scale counterpart, the forced-choice data yielded a parsimonious model with two clear factors corresponding to the theoretical model. The result is expected since participants that had access to the forced-choice format had to make mental comparisons thus facilitating a finer differentiation between stimuli (Kahneman, 2012).

The longitudinal forced-choice data reinforced previous results about the structure of core affect, as well as it confirmed that the same two constructs explain the variation within- and between-people. Using daily assessments provided evidence that, although people have a range of feelings across their lives, valence and activation explain well how they feel overall (between level) and every day (within level). The use of rating scales also gathered evidence in favour of valence and activation constructs; however, the method factor related to acquiescence remained present in the structures at both within and between levels. Thus, similar to previous findings (Wetzel et al., 2016), response styles also have long-term effects on core affect.

Considering that the forced-choice measurement model of core affect was more parsimonious, the external variables were tested to establish relations at momentary and person levels. As expected, personality traits have an influence in how people experience feelings during their daily lives (Howell & Rodzon, 2011; Komulainen et al., 2014; Kuppens et al., 2007; Letzring & Adamcik, 2015). Higher scores on neuroticism predicted a tendency to feel more affects that are negative across the days. More agreeable and open-minded people were more prone to feel positive affects, as expected. Interestingly, extroverts felt more positive and high activation affects, and were also more prone to interact with friends and less prone to interact with work colleagues.

At the within level, social interactions significantly predicted core affect. Participants that had contact with friends and their family felt more positive and high activation feelings during the day. Similarly, participants that had contact with their boyfriend/girlfriend reported more positive affects. Thus, interacting with other people positively enhanced people's feelings, as expected (Hawkley et al., 2007; Sandstrom & Dunn, 2014).

The average reported mood was highly (and positively) influenced by valence, leading to two possible hypotheses. One is that mood and valence scores were about the same construct. The other hypothesis is that valence and mood are similar but self-report measures cannot account for their differences without specific manipulations. The latter one is supported by valence scores predicting significantly (and positively) but not strongly one's mood at assessment $t + 1$ in a daily basis. These hypotheses have to be tested in future studies.

Aligned with EMA technology and short core affect measure, these results are easily applicable in the fields of clinical psychology, developmental psychology, social psychology and the field of public mental health.

6 Overall discussion

The main objective of this thesis was **to explore the dimensionality of core affect by overcoming existing methodological issues.** Core affect is hypothesised to be a circumplex and, in general, confirmatory models are applied to test this hypothesis. The problem with this approach is that circumplex models are too restrictive and often cannot be fitted to empirical data, as it was shown in Study 1 (Chapter 3 and Appendix B).

To overcome this problem, core affect can be understood as a two-dimensional construct with factorially complex indicators. Understanding core affect in this manner opened possibilities regarding which analyses could be performed with the data, as well as it allowed to solve problems related to response styles. These problems were well known and acknowledged in core affect literature (Russell, 1980; Yik et al., 2011), as demonstrated in theoretical chapters.

Exploratory analysis in the first study broadened the perspective about how methodological issues interfere in core affect data. Testing hypotheses about core affect models with exploratory item factor models using target rotations, and confirmatory item factor models was important in **verifying validity evidence for current core affect models** and **establishing its dimensionality**. As shown in Table 1, core affect has been mainly measured with single stimulus items using rating scales (i.e. Likert scales), which facilitate quick categorisation of feelings according to the rating options used. This type of judgement is likely to rely extensively on heuristics rather than slow, considered thinking (Kahneman, 2012) and result in responses that lack deep consideration of how one actually feels, lack differentiation between similar feelings and use the rating scale idiosyncratically.

The quality of judgements can be improved by making participants to choose the stimulus that is more attractive to them, thus the slow and considered thinking characteristic for comparative judgements (Kahneman, 2012). To this end, the rating scales can be replaced with forced-choice items. In study 2, results showed that the forced-choice format prevented the necessity of modelling a method factor found in Study 1 with Likert scale data, as well as representing the structural complexity of the core affect better. Thus, the objective of **developing a psychometrically valid and robust measure of core affect** was accomplished.

Using the forced-choice format in the personality measure (Brown & Maydeu-Olivares, 2011a) at the baseline of the longitudinal Study 2 and the core affect measure during the momentary assessments provided evidence about the effects of the stable components of one's personality on feelings experienced on a daily basis. Empirical evidence about the relationship between core affect and personality traits existed but it was often related to positive and negative affect dimensions (Hadden et al., 2017; Komulainen et al., 2014; Letzring & Adamcik, 2015), or relied on correlational designs and recalled appraisals of affect thus failing to separate its momentary and stable components. Especially in the case of Extraversion, the use of activation as a dimension of core affect enabled understanding of how extraverted people not only feel more positive in their daily lives but also experience higher activation levels. Thus, the objective of **verifying the relationship between core affect, contextual variables and personality variables** was accomplished**.**

6.1 Overview

To explore validity evidence of core affect is a task that involves in-depth literature review, followed by empirical evidence. Hence, this thesis was organised according to theoretical contributions and empirical studies.

In Chapter 2, I defined the construct of interest – core affect as well as related constructs of mood and emotions. The perspective was taken that core affect, emotions, and mood are not interchangeable terms (Ekkekakis, 2013). These definitions are the groundwork of the thesis.

In Chapter 3, core affect measures and theoretical models behind them were discussed. In addition, measures characteristics such as validity evidence, items formats, and other psychometric properties were presented. This was essential to understand how core affect has been operationalised in past research.

The theoretical part of the thesis enlightened methodological matters of core affect research that were often neglected, such as disagreements about theoretical dimensions (e.g. positive and negative affect, or valence and activation) and most parsimonious representations of the domain (e.g. simple structure or circumplex). Scrutiny of these issues guided the process of deriving hypothesis about core affect's structure. For example, if not two-dimensional, is core affect better explained by a three-dimensional structure that accounts for approach/avoidance (Carver, 2001)? Or, is a third factor due to method-related variance (e.g. response styles) (Yik et al., 2011)?

Empirical studies were necessary to answer these questions. After gathering data on several core affect measures and categorising their items according to levels of activation and valence (Appendix A), an initial extended measure of core affect was developed. Importantly, the extended 68-item measure was compiled not only from measures that conform to the circumplex theory (Russell, 1980; Yik et al., 2011). The 68-item measure was tested in an online survey using a random sample from the general population (Study 1). The most parsimonious solution incorporated a Random Intercept factor (i.e. acquiescence-related factor) in addition to two substantive factors – Valence and Activation. In other words, the best-fitting solution for core affect data needed to account for a method factor, as previously suggested in the literature (Lenk et al., 2006; Russell, 1980; Yik et al., 2011).

Thus, a second study (Study 2) was designed to tackle ongoing questions that were not addressed in the literature and in Study 1, such as preventing response styles and assessing participants in their natural environments. Although modelling response styles after data collection is a possible solution, the use of forced-choice items and the Thurstonian IRT model (Brown & Maydeu-Olivares, 2012) aimed to prevent response styles prior to analysis. To the author's knowledge, no previous research addressed the measurement of core affect with forced-choice items before.

The comparison between rating scales and forced-choice formats showed clearly that response styles could be prevented, gathering evidence in favour of the use of forced-choice core affect measures. Evidence from the longitudinal part of Study 2 reinforced this conclusion, confirming that acquiescence has to be accounted for every time core affect is assessed with rating scales .

In the multilevel models fitted to longitudinal data from Study 2, valence and activation factors explained well the item variance within and between persons. Hence, evidence suggests that the core affect two-dimensional structure holds well within persons too. Previous studies (Diener et al., 1985; Kuppens et al., 2007; Kuppens, Oravecz, & Tuerlinckx, 2010) that assessed core affect longitudinally developed optimal indices or sum scores for valence and activation, instead of modelling these constructs. In such designs, the core affect structure is fixed by definition and cannot be tested.

Therefore, to achieve the last objective of this research (i.e. to verify the relationship between core affect, contextual variables and personality variables), personality traits were incorporated in the multilevel CFA models with forced-choice items. Evidence for significant relationships between core affect and other substantive constructs emerged from these models; for example, at the within level, valence at assessment t positively predicted mood at the next assessment ($t + 1$). At the between level, neuroticism measured at baseline negatively predicted overall level of valence across the days, while extraversion at baseline positively predicted overall levels of valence and activation. Such relationships support criterion validity of core affect scores derived from the forced-choice measure, considering that their strength and directions are in accordance with other research (Komulainen et al., 2014; Kuppens et al., 2007; Yik et al., 2011).

6.2 Implications for core affect research

Theoretical considerations

The theory about core affect is well established and it can be traced back to Wundt (1897). However, given the amount of subjective indicators that can be derived from the chief directions (namely, valence and activation), the adjectives applied in core measures are not standardised; thus, leading to different conclusions in different studies.

Besides instrument development issues, the controversies found are linked to interchangeable concepts of emotions, core affect, and mood (Ekkekakis, 2013). Evidence from studies 1 and 2 did not support the argument that these constructs are the same. This corroborates other researchers' findings that emotional reports were remembered with less intensity than mood reports in the context of political decision-making, for example (Kaplan, Levine, Lench, & Safer, 2016) .

As the results of Study 2 show, mood has a strong relationship with overall levels of valence (between-person level); however, valence predicts significantly but weakly mood at assessment *t+1* (within-person level). Consequently, it can be concluded that mood and core affect are similar, but not equivalent constructs.

Methodological considerations

Although testing the circumplexity of core affect data was partially compromised by the use of categorical item responses in this research (see Appendix B), gathered evidence across all procedures suggests that core affect is a *quasi*-circumplex. This is assumption is not always explicit in the literature (Carroll et al., 1999; Russell, 1980; Yik et al., 2011); however, the acknowledgment of it helps other researchers guide their own research.

One firm conclusion from the literature is that core affect is a complex structure (Russell, 1980). Working with this hypothesis led to the exploration of core affect's structure beyond confirmatory circumplex models only. Thus, in this research, the analysis was broadened to multidimensional latent factors models that do not necessarily comply with a simple structure.

Core affect has been traditionally analysed with methods for continuous data that do not comply with the type of data collected. For example, rating scales are often analysed as interval scale, while they are clearly ordinal. Scales with more than 5 categories are not substantially affected by this; however, depending on sample size, scales of less than 5 categories can be affected by the choice of method substantially (Rhemtulla, Brosseau-Liard, & Savalei, 2012). Thus, this research also advanced measurement of core affect by treating item responses as categorical and applying appropriate estimators (e.g. WLSMV).

Scrutiny of item responses collected from developed measures can help address another common problem that is overlooked in core affect research: response styles (Russell, 1980; Yik et al., 2011). The problem can be effectively solved by using comparative judgements (i.e. the forced-choice response format) and using the Thurstonian IRT model to analyse the data (Brown & Maydeu-Olivares, 2012; Brown & Maydeu-Olivares, 2011b).

In conclusion, besides construct, convergent/discriminant, and criterion validity evidence, ecological validity was also pursued in this study with Ecological Momentary Assessment (EMA) technology. Online studies are good starting points for developing a new measure, but it is important to explore validity evidence outside this context, particularly for a new measure of core affect, which is a state-related construct.

Limitations of this research

Although this research aimed to overcome methodological issues from previous studies, some gaps remain. Firstly, the sample from both studies are predominantly female, limiting generalisation of the results to the general population. Although other socioeconomic characteristics presented more variation (e.g. age), gender should be controlled better in future studies in order to confirm these results.

Another limitation concerns the number of days that participants remained in the longitudinal study. One of the objectives of Study 2 was to obtain evidence for ecological validity of the core affect measure; however, the number of days participants were followed up was somewhat limited. Moreover, participants were not assessed during weekends. Thus, for a more general perspective over how people feel across days, it is suggested that future studies extend for longer periods and also include weekends, covering a greater range of feelings and events that can happen in someone's daily life.

6.3 Future directions

Considering that a robust-to-biases measure of core affect was developed, the relationship between core affect and other phenomena can be explored in future research without compromising the validity of findings. Gathering information with a short but reliable measure is useful for a variety of fields, particularly psychology and mental health.

For example, the interchangeability of the terms mood, core affect, and emotions was briefly explored in this work. With an appropriate core affect measure, laboratory-controlled experiments with emotion-induction methods can be designed to understand the differences between these constructs more efficiently.

Looking into the future, procedures such as *network analysis* are promising to understand chains of events between personality and the affective experience (Bringmann et al., 2016). The procedure can also be useful to understand how one feeling is connected to others (Epskamp, Rhemtulla, & Borsboom, 2017); thus, testing directly or indirectly for the circumplexity of the data.

7 References

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8 Appendices

Appendix A - Core affect adjectives allocated according to 12-PAC

Measures	Authors							
	Yik, Steiger, & Russell (2011)	Barrett & Russell (1998)	SDMES - Mehrabian & Russell (1974)	PANAS - Watson & Tellegen (1988)	Affect Grid - Adapted Yik, Steiger & Russell (2011)	AD ACL - Thayer (1978)	Scherer Wheel (2013) based on results	Scherer Wheel (2013) theory-derived
Pleasure (0)	Happy, Content, Satisfied, Pleased	Happy, Pleased, Content	Happy, Pleased, Satisfied, Contented		Extremely pleasant		Pleasure, Joy, Contentment	Pleasure, Contentment
Activated Pleasure (30)	Proud, Enthusiastic, Euphoric	Enthusiastic,	Hopeful	Enthusiastic			Pride, Amusement, Interest	Joy, Pride
Pleasant Activation (60)	Energetic, Full of pep, Excited, Wakeful, Attentive, Wide awake, Active, Alert, Vigorous	Interested, Excited, Strong, Proud, Inspired, Determined, Attentive, Active. **From PANAS**.	Excited, Wide-awake	Interested, Excited, Strong, Proud, Inspired, Determined, Attentive, Active, Alert		Active, Energetic, Vigorous, Lively, Full-of-pep, Wide-awake, Wakeful		Amusement, Interest
Activation (90)	Aroused, Hyperactivated, Intense	Aroused, Alert, Hyperactivated	Stimulated, Aroused		Extremely aroused	Intense		
Unpleasant Activation (120)	Anxious, Frenzied, Jittery, Nervous	Distressed, Irritable, Nervous, Jittery, Afraid. **From PANAS.**	Jittery, Frenzied	Distressed, Irritable, Nervous, Jittery, Afraid		Jittery, Tense	Anger, Hate,	Anger, Hate
Activated Displeasure (150)	Scared, Upset, Shaky, Fearful, Clutched up, Tense, Ashamed, Guilty, Agitated, Hostile	Ashamed, Upset, Guilty, Scared, Hostile,	Annoyed	Ashamed, Upset, Guilty, Scared, Hostile		Clutched-up, Fearful	Disgust, Contempt	Contempt, Disgust
Displeasure (180)	Troubled, Miserable, Unhappy, Dissatisfied	Miserable, Troubled, Unhappy	Unhappy, Unsatisfied, Melancholic		Extremely unpleasant		Fear, Disappointment	Fear, Disappointment
Deactivated Displeasure (210)	Sad, Down, Gloomy, Blue, Melancholy		Despairing				Shame, Regret, Guilt, Sadness	Shame, Regret
Unpleasant Deactivation (240)	Droopy, Drowsy, Dull, Bored, Sluggish, Tired	Tired, Sluggish, Droopy, Dull, Drowsy, Bored	Bored, Dull, Sluggish			Tired, Drowsy		Guilt, Sadness
Deactivation (270)	Quiet, Still	Sleep, Still, Quiet	Sleepy, Unaroused		Extremely sleepy	Sleepy, Still, Quiet	Compassion	
Pleasant Deactivation (300)	Placid, Relaxed, Tranquil, At rest, Calm	Relaxed, At rest, Calm	Relaxed, Calm			Placid, Calm, At-rest		Compassion, Relief
Deactivated Pleasure (330)	Serene, Soothed, Peaceful, At ease, Secure	Serene, At ease	Controlling-Controlled, Influential-Influenced, In control-Cared for, Important-Awed, Dominant-Submissive, Autonomous-Guided				Relief, Love	Love, Admiration
Total number of items	60	42	35	20	4	20	19	20

Appendix B – Circumplex simulations

Circumplex structures are often tested with psychological data (Browne, 1992; Fabrigar et al., 1997). However, the usual case is in general with matrices based on Pearson correlations, given that variables values are treated as intervals, and not categories. When categorical data correlations are estimated with Pearson correlations, their strength tends to be underestimated (Olsson, 1979). Thus, the case of circumplexes with categorical data and polychoric correlations is going to be presented next.

Method

Participants

An empirical dataset and three simulated datasets were used. The empirical dataset (N = 422) is from a study about core affect, where responses were collected online via Qualtrics platform. Additional datasets were simulated with samples of N=400, N=600 and N=800.

Measures

In the empirical dataset, there are 47 categorical variables (3-point scale: "not at all", "somewhat", "a great deal"), which are core affect items.

Procedures

Data for the empirical dataset was retrieved from a validation study about core affect. The model tested has 47 items. According to literature, core affect is a complex construct that fits a circumplex structure (Russell, 1980; Yik et al., 2011). Validity and reliability evidence are provided in the chapter 4.

Simulated datasets were estimated using the *sim.circ* function from *psych* package. This function allows to simulate datasets with circumplex structure and control for the number of items, number of categories of the items, sample size and average factor loadings for each dimension. Three datasets were simulated with the same characteristics of the empirical dataset (47 variables with 3-point scale), but varying in sample size (N= 400, N=600, N=800). Factor loadings were set to average to 0.6 in each dimensions.

Data analysis

The softwares used in the data analyses were Mplus 7.4 and R packages (*qgraph*, *psych*, *CircE*). After simulating the datasets, polychoric correlations matrices were estimated for each dataset using the function *cor_auto* (package *qgraph*). For comparison, Pearson correlations were estimated with the same package for all data sets. Correlations matrices were estimated before in order to apply the Circular Stochastic Process with FS model from *CircE* package. After the models were estimated, the residuals and circumplex plot from "CircE" were saved. Heat maps were created based on the sample and reproduced common score correlation matrices. Items of the empirical dataset were organised according to the order presented in Table 9.

Lastly, Exploratory Factor Analysis (EFA) with Geomin rotation were performed with all datasets in Mplus. All analyses were performed considering the ordinal characteristics of the data. In the following analyses, a more parsimonious statistical routine will be presented in order to explore circumplex's analysis. The following analyses should also bring a perspective about the use of statistical procedures that are available for a variety of software, which improves the quality of reproducing the same results in future research and making more possible to compare results from different populations with the same model.

Results

Empirical dataset

The performance of the Circular Stochastic Process with FS was firstly tested with the dataset with 47 items (N = 422). The *circulant*-type of correlation matrix was tested by constraining the angles to be equal and having $m = p/2$, where p is the number of variables, as suggested by Browne (1992). The other models were tested without any constraints, varying only in the number of m elementary components. Considering that m is approximately 24 for the *circulant* matrix with 47 variables, there are approximately 12 variables per quadrant of the circle, resulting in variables starting to have weak correlations around the 6^{th} and 12^{th} position of the correlation matrix; thus, the decision of testing models with $m \leq 6$ ($\beta_k \leq 6$) . According to Browne (1992), after a certain number of free parameters β_k, little improvement is achieved, and increasing the risk of overestimating the model. Results for each model are presented in Table 36.

Table 36 *Circumplex fit indices of empirical data with Pearson and polychoric correlations*

Correlation	*m*	$\rho_{180°}$	χ^2	*df*	RMSEA	SRMR	CFI	AIC	BIC
Polychoric	1	-.690	46930.87	987	.333	.097	.246	110.805	112.548
	1_{equal}	-.626	48329.09	1033	.330	.268	.224	114.345	113.432
	2	-.418	46226.22	986	.330	.173	.258	109.126	107.762
	3	-.559	45902.77	985	.329	.223	.263	108.353	106.979
	4	-.456	45619.15	984	.328	.136	.268	107.675	106.291
	5	-.451	45477.04	983	.328	.136	.270	107.333	105.939
	6	-.397	45461.00	982	.328	.143	.270	107.290	105.887
Pearson	1	-.620	2957.450	987	.069	.061	.807	6.355	5.000
	1_{equal}	-.530	3847.805	1033	.080	.182	.725	8.688	7.776
	2	-.337	2447.469	986	.059	.099	.857	5.139	3.775
	3	-.438	2209.704	985	.054	.108	.880	4.569	3.195

4	-.385	2129.891	984	.053	.089	.888	4.375	2.991
5	-.417	2084.961	983	.052	.082	.892	4.264	2.870
6	-.419	1980.800	982	.049	.077	.902	4.011	2.609

The model with *m* = 24 was not identified for Pearson or polychoric correlations; thus, the model with best fit (*m* = 1) was tested with the equal-spacing constraint (m_{equal} = 1). The model with *m* = 6 has a good fit for both correlations, but the third β_k weight attained the lower bound of zero in the polychoric correlation data, and the same happened to the fourth β_k weight of the Pearson correlation data. There is a clear discrepancy between the model fit results of the polychoric correlation and the Pearson correlations. Models based on Pearson correlations present better fit in all models when compared to models with polychoric correlations. Heat maps are presented next for further verification.

a) Sample-based correlation matrix – Polychoric correlations

b) Sample-based correlation matrix – Pearson correlations

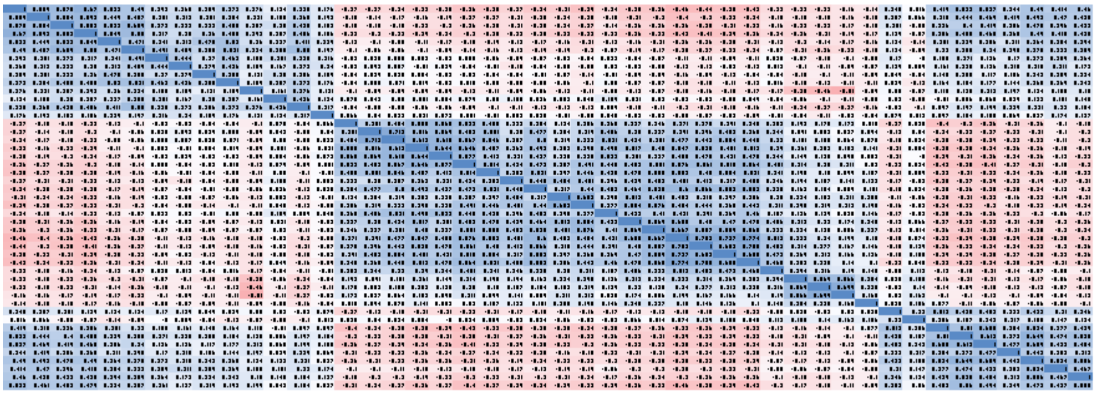
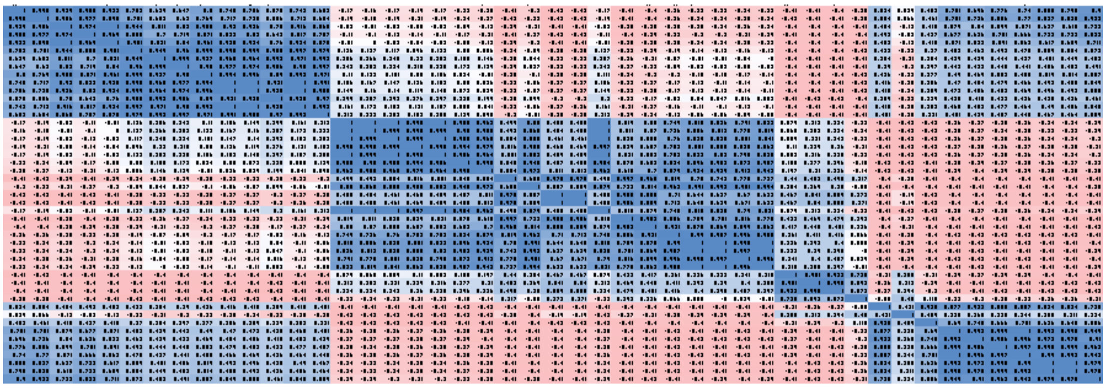


Figure 30 Heat maps of sample-based correlation matrices

a) Reproduced common score correlation matrix – Polychoric correlations $m = 1$



b) Reproduced common score correlation matrix – Pearson correlations $m = 1$

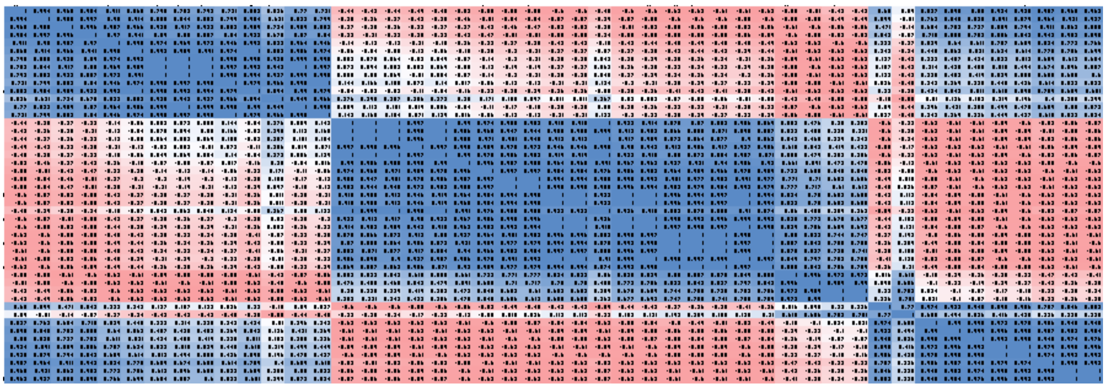
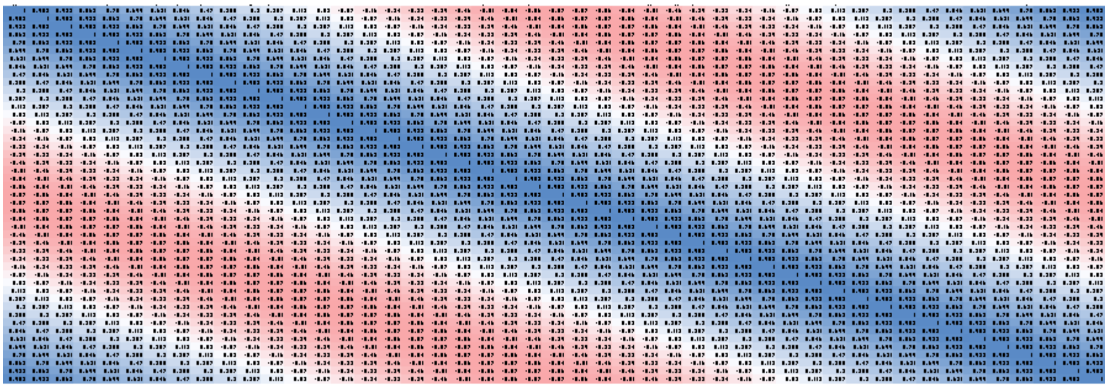


Figure 31 Heat maps of reproduced common score correlation matrices with $m = 1$

a) Circulant common score correlation matrix – Polychoric correlations $m = 1$



b) Circulant common score correlation matrix – Pearson correlations $m = 1$

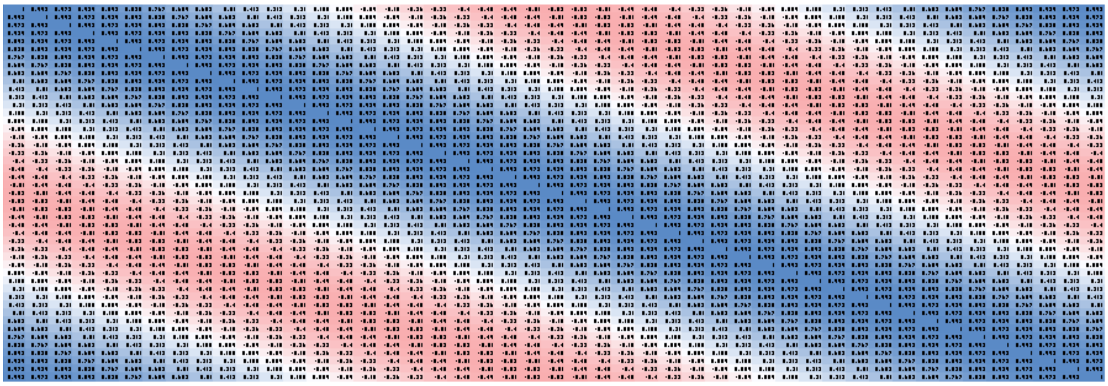


Figure 32 Heat maps of *circulant* reproduced common score correlation matrices with $m = 1$

The two sample-based correlation matrices are very similar, varying only in the strength of the correlations. As expected, polychoric correlations are greater than Pearson correlations for ordinal data (Olsson, 1979). The unexpected difference is visible in the reproduced common score correlation matrices. In this case, Pearson correlations presented greater values than polychoric correlations. C*irculant* common score correlation matrices were presented to exemplify the equal spacing characteristic of the circumplex when the model is constrained. Both matrices follow the same pattern and do not appear to differ substantially between the two types of correlations, even though the model fit results are substantially different.

One of the advantages of Browne's model is to plot the circular representation of the variables inputted in the model. The circular representations of the unconstrained models (m = 1) are presented below. Interestingly, the variables have a very similar location in the circumplex for both types of correlations.

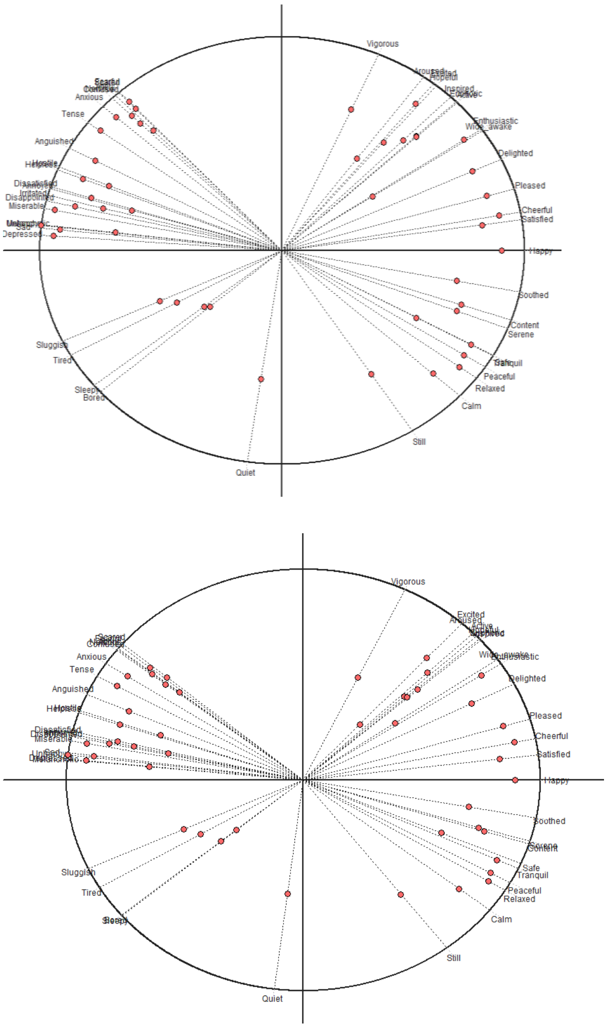


Figure 33 Circular representation of polychoric-based and Pearson-based unconstrained models with m = 1.

Note. The first circle is from the model based on polychoric correlations. The second circle is from the model based on Pearson correlations.

Based on these results, model fit indices derived from the models with polychoric correlations are not reliable. To test these assumptions further, circumplex simulated datasets were estimated with the function *sim.circ* (*psych* package). This function was created to test circumplex characteristics proposed by Acton and Revelle (2004); however, they can be used to test extra characteristics with other models.

Simulated datasets

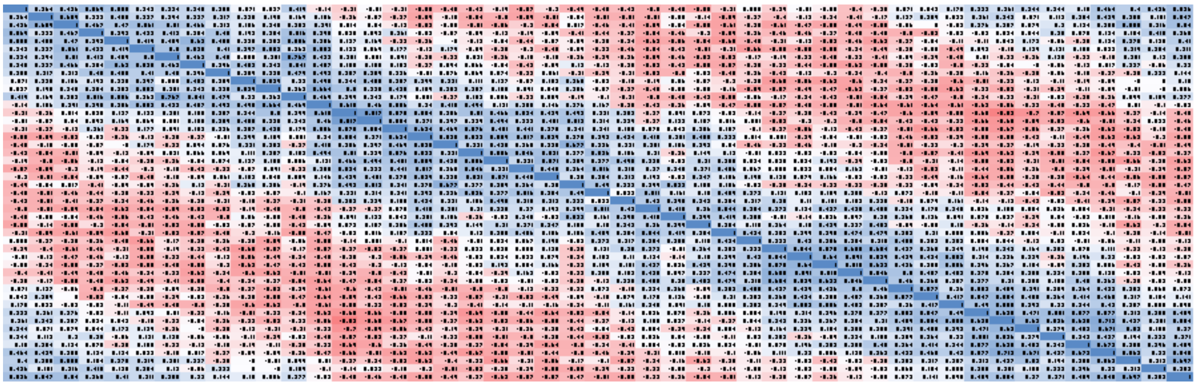
Models were tested with three sample sizes (N = 400, 600, 800). Model fit indices are presented in Table 37.

Table 37 *Circumplex fit indices of simulated data with Pearson and polychoric correlations*

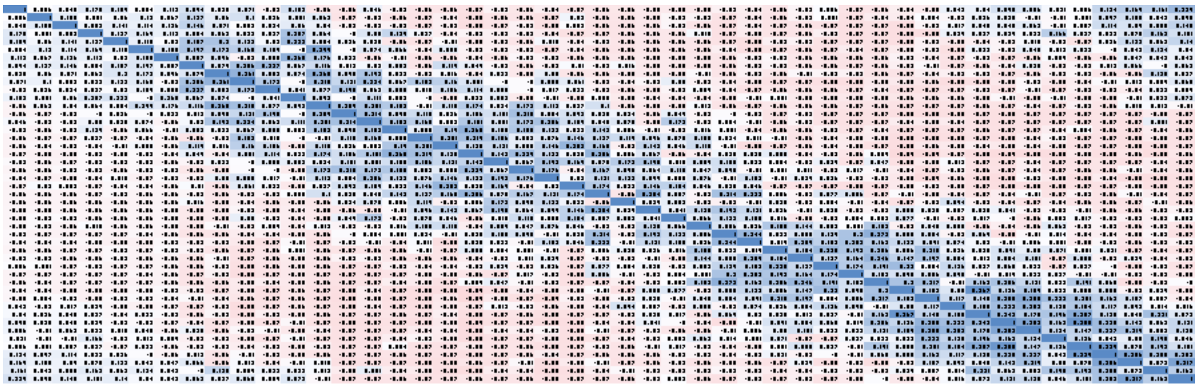
Correlation	*N*	*m*	$\rho_{180°}$	χ^2	*df*	RMSEA	SRMR	CFI	AIC	BIC
Polychoric	400	1	-1	164692.2	987	.645	.120	.062	412.056	410.645
		1_{equal}	-1	165387.1	1033	.631	.151	.058	414.028	413.078
		$1_{equal+com}$	-1	166102.6	1079	.619	.162	.054	416.052	415.562
		2	-1	164692.5	986	.645	.120	.062	412.051	410.631
		3	-1	164692.9	985	.645	.120	.062	412.047	410.617
	600	1	-1	238638.3	987	.634	.111	.060	397.924	396.889
		1_{equal}	-1	239246.9	1033	.620	.137	.057	399.093	398.396
		$1_{equal+com}$	-1	240188.5	1079	.608	.149	.054	400.819	400.459
		2	-1	238638.3	986	.634	.111	.060	397.920	396.878
		3	-1	238089.5	985	.634	.211	.062	397.001	395.951
	800	1	-1	283944.7	987	.599	.104	.064	355.022	354.195
		1_{equal}	-1	284505.3	1033	.586	.121	.062	355.839	355.282
		$1_{equal+com}$	-1	285308.8	1079	.574	.130	.060	356.960	356.672
		2	-1	283945.2	986	.599	.105	.064	355.020	354.188
		3	-1	282932.1	985	.599	.155	.067	353.750	352.911
Pearson	400	1	-.627	1368.546	987	.031	.049	.747	2.723	1.313
		1_{equal}	-.612	1401.250	1033	.030	.052	.755	3.036	2.085
		$1_{equal+com}$	-.661	1502.769	1079	.031	.056	.718	3.521	3.031
		2	-.281	1152.853	986	.021	.044	.889	2.178	0.757
		3	-.325	1125.670	985	.019	.045	.907	2.104	0.674
	600	1	-.577	1315.194	987	.024	.039	.857	1.725	0.690
		1_{equal}	-.575	1378.071	1033	.024	.043	.849	1.983	1.286
		$1_{equal+com}$	-.587	1508.660	1079	.026	.047	.812	2.355	1.995
		2	-.284	1060.983	986	.011	.035	.967	1.297	0.255
		3	-.299	1054.450	985	.011	.035	.970	1.283	0.233
	800	1	-.612	1379.324	987	.022	.035	.852	1.373	0.547
		1_{equal}	-.604	1432.572	1033	.022	.038	.849	1.555	0.998
		$1_{equal+com}$	-.622	1507.678	1079	.022	.040	.838	1.764	1.477
		2	-.348	1141.571	986	.014	.032	.941	1.073	0.241
		3	-.358	1137.821	985	.014	.032	.942	1.066	0.228

Similar to empirical data, model fit indices are substantially different between polychoric and Pearson correlations. Increasing the sample size did not improve model fit indices for polychoric correlations. Thus, the problem is not associated to sample size. Different *m* elementary components were tested; however, as it was seen in the empirical dataset, SRMR and $\rho_{180°}$ are the only estimates that do not appear to be severely affected by the type of correlation applied. In the case of polychoric correlations, β_k estimates in the models with *m* = 2 and *m* = 3 attained the lower bound of zero. Models with *m* = 1 are more parsimonious o. Heat maps of models with *m* =1 are presented next.

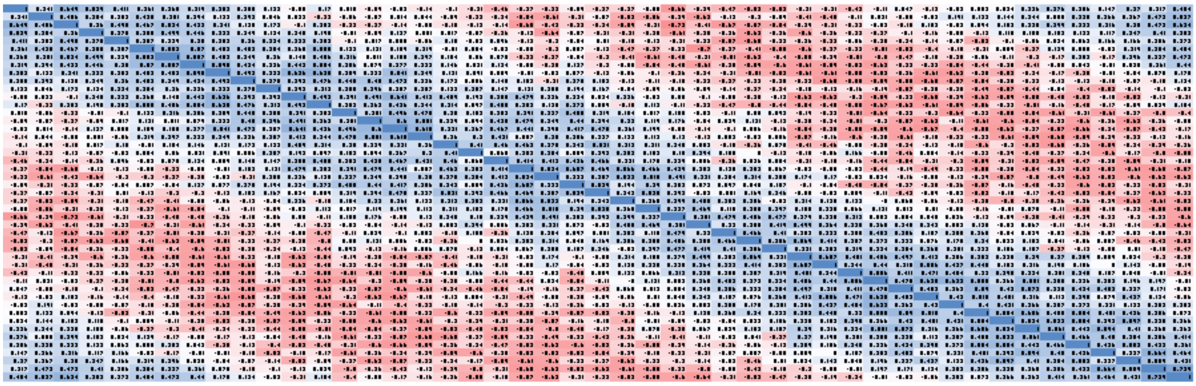
a) Sample-based correlation matrix – Polychoric correlations N = 400



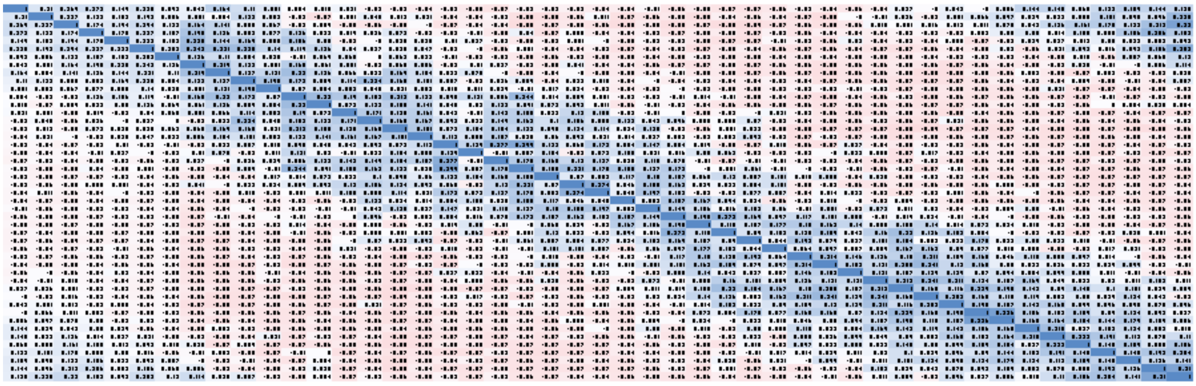
b) Sample-based correlation matrix – Pearson correlations N = 400



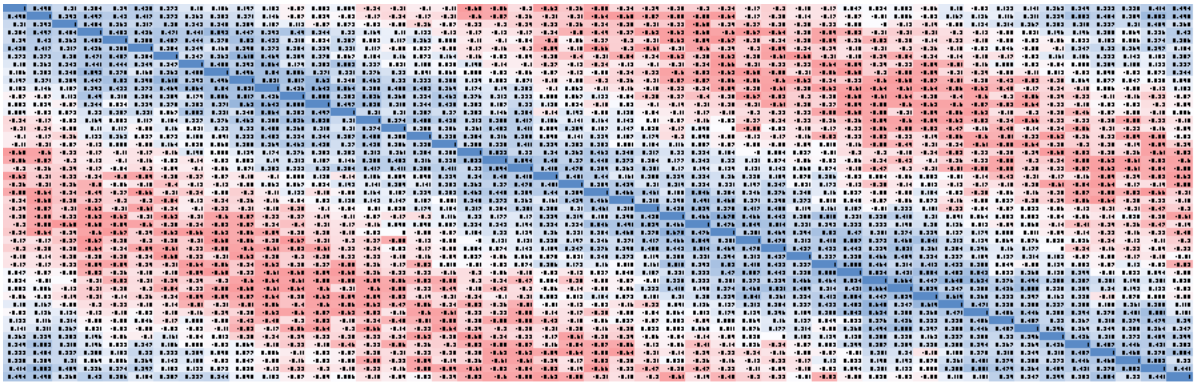
c) Sample-based correlation matrix – Polychoric correlations N = 600



d) Sample-based correlation matrix – Pearson correlations N = 600



e) Sample-based correlation matrix – Polychoric correlations N = 800



f) Sample-based correlation matrix – Polychoric correlations N = 800

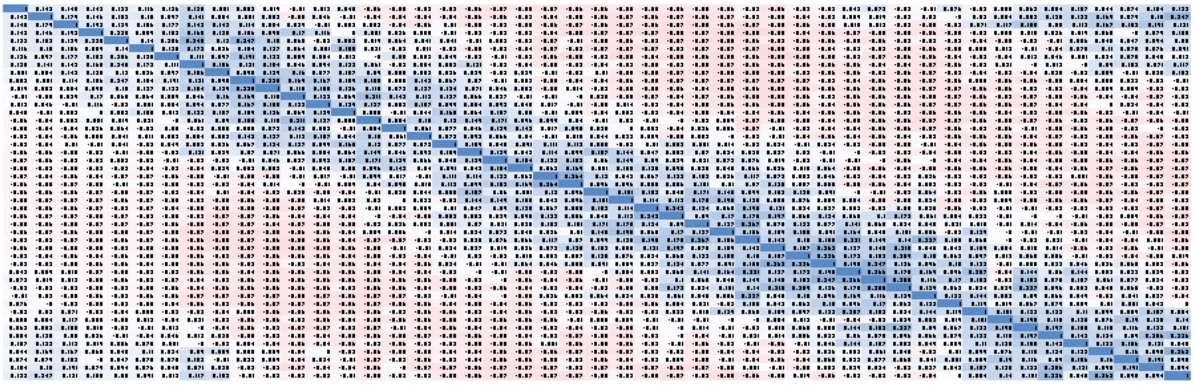
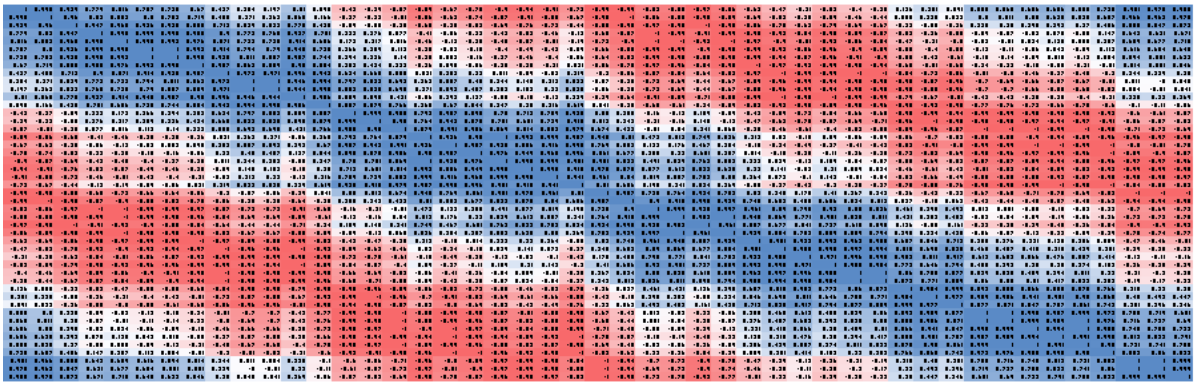
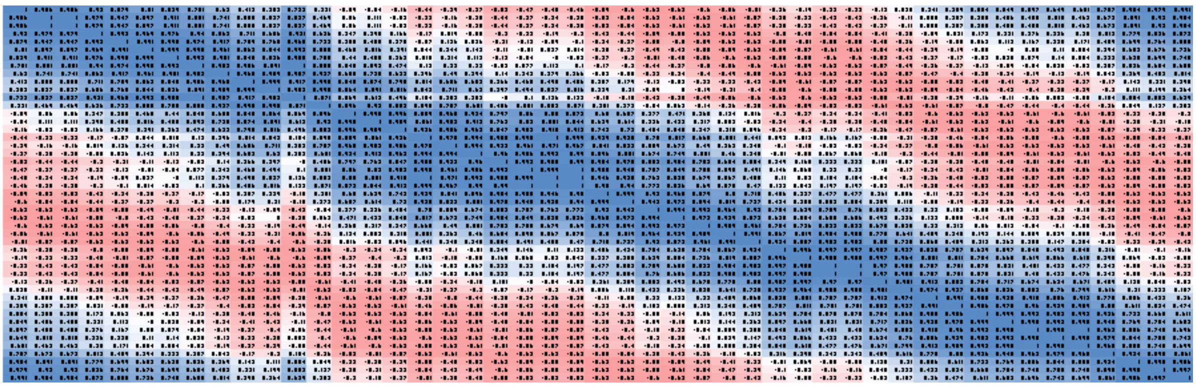


Figure 34 Heat maps of simulated sample-based correlation matrices

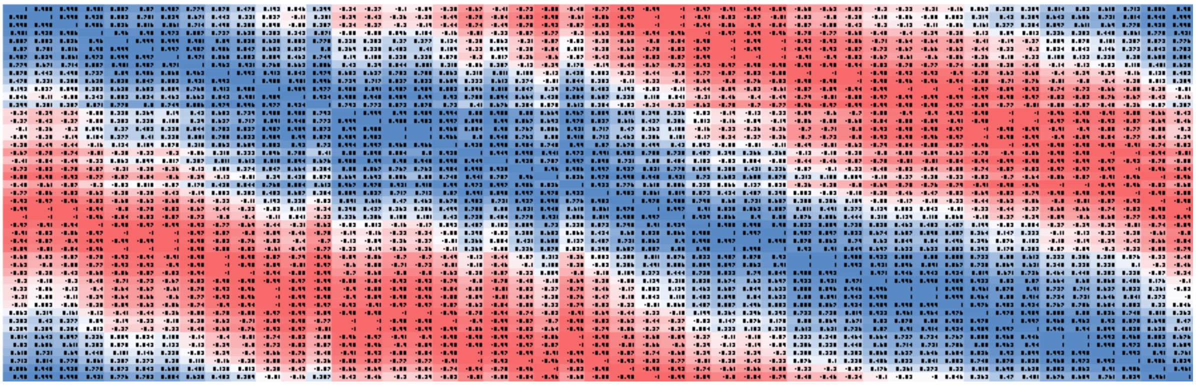
a) Reproduced common score correlation matrix – Polychoric correlations N = 400



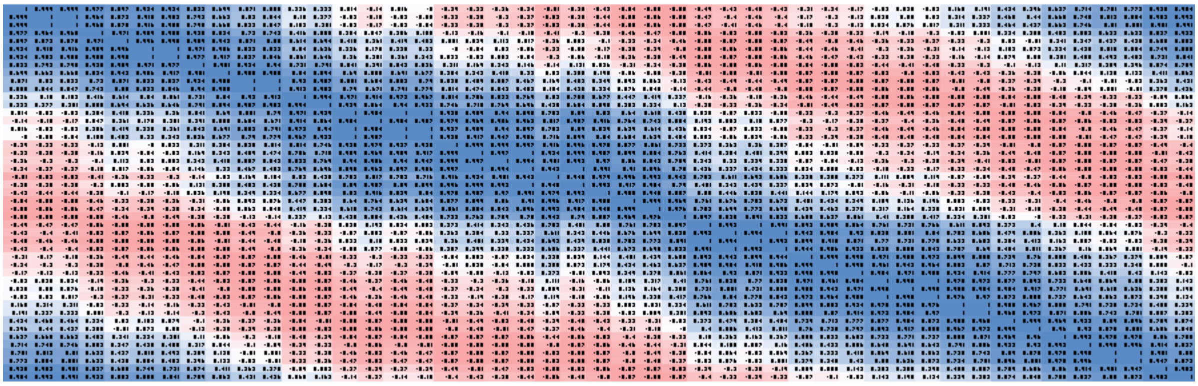
b) Reproduced common score correlation matrix – Pearson correlations N= 400



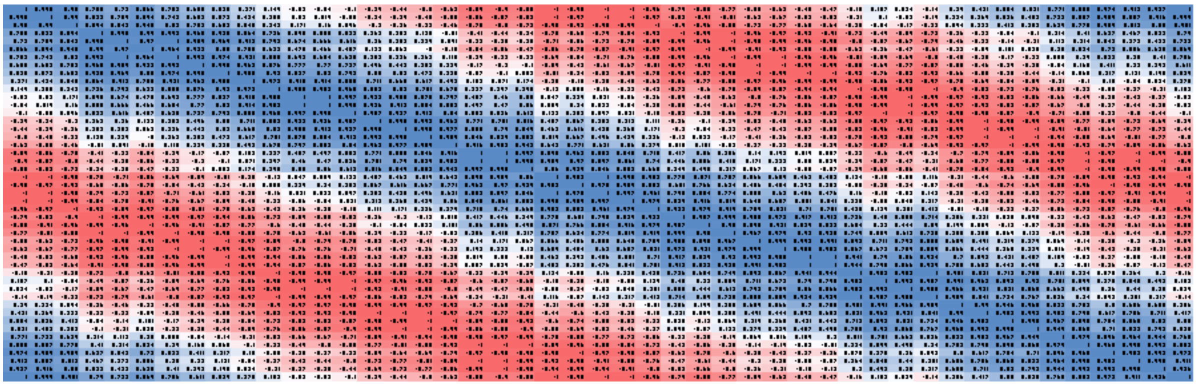
c) Reproduced common score correlation matrix – Polychoric correlations N = 600



d) Reproduced common score correlation matrix – Pearson correlations N= 600



e) Reproduced common score correlation matrix – Polychoric correlations N = 800



f) Reproduced common score correlation matrix – Pearson correlations N= 800

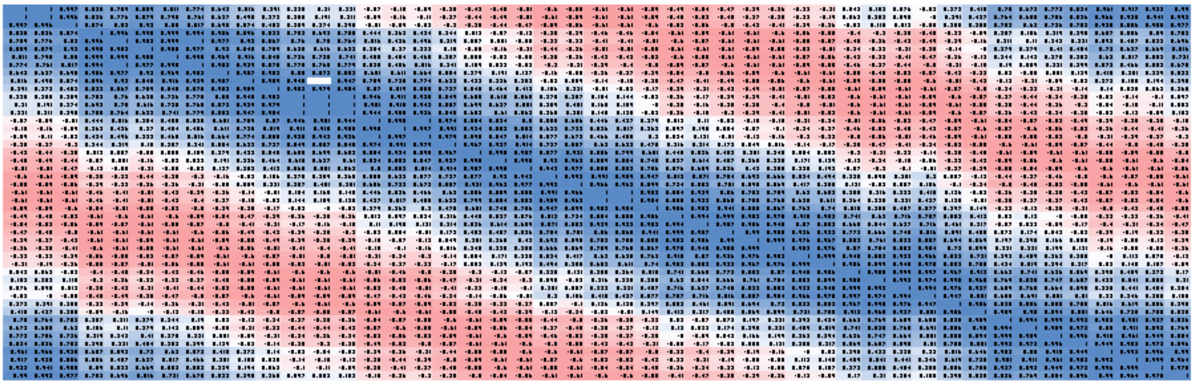


Figure 35 Heat maps of simulated reproduced common score correlation matrices

Similar to the case with empirical data, Pearson correlations are weaker than polychoric correlations. Considering that the datasets were simulated to have categorical data, this was expected. The circulant-type of pattern is visible in both sample-based correlation matrices; thus, showing that the simulated data has circumplex characteristics. However, even though Pearson correlations are smaller, their models fit indices are better than the polychoric correlations. The circular representation of the models with m = 1 are presented below.

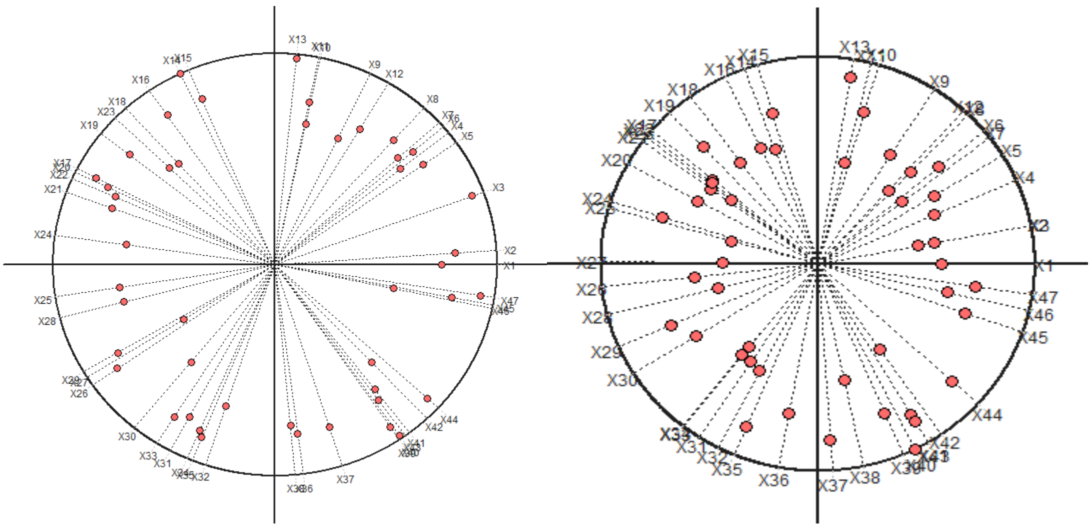


Figure 36 Circular representation of simulated datasets with polychoric-based and Pearson-based unconstrained models with m = 1 and N = 400

Note. The first circle is from the model based on polychoric correlations. The second circle is from the model based on Pearson correlations.

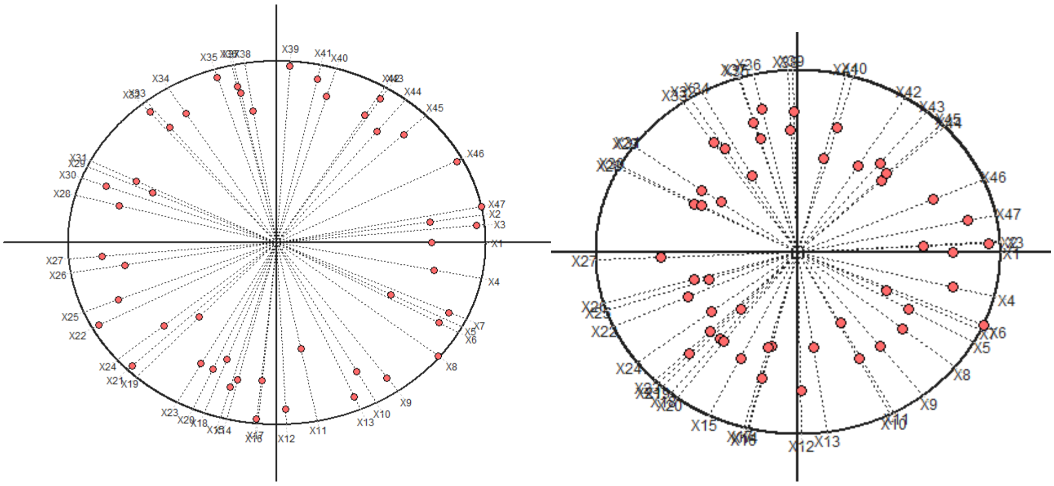


Figure 37 Circular representation of simulated datasets with polychoric-based and Pearson-based unconstrained models with m = 1 and N = 600

Note. The first circle is from the model based on polychoric correlations. The second circle is from the model based on Pearson correlations.

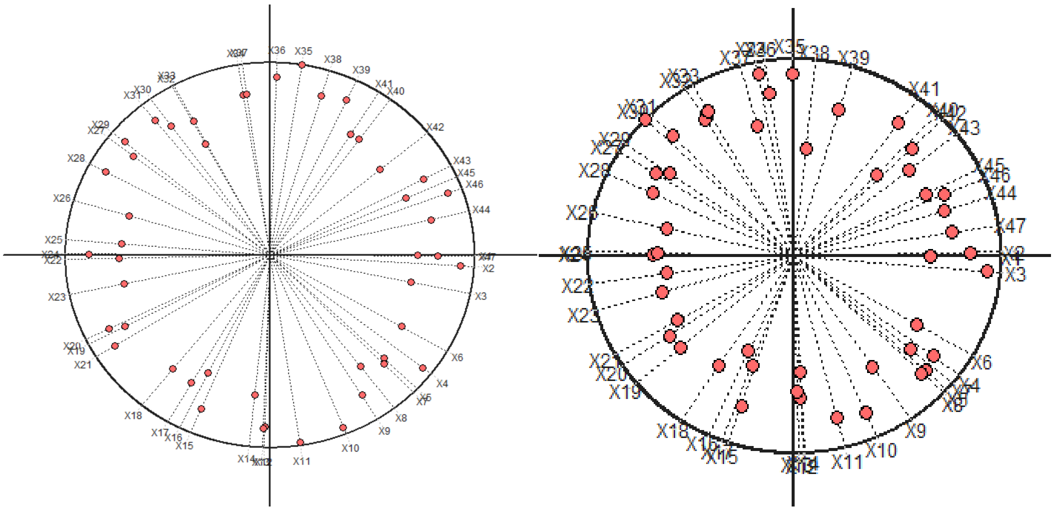


Figure 38 Circular representation of simulated datasets with polychoric-based and Pearson-based unconstrained models with m = 1 and N = 800

Note. The first circle is from the model based on polychoric correlations. The second circle is from the model based on Pearson correlations.

Variables spread around the circle in the same manner across all datasets. Considering that the datasets were simulated to have categorical data, it was also expected that models estimated with Pearson correlations would have a worse fit than models estimated with polychoric correlations. Instead, models with Pearson correlation had better model fit indices.

Model fit indices appear to misrepresent the fit of models based on polychoric correlations. The reason for this conclusion is twofold. Firstly, the correlation pattern of Pearson and polychoric matrices are similar. Secondly, polychoric correlations have stronger correlations, which should improve model fit indices results. Thus, results of the Circular Stochastic Process with Fourier Series model with categorical data and polychoric correlations are not reliable.

Latent trait models

EFA models were performed with the simulated datasets with N = 400, N = 600, and N = 800. Models were estimated based on polychoric correlations, with WLSMV estimator, and Geomin rotation (oblique). The scree plots are presented below.

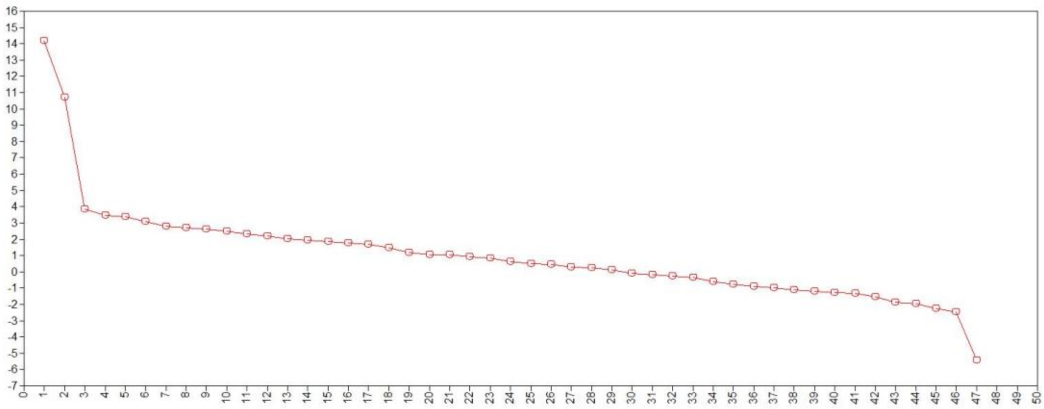


Figure 39 Scree plot of EFA with simulated dataset N = 400

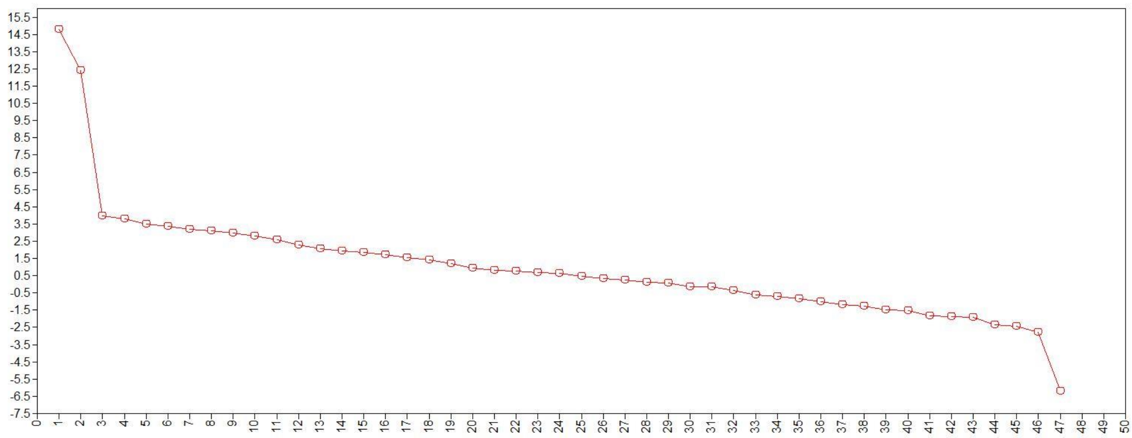


Figure 40 Scree plot of EFA with simulated dataset N = 600

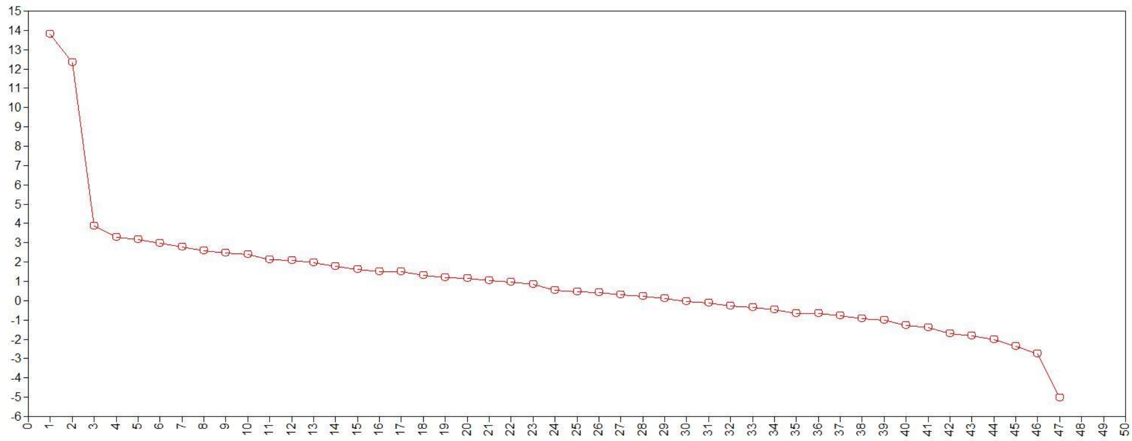


Figure 41 Scree plot of EFA with simulated dataset N = 800

All scree plots present the same characteristic: two strong factors. At the end of the scree, there is another slope because of the negative eigenvalues. These are often related to non-positive definite correlation matrices. The hypothesis that these datasets can be represented by two factors are supported by the comparison of χ^2 values in Table 38.

Table 38 *Model comparison of simulated datasets with N = 400, 600, 800*

Sample size	Models comparison	χ^2	df	p-value
N = 400	1-factor against 2-factor	1709.924	46	< 0.0001
	2-factor against 3-factor	449.888	45	< 0.0001
	3-factor against 4-factor	347.117	44	< 0.0001
N = 600	1-factor against 2-factor	1837.203	46	< 0.0001
	2-factor against 3-factor	543.702	45	< 0.0001
	3-factor against 4-factor	396.791	44	< 0.0001
N = 800	1-factor against 2-f`actor	2143.711	46	< 0.0001
	2-factor against 3-factor	425.339	45	< 0.0001
	3-factor against 4-factor	341.739	44	< 0.0001

The most substantive drop in χ^2 values is from the comparison between the 1-factor and 2-factor solutions; thus, supporting the hypothesis that these datasets can be represented by two-factor solutions. Model fit indices for the 2-factor solution are presented in Table 39.

Table 39 *EFA model fit indices of 2-factor solutions of simulated datasets*

	2-factor solutions		
	N = 400	N = 600	N = 800
χ^2	4365.737	4409.309	4185.991
Degrees of freedom	988	988	988
P-value	< 0.001	< 0.001	< 0.001
RMSEA	.065	.076	.064
RMSEA CI 90%	.063-.067	.074 -.078	.062-.066
CFI	.585	.547	.621
SRMR	.267	.296	.257

The RMSEA results are acceptable for the 2-factor solutions. Considering that RMSEA is approximation of the close fit of the model, these results are acceptable. The CFI results are not acceptable; however, they can be a result of the circumplex structure being similar to a correlation matrix with several zero-order correlations. Such model fit indices are applied in general to find simple structure, while circumplex is known to be a complex structure. The Geomin rotation is resourceful for complex structure but the more complex the structure, the worse it can be the fit of the data (Asparouhov & Muthén, 2009). SRMR results are not optimal, however, this can be an effect of the model being expected to be a simple structure. Solutions with more than two factors were investigated but results did not improve with the addition of more factors. Loadings plot are presented below.

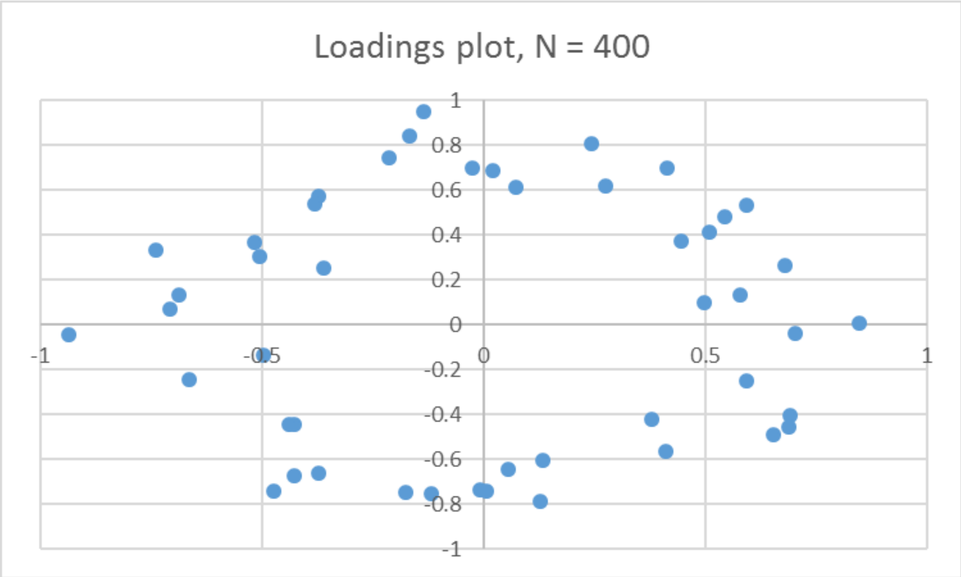


Figure 42 Loadings plot of 2-factor solution of simulated data with N = 400

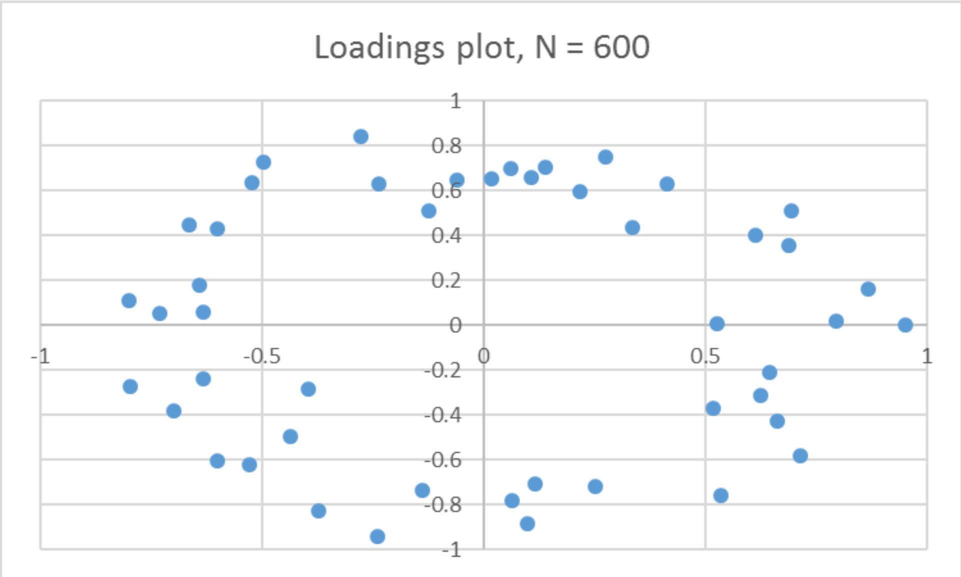


Figure 43 Loadings plot of 2-factor solution of simulated data with N = 600

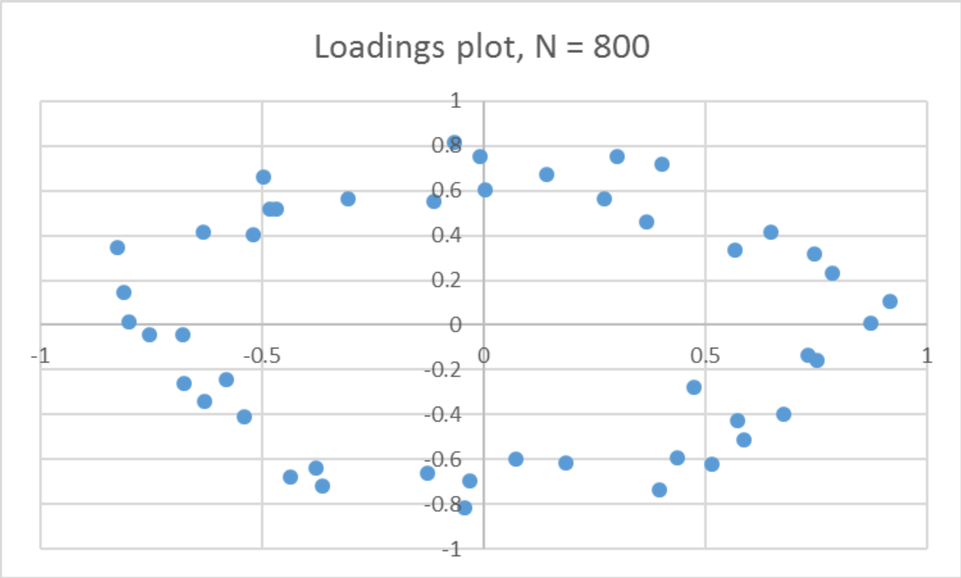


Figure 44 Loadings plot of 2-factor solution of simulated data with N = 800

The use of loadings plots confirm that circumplexes are complex structures; thus, model fit indices from EFA can be affected, given that simple structure is expected. Even though the EFA results are suboptimal for simple structure standards, they are insightful regarding the spreading of factor loadings and the amount of factors that are strong in the factor solution. Further analysis can be pursued with confirmatory models, which can consider for data complexity, as it is proposed in chapter 4 and 5 of this thesis. Although not ideal, the use of latent trait models with complex structures, such as the circumplex, brings insightful considerations about the modelling of psychological constructs.

Appendix C - Computerized Adaptive Testing (CAT) parameters

One possibility for future studies of core affect includes the use of CAT. To facilitate future applications, the parameters estimated in this project are presented in Table 40. Items were calibrated with the sample of the first study (N = 422) (RI model - Section 4.3.1.3). Parameters were estimated using the Graded Response Model (GRM). The intercept/slope parameterisation (equations 8 and 9) was applied (McDonald, 2014). Thus, *a* refers to the difficulty parameter and *b* relates to the discrimination parameter.

Table 40 CAT parameters

Adjectives	$b_{Valence}$	$b_{Activation}$	a_1	a_2
Happy	1.580	0	-1.580	1.696
Pleased	1.196	0	-0.177	2.121
Satisfied	1.158	0.168	-0.492	1.970
Cheerful	1.694	0.376	-0.447	2.480
Delighted	1.194	0.494	0.993	2.877
Enthusiastic	1.080	0.673	0.265	2.665
Inspired	0.508	0.433	0.644	2.306
Hopeful	0.403	0.386	-0.023	1.954
Excited	0.666	0.631	0.927	2.784
Euphoric	0.647	0.505	1.563	3.293
Wide awake	0.676	0.888	-0.853	1.547
Vigorous	0.258	0.626	1.520	2.821
Active	0	0.614	0.597	2.019
Aroused	0	0.265	1.341	2.865
Jittery	-1.056	0.673	1.489	3.223
Scared	-1.300	1.071	2.357	4.456
Fearful	-1.383	1.081	2.071	4.063
Anxious	-1.291	0.750	0.891	2.692
Nervous	-1.344	0.997	1.643	3.718
Tense	-1.507	0.640	1.040	3.196
Irritate	-1.342	0.131	1.081	3.084
Anguished	-1.489	0.577	1.848	4.177
Hostile	-1.376	0.345	2.336	4.719
Annoyed	-1.138	0.071	1.294	3.266
Confused	-0.952	0.618	1.442	3.122

Dissatisfied	-1.277	0	0.744	2.397
Disappointed	-1.487	0.247	1.533	3.156
Unhappy	-3.008	0	1.856	5.155
Miserable	-2.513	0.338	2.372	5.016
Depressed	-1.904	0.132	1.377	3.713
Sad	-1.794	0.114	1.443	3.505
Helpless	-1.436	0.463	1.871	3.356
Melancholic	-0.757	0.045	0.742	2.39
Sluggish	-0.823	-0.711	-0.301	1.499
Tired	-0.911	-1.125	-1.115	1.181
Sleepy	-0.836	-1.318	-0.679	1.716
Bored	-0.406	-0.403	0.098	1.745
Still	0	-0.734	-0.909	1.012
Quiet	0	-0.45	-1.224	0.785
Safe	0.722	-0.208	-1.404	0.540
Soothed	0.798	-0.090	0.368	2.361
Calm	1.084	-0.737	-2.074	0.789
Tranquil	1.127	-0.384	-0.385	1.890
Relaxed	1.262	-0.537	-1.446	1.130
Peaceful	1.256	-0.518	-0.949	1.654
Serene	0.952	-0.193	-0.169	1.700
Content	1.222	-0.330	-1.299	1.18