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Abstract

According to several researchers, core affect lies at the foundation of our affective lives and may be characterized as a consciously accessible state combining arousal (activated-deactivated) and valence (pleasure-displeasure). The interaction between these two dimensions is still a matter of debate. In this paper we provide a novel hypothesis concerning their interaction, by arguing that subjective arousal levels modulate the experience of a stimulus' affective quality. All things being equal, the higher the arousal, the more a given stimulus would be experienced as pleasant (or unpleasant). While marshaling some preliminary evidence in favor of this hypothesis, we also show how it might be relevant in reframing our conception of depressive disorders (i.e., major and bipolar depression).

Keywords: emotion, arousal, valence, affective disorders, depression

1. Introduction

In the past thirty years, the debate on emotion and other affective states has flourished in a number of subfields within psychology and philosophy. Notably, there have been several attempts to construct models that would successfully describe affective experience by individuating its basic components. Relevant work in this sense has been conducted by James Russell (1980; 2003), and has been later expanded by a number of researchers interested in characterizing affective states at a progressively finer-grained level (see Feldman 1995; Kuppens, Oravecz & Tuerlinckx 2010; Hamaker *et al.* 2015; Kron *et al.* 2015; Larsen *et al.* 2017). On Russell's seminal account, our affective lives are characterized by a baseline neurophysiologic state called core affect, which consists in a certain degree of arousal (activation-deactivation) combined with a certain degree of valence (pleasure-displeasure, sometimes also called "hedonic valence"). These two dimensions are usually represented in what Russell (1980) dubbed the Affect Circumplex. For example, an emotion such as anger would be characterized by high arousal and negative valence, whereas a calm mood would be characterized by low arousal and positive valence: these two states thus occupy opposite points of the Affect Circumplex. Russell later refined his account by distinguishing between core affect and *affective quality*: while the former may be characterized as a subjective feeling of pleasure/displeasure and activation/deactivation, the latter concerns the potential that objects and events have to change core affect. As Russell (2003) puts it: "Phenomenologically, core affect is a feeling inside oneself, whereas an affective quality is a property of the thing perceived" (p. 157). In this paper we build on these notions to propose a novel interaction between arousal and valence, one that increases our understanding of everyday affective variations and also sheds light on pathological ones (depressive disorders in particular).

First, we introduce Russell's Affect Circumplex as a model characterizing affective experience in terms of two dimensions, arousal and valence, and we briefly discuss some possible relations between them, primarily drawing on the data analyzed by Kuppens and colleagues (2013). Then we address the challenge recently raised by some researchers working on affective experience, who characterize valence as unipolar (i.e., separate axes for positive and negative valence) as opposed to bipolar (i.e., one axis ranging from pleasant to unpleasant), thereby making room for mixed emotions. With these building blocks in place, we flesh out a novel hypothesis concerning the interaction between arousal and valence. Specifically, we suggest that – in ordinary as well as pathological cases – subjective arousal (or some underlying mechanism that correlates with it) could have a *modulatory effect on the experience of a stimulus' (un)pleasantness*. When arousal increases, stimuli that would be otherwise perceived as similar in terms of affective quality produce a greater experience of (dis)pleasure, thus resulting in a wider variation of a subject's valence level. This may happen in everyday situations – e.g., when one is over-caffeinated – as well as in pathological ones. By contrast, when arousal decreases it becomes easier to get "stuck" in a particular valence state: this happens whenever we have trouble snapping out of a mood, and more severely in cases of major depression. Finally, we show that our hypothesis is consistent with existing empirical evidence and we discuss how it may advance the debate on how to model affective experience as well as our understanding of depressive disorders. We conclude by advancing some methodological considerations on how our hypothesis could be tested.

2. The components of affect

2.1 Arousal and valence

The idea of a dimensional characterization of affect traces back to Wundt (1897/1998), who proposed to construe affective states as if they were distributed along three axes: pleasantness-unpleasantness, arousing-subduing, and strain-relaxation. Similarly, Freud (1915) thought that affective life was governed by three polarities: pleasure-unpleasure, active-passive, and subject-object. Unlike these early characterizations, most contemporary dimensional views of affect employ only two dimensions, often construed in terms of *arousal* (from sleepy to activated) and *valence* (from unpleasant to pleasant). These two dimensions interlock into a circumplex structure, which Russell (1980) dubbed the Affect Circumplex (Fig. 1):

Fig. 1. *A graphical representation of the Affect Circumplex. Reprinted from Russell (2003).*

Russell (1980) validated the Affect Circumplex as a model of affective states at the phenomenological level, based on the consistency of self-reports and on the analysis of verbal concepts across multiple subjects. The circumplex construct has also been claimed to be equivalent (see Yik, Russell & Feldman Barrett 1999) to other bidimensional models of affect, such as the ones proposed by Larsen & Diener (1992), Thayer (1989), and Watson & Tellengen

(1985); it has also been validated cross-culturally (Yik & Russell 2003). The popularity of this model is attested by the fact that the most popular databases of affective stimuli – such as the International Affective Picture System or IAPS (Lang, Bradley, & Cuthbert 1997) – are arranged along arousal and valence axes. Although some individual variations result in some people being more focused on arousal and others on valence (Feldman 1995; Feldman Barrett 1998), these two axes are taken to describe the affective structure of every human being (Russell & Feldman Barrett 1999; Russell 2003; Feldman Barrett & Bliss-Moreau 2009). Russell defines core affect as "a neurophysiological state that is consciously accessible as a simple, nonreflective feeling that is an integral blend of hedonic (pleasure-displeasure) and arousal (sleepy-activated) values" (2003, p. 147). On Russell's view, every person always stands at some point on the Affect Circumplex, although one may not be aware of this fact outside discrete emotional episodes (2003, p. 157). It is worth stressing here that the dimensions of core affect are meant to represent one's *conscious experience* of affect, rather than its underlying mechanism(s). Indeed, while valence and arousal can be also studied at the behavioral and neural level, their historical formulation, as well as their individuation, lies at the phenomenological level (i.e., the arousal and valence variations experienced and reported by individuals).[1]

Based on dissociations between self-reported levels of valence and arousal (notably in Russell 1980), these dimensions have been often assumed to be independent (see Barrett & Russell 1999; Feldman Barrett 1995; Larsen & Diener 1992). However, Kuppens and colleagues (2013)

[1] Posner, Russell & Peterson (2005) advance some hypotheses concerning the neural underpinnings of arousal and valence. However, recent attempts to localize them onto neural bases revealed sparse mappings (see for instance Lindquist *et al.* 2015; Wager *et al.* 2015). It is also worth noting that, as Satpute and colleagues (2018) recently stress, arousal comes in three varieties: wakeful, autonomic, and affective. While the three phenomena are slightly different and are studied in different research contexts, they also are deeply intertwined, likely co-varying, and bear on largely overlapping neural bases. Therefore, it seems safe to take heightened or lowered wakeful and/or autonomic arousal states as reliable proxies for higher/lower affective arousal state.

perform an extensive review and meta-analysis of the relevant literature to check for their interactions. Before reviewing the data, they flesh out six possible relations between valence and arousal (see fig. 2 below):

a) *Total independence:* most scholars working on core affect simply assume that arousal and valence are independent and unrelated dimensions. On this view, "how pleasant one is feeling gives no information about how activated one is feeling and vice versa" (Kuppens *et al.* 2013 p. 919).

b) *Positive linear relation:* the idea that arousal would positively co-vary with valence is also widespread among Western psychologists, and reflects the common idea that "exciting" affective states are prototypically positive (Tsai, Knutson & Fung 2006).

c) *Negative linear relation:* by contrast, the preference for low-arousal states in some Eastern cultures may suggest that valence is inversely proportional to arousal (Tsai, Knutson & Fung 2006).

d) *V-shaped relation:* some theories (e.g. psychobiological theories of motivation and personality) argue that arousal reflects the intensity of either pleasure or displeasure, with neutral hedonic states corresponding to low arousal.

e) *Asymmetrical v-shaped relation:* theories that conceive valence and arousal as independent dimensions suggest that, although both pleasure and displeasure co-vary with arousal, such co-variation may not be linear.

f) *Inverted v-shape:* an affective state would be maximally pleasant when arousal and valence are balanced, and valence would decrease when arousal levels are extreme – i.e. too low or too high.

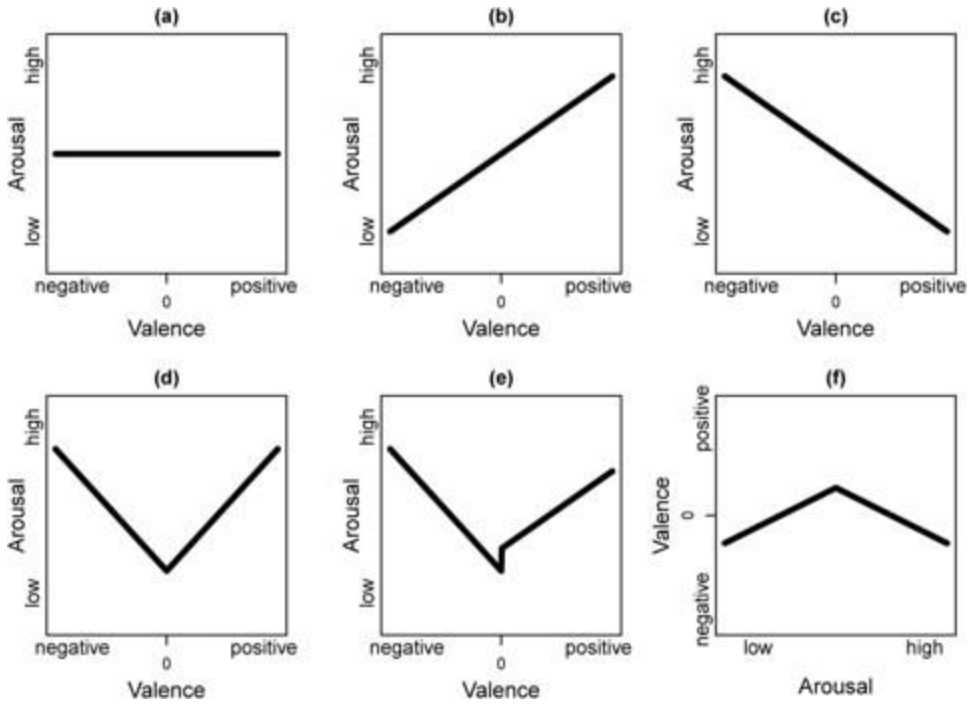

Fig. 2. *Six relations between valence and arousal discussed by Kuppens and colleagues (2013): (a) independence, (b) positive linear relation, (c) negative linear relation, (d) symmetric V-shaped relation, (e) asymmetric V-shaped relation, and (f) inverted V-shaped relation. Reprinted from Kuppens et al. (2013, p. 919).*

In light of their meta-analysis, Kuppens and colleagues (2013) found some evidence for a V-shaped relation between arousal and valence (see fig. 2d), albeit this finding is probabilistic rather than deterministic. This implies that states combining high arousal and neutral valence, or low arousal and positive/negative valence, are not impossible but simply less frequent. For this

and other reasons that we briefly detail below, the preference for a V-shaped relation should be taken with a grain of salt due to some caveats (see also Mattek, Wolford & Whalen 2017).[2]

2.2 Is valence bipolar?

When it comes to describing affective experience, many researchers agree with Russell (2003) in characterizing it as a "simple, nonreflective feeling" (p. 147). Yet, the claim that this feeling is best captured by "an integral blend of hedonic (pleasure-displeasure) and arousal (sleepy-activated) values" (*ibid.*) is way more controversial.[3]

In the Affect Circumplex, like in similar models, valence is represented by a bipolar axis, going from completely negative (-1) to completely positive (+1). As a consequence, subjects cannot *simultaneously* feel positive and negative affect (Russell & Carroll 1999); in other words, the model rules out the existence of *mixed emotions*.

However, a recent wave of research has specifically challenged this impossibility by collecting some interesting data on mixed emotions, e.g. in bittersweet situations (see Larsen *et al.* 2017 for a recent review). To allow for the possibility of positive *and* negative affective states, Kron and colleagues (2013; 2015) propose to replace the Affect Circumplex with another model employing two unipolar axes for valence (i.e. positive and negative). They maintain that "the

[2] The main caveats acknowledged by Kuppens and colleagues as constraining the interpretation of the V-shaped relation between valence and arousal are the following: (I) their dataset comes from studies that were not intended to explicitly test these hypotheses; (II) a great number of the studies they examined rely on affective-inducing stimuli, such as the International Affective Picture System (IAPS), rather than on real-life situations contexts (thus possibly involving the perception of affective quality rather than core affect); (III) cultural and individual variability is significant (see Kuppens *et al.* 2013; Kuppens *et al.* 2017).

[3] There is clearly a tension between the apparent simplicity of core affect as experienced at the phenomenological level and the complexity of its subcomponents when it comes to measurement. This is a complex issue that affects psychology across the board, and studies on introspection in particular (see Hurlburt 2011). Although we cannot fully address the issue in this paper, we still want to alert the reader about the existing gap between a simple phenomenological experience and its far more complex measurement and representation via psychological constructs.

dissociation between valence and arousal […] might be more an issue of measurement than a reflection of distinct qualia underlying emotional experience" (Kron *et al.* 2013, p. 1504). To substantiate this claim, they compared the reported judgment of a group of subjects on the same set of stimuli (i.e., a set of pictures) according to both models (i.e., arousal + bipolar valence scale, and arousal + dual unipolar valence scales). They also employed robust physiological measures for valence (electromyographic activity, or EMG) and arousal (electrodermal activity, or EMA). The most interesting results pertain those situations where arousal and valence maximally dissociate in the Affect Circumplex model – i.e. high arousal and neutral valence. In fact, in the dual unipolar model, the same situations correspond to high scores in both positive valence *and* negative valence. Since in these cases reported arousal is equivalent to the sum of positive and negative affect, Kron and colleagues suggest that the former might not be distinctly perceived in experience. More recently, a similar model has been proposed (Mattek *et al.* 2017) and validated (Brainerd 2018). On this account, the degree of dissociation between arousal and valence is predicted by third parameter, namely the degree of *valence ambiguity* of a stimulus.

Russell (2017) recently responded to the challenge of mixed emotions by proposing several explanations that would make the evidence presented above consistent with his own model. For instance, he maintains that some mixed emotional judgments may be due to the simultaneous presence of multiple affective qualities (see the next subsection) in the same stimulus. Russell's rebuttal is especially relevant given that most studies on mixed emotions focus on the affective qualities of the stimuli rather than on subjective valence (see Itkes, Eviatar and Kron 2019 for an exception). When it comes to core affect, some reported experiences of mixed states may actually be due to a rapid vacillation from one state to another (Kahneman 1992), just like in bistable figures where one goes back and forth from seeing a rabbit to seeing a duck.

While in the remainder of this paper we assume Russell's model, we are careful about not taking a definitive stance on the debate between bipolar and unipolar accounts of valence. As Russell himself concedes, "[b]oth sides remain viable" (2017, p. 116). However, if proven correct, our hypothesis may substantiate the vacillation hypothesis when it comes to mixed emotions.

2.3 Affective quality

Before moving on to flesh out our hypothesis, we need to further discuss another conceptual distinction. As we mention above, Russell (2003) distinguishes between core affect as a *subjective property*, and *affective quality*, which he dubs "a property of the stimulus: its capacity to change core affect" (Russell 2003, p. 149). For example, the slice of cake in front of me possesses a certain affective quality in virtue of its capacity to significantly change my subjective arousal and valence levels. Affective qualities such as the ones exhibited by the slice of cake are dispositional (rather than intrinsic) properties: we perceive some objects or events as arousing if they make us more activated, or as pleasant or unpleasant if they have the power to make us pleased or displeased. Clearly, these changes are not deterministic: since their impact on core affect depends on subjective factors such as one goals and preferences, they may greatly vary across subjects and conditions – e.g., whether someone likes or hates cake, or whether the specific cake is a traditional dish in the person's country.

Given all this complexity, every discussion about the affective quality of a stimulus should be interpreted with caution, as it expresses an average estimate in standard conditions. In Russell's own terms, "[t]o perceive affective quality is to *represent* rather than to *experience* core affect. Nevertheless, the two processes are linked empirically, although sometimes in complicated

ways" (2003, p. 149, emphasis ours).[4] Notably, one of these interactions lies at the core of the hypothesis we are about to delineate.

[4] The notion of perception of affective quality admittedly resembles the notion of appraisal, employed by several theories of affect to describe how subjects differently assess objects and events. Russell himself acknowledges this conceptual similarity, while flagging an important difference between the two theories: "Perception of affective quality must also be distinguished from appraisal. Appraisal, in Lazarus's (1991) account, is a weighing of the implications of an event for one's well-being; perception of affective quality is much simpler. For example, you might appraise a medicine as best for your health; nevertheless, your perception of its affective quality is that the stuff smells and tastes unpleasant" (2003, p. 149). More recently, echoing Russell's original distinction, some researchers elaborated on the construct of valence by distinguishing affective and semantic valence (Itkes & Kron 2019; Itkes *et al.* 2017). The former characterizes the experience of a given feeling being pleasant or unpleasant and underscores "hot" physiological and emotional changes, whereas the latter refers to "colder" assessments about an object's or event's value. These two modes of valence are often intertwined, but they may come apart: for example, we might know that funerals are sad events without having strong affective responses upon hearing about a stranger's funeral (Itkes & Kron 2019, p. 283). As helpful as these distinctions may be, for the sake of terminological consistency we stick to Russell's lexicon as closely as possible in this paper.

3. Arousal as a modulator of valence

So far we have subscribed to the following claims. First, at any given time everyone has an affective state that can be described as a point on a bidimensional space constituted by *valence* and *arousal* (Russell 2003). Second, although there are several possible relations between these two variables, the available evidence shows that high arousal is more likely to go on a par with either strongly negative or strongly positive (as opposed to neutral) valence (Kuppens *et al.* 2013). Third, for stimuli judged as highly arousing but neutral in a bipolar scale of valence, the dissociation between arousal and valence may derive from the valence ambiguity of the stimuli (Mattek *et al.* 2017). The purpose of this paper is to articulate a hypothesis that may shed light on *why* these relations occur.

Most theories concerned with the relation between valence and arousal attempt to *reduce* the former to the latter while adding something else (or vice versa). In general, the researchers who posit some relation between these two dimensions do so in terms of one of them playing a *constitutive* role in the other, confining their analysis to a synchronic perspective (i.e. arousal and valence levels experienced by an individual at a given time *t*). Take for instance Schachter and Singer's (1962) popular two-factors theory: on their view, emotional states boil down to a certain level of arousal plus a cognitive interpretation.[5] Or recall the proposal advanced among others by Kron and colleagues (2013, 2015), that arousal is nothing but the sum of positive and negative valence. Yet, other researchers have recently started focusing on the dynamical facets of affect and on the ways in which core affect develops over time (see Kuppens & Verduyn, 2017). Here

[5] "Given a state of physiological arousal for which an individual has no immediate explanation, he will 'label' this state and describe his feelings in terms of the cognitions available to him. To the extent that cognitive factors are potent determiners of emotional states, it could be anticipated that precisely the same state of physiological arousal could be labeled 'joy' or 'fury' or 'jealousy' or any of a great diversity of emotional labels depending on the cognitive aspects of the situation" (Schachter & Singer 1962, pp. 381-382).

we propose to see arousal as playing a modulatory role in perceiving the affective quality of a stimulus within an emotional episode, and thus in regulating valence changes diachronically. More specifically: a state of heightened (or diminished) subjective arousal would exercise a magnifying (or shrinking) effect on the experienced (un)pleasantness of an object, corresponding to an amplified (or narrowed) movement along the subjective valence axis. Metaphorically speaking: a church's bell may produce a louder or softer sound depending on the strength exercised by the person who strikes it. Similarly, stimuli of comparable perceived valence quality will produce greater or smaller changes in (subjective) valence state depending on one's (subjective) arousal level.

In high subjective arousal conditions stimuli would be experienced as *more* pleasant or unpleasant: for example, I am more disturbed by the sight of a stranger in a dark alley if I am feeling jittery or tense; if I just drank a coffee and I find out that a paper of mine was accepted for publication, I would be more excited as opposed to discovering the same piece of news while lying in bed. By contrast, in low arousal conditions the impact of stimuli would be experienced as less intense: in other words, we are less "moved" by what happens in our surroundings.

Our hypothesis predicts that high arousal conditions would facilitate a wider oscillation in terms of valence; that is, our mood would swing more easily between pleasant and unpleasant sensations (hence making it more likely to experience the vacillations that may underlie self-reports of "mixed emotions"). By contrast, low arousal conditions would correspond to a certain fixity in the affective sphere, with a narrow range of options available in terms of valence.

More specifically: (1) we assume that the experience *E* of (un)pleasantness of a stimulus *x* at time *y* affects the subjective valence level *V* before the experience, so that:

$$V_{t_y} = V_{t_{y-1}} + E_{x,t_y} \qquad (1)$$

(2) Our hypothesis predicts that the experienced (un)pleasantness *E* of a stimulus *x* at time *y* depends both on the perceived valence quality *Q* of the stimulus *x* and on the subjective arousal level *A* following the experience of the stimulus:

$$E_{x,t_y} = f(Q_x, A_{t_y}) \qquad (2)$$

(3) Moreover, we predict that for each pair of positive/negative stimuli *x* and *w*, experienced respectively at time *y* and *z*, provided that the perceived valence quality *Q* of *x* is equal or more positive/negative than that of *w*, if the subjective arousal *A* at time *y* is higher than the subjective arousal *A* at time *z*, then the experienced pleasantness/unpleasantness of *x* is equal or higher to the experienced pleasantness/unpleasantness of *w*. A bit more formally,

$$(Q_x \geq Q_w > 0) \& \left(A_{t_y} > A_{t_z}\right) \rightarrow E_{x,t_y} > E_{w,t_z} \qquad (3a)$$

$$(Q_x \leq Q_w < 0) \& \left(A_{t_y} > A_{t_z}\right) \rightarrow E_{x,t_y} < E_{w,t_z} \qquad (3b)$$

A few clarifications are in order. First, since we are not implying that a lower than average arousal state has the ability to *reverse* the valence of a given stimulus, in our model arousal is unipolar, i.e. ranging from 0 to 1, whereas valence is bipolar, i.e. ranging from -1 to +1. Second, the affective quality of a stimulus would concern both valence and arousal, given that unexpected events are probably going to arouse you regardless of whether they are good or bad. The subjective arousal variations that ensue then contribute to determine the subject's arousal state, which in turn influences the valence changes, according to our hypothesis. Third, given the same level of perceived valence quality, the relation between subjective arousal and

experienced pleasantness need not be linear. All we maintain is that it *cannot* be the case that, given the same (or higher) level of perceived valence, a stimulus experienced when the subjective arousal is higher produces a smaller impact on subjective valence than a stimulus experienced in lower subjective arousal conditions. Fourth, we neither claim that this is the *sole* interaction, nor that this is a *direct* interaction, between the two variables.

Indeed, while they legitimately figure in scientific generalizations, arousal and valence should not be interpreted as neuropsychological mechanisms with causal efficacy, but rather as control variables, i.e. "a variable on which intervention is possible that robustly has large, systematic and specific impacts on the outcome space" (Campbell 2008, p. 426). A preliminary explanation of their underlying functioning is the following: higher arousal levels may reflect the enhanced activity of a salience mechanism, purported to facilitate attention-shifting towards stimuli experienced as significant in a given context. Such increased disposition to attend to emotional stimuli – i.e. the cup of coffee in front of me after a sleepless night – might in turn contribute to explain our heightened affective reaction to it (see Higgins 2006). The stimuli that end up being "tagged" as more relevant also become the locus of our affective reactions on the valence axis.

Some recent experimental evidence offers preliminary support to our suggestion. Sutherland & Mather (2018) found that higher arousal conditions were connected to enhanced visual processing of perceptually salient targets, while Olteanu *et al.*'s (2018) results show that a highly salient stimulus – e.g. one's test score granting access to university – has a greater impact on subjective valence. On our view, higher arousal levels work as indicators of the increased salience of a stimulus and – as a consequence – of our heightened affective response to it.

4. Substantiating the hypothesis

Testing the hypothesis outlined above would require extensive data collection, experimental design, and empirical trials. This goes well beyond the scope of this paper. In what follows we focus on showing that our hypothesis *is worth such* an endeavor. In this process, the first step would be to ascertain that our claim is not falsified by already available evidence. As we maintain above, the model we propose fits nicely with the data reported by Kuppens *et al.* (2013), Mattek *et al.* (2017) and Brainerd (2018). Moreover, we believe that this hypothesis is worth testing because – if proven true – it would help us reframe our understanding of mixed emotions and, more relevantly, of depressive disorders.

4.1 Plausibility

One source of plausibility is merely intuitive. While phenomenological intuitions about one's own state may not be strong enough to support a theory, they nonetheless play a pivotal heuristic role in preliminarily assessing hypotheses. Our intuitions tell us that we are less impressed by some good or bad news when we are very sleepy as opposed to when we are very excited. Of course, since most stimuli also influence arousal, some *very* good or bad news can easily awaken us and make us suddenly excited. But according to our hypothesis and our experience, if we were *already* very excited, then the news would tend to seem even better or worse. Given our high caffeine consumption (which arguably increases arousal levels), we often experience that after the fourth cup of coffee, anything seemed either *wonderful* or *terrible*, *tertium non datur*.

This is consistent with the phenomenon that Marañon (1924) labels "affective imminence", which can be described as a disposition to feel stronger emotions than normal under similar circumstances. In his experiment, Marañon injects a group of subjects with adrenaline and tests

their affective reaction to various kinds of positively or negatively valenced news. Under the effect of adrenaline, and thus in a state of heightened arousal, the subjects tended to exhibit an emotional reaction to topics that left them indifferent before. As Marañon puts it: "In several cases we spoke to our patients *before* the injection of their sick children or dead parents and they responded *calmly* to this topic. *The same topic presented later*, during the adrenal commotion, was sufficient to trigger *emotion*" (pp. 307–308, emphasis ours). The effect described by Marañon suggests that increased arousal levels may reflect a corresponding increase in the salience of stimuli. In other words, the same topic may trigger a substantially different affective reaction when brought up to a subject in different arousal conditions. Interestingly, Marañon's experiment also suggests a direction to this alteration: heightened arousal levels appear to go on a par with an *increased* affective significance of the given stimulus.

Similar results can be found in an experiment conducted on rats several years later (Singer 1961, cited in Schachter & Singer 1962). In this study, two groups of rats – one injected with epinephrine (i.e., adrenaline) and the other with a placebo – are exposed to the same fear-inducing conditions which include the simultaneous presentation of a loud bell, a buzzer, and a bright flashing light. Singer notes that epinephrine-injected rats exhibit a stronger emotional reaction with respect to the control group: in particular, they act more frightened with respect to their placebo-injected counterpart. Given the same set of stimuli, "epinephrine-injected rats "defecated, urinated, and trembled more than did placebo-injected rats" (reported by Schachter & Singer 1962, p. 396). Assuming that behavioral differences would work as (imperfect) proxies for the animals' affective states, this result indicates that the effects of high arousal states on affect may extend to non-human animals, in the same direction found by Marañon. In a nutshell: the higher the arousal, the stronger the emotional reaction to a given set of stimuli. Schachter &

Singer come to a similar conclusion when commenting on this result: "Varying the intensity of sympathetic activation serves to vary the intensity of a variety of emotional states in both rats and human subjects" (1962, p. 396). These results coming from classic studies on affect sit comfortably with our empirical prediction, namely that *arousal positively co-varies with valence changes.*

4.2 Relevant Implications

With respect to the mixed emotions issue outlined above, the hypothesis we are delineating may contribute to substantiate the vacillation hypothesis. Inspired by Kahneman (1992), Russell (2017) suggests that some cases of (putatively) mixed emotions can be reinterpreted as rapid vacillations from one point to another of the Affect Circumplex. As a matter of fact, recent evidence (Kron *et al.* 2013, 2015; Mattek *et al.* 2017) shows that the ambivalence of a stimulus (i.e., scoring high on both positive and negative valence scales) goes on a par with its reported arousal, and that this relation is linear (Brainerd 2018). Kron and colleagues interpret such findings as evidence for adopting a deflationary stance toward arousal, by suggesting that it can be reduced to the sum of positive and negative valence. Our alternative view suggests that arousal exists as an independent dimension, and that subjective states of high arousal facilitate rapid vacillations between positive and negative valence states. Due to their temporal proximity, such states are conflated when subjects are explicitly asked to report valence judgments.

Another interesting implication of our hypothesis would be that, by clarifying the nature of arousal functioning we also shed some light on how this mechanism can go awry. In other words, we would learn more about arousal dysfunctions and how they may be connected with some common and debilitating psychiatric conditions. Following the dimensional nature of the model

proposed here, we stipulate that arousal may be disrupted in two opposite directions. On the one hand, a situation where arousal is very *high* would correspond to an experience of the world where too many objects, events, or goals are experienced by the subject as being significant. In such a scenario, the subject's attention would wander from one thing to the next and would encounter trouble focusing or concentrating on anything, thereby creating a situation of permanent distraction. From a behavioral viewpoint, a subject whose arousal is very high would tend to act impulsively and on the spur of the moment, undertaking too many tasks at once or relentlessly jumping from one thing to another. On the other hand, a situation where arousal is very *low* would correspond to an experience where the subject struggles to find any significance in the objects, events and goals surrounding her. In this case, attention would appear stuck and thought patterns may become increasingly slow and fixated on fewer objects. Behaviorally speaking, we would observe a significant decrease in bodily movement connected with a loss of motivation with respect to action.

It is worth noting that the conditions of low or high arousal just described are not *per se* pathological. In fact, they are quite common in our everyday life. For example, when we fall in love with someone we stereotypically experience a state of heightened arousal where every small detail about the relevant person may take on an exaggerated significance. Connected with the phenomenology of falling in love, many people experience unusual trouble concentrating and carrying out everyday tasks. Love-driven impulsive acts are also part and parcel of most romantic comedy scenarios. On the opposite end of the spectrum, waking up after a night where we did not have enough sleep may put us in a prototypical low-arousal condition. We struggle to find good reasons to get out of bed, and even the most pleasant activities seem to have lost their enticing pull. Our body wanders around the room in slow motion and our mind may become

fixated on one object (e.g., coffee) or thought (e.g., "I should really go to bed earlier"). Although many people may be familiar with similarly low or high arousal conditions, these are usually transitory.

However, patients affected by depressive disorders seem unable to successfully regulate their arousal levels to a more significant degree. In particular, manic states within bipolar depression may be characterized as situations where arousal is *pathologically* high. By contrast, major depression (as well as depressive states within bipolar disorder) would correspond to situations of *pathologically* low arousal. In what follows, we discuss some first-person reports from psychiatric patients that corroborate our suggestion. The discussion of these reports serves to further illustrate the idea that different arousal levels significantly influence subjective valence variability. Given that manic and depressive states lie on opposite ends of the arousal dimension, they represent privileged vantage points on the arousal-valence interaction. The exploration of these case studies also helps us cast a new light on the nature of depressive disorders and their treatment. Indeed, while depression has often been described and treated as a disorder of valence – e.g. "bad or low mood" – our hypothesis indicates that it could be reframed as an arousal dysfunction.

4.3 Arousal dysfunctions and depressive disorders

As we discuss above, our hypothesis predicts that subjective valence variability would significantly decrease in situations of low arousal. This implies that a subject with low arousal levels would experience greater difficulty in moving along the valence spectrum, thus exhibiting some form of emotional *rigidity*. In other words, we predict that a depressed subject would remain largely unaffected by the affective qualities of a stimulus. Russell himself seems to hold a

similar view when he acknowledges that "[a] stimulus can be perceived as to affective quality with no change in core affect—it is then cold and detached, as when a depressed patient admits that the sunset is indeed beautiful but is still not able to alter a persistently depressed mood" (Russell 2003, p. 149).

A vivid illustration of this phenomenon may be found in first-person reports of patients affected by major depression. In her semi-autobiographical novel *The Bell Jar* (1963), Sylvia Plath poignantly describes her complete lack of motivation that extends to the most basic and everyday tasks, such as washing her hair or clothes (1963, p. 66). To better explain why she sees no point in undertaking these simple actions, Plath metaphorically compares her life to an endless stretch of boxes, where every day is staggeringly similar to the next:

> I saw the days of the year stretching ahead like a series of bright, white boxes, and separating one box from another was sleep, like a black shade. Only for me, the long perspective of shades that set off one box from the next had suddenly snapped up, and *I could see day after day after day glaring ahead of me like a white, broad, infinitely desolate avenue* (1963, p. 67, emphasis ours).

Given Plath's extremely low levels of arousal (e.g., thinking about everyday tasks appears unbearable), she appears *stuck* in a negatively valenced state. Nothing in her life seems interesting, appealing, or worth exploring. She experiences her days as being undifferentiated from one another because nothing sticks out, nothing shows up as salient or important enough to be noticed. This condition of painful indifference is also beautifully described by William Styron in his memoir *Darkness Visible*:

> Afternoons were still the worst, beginning at about three o'clock, when I'd feel the horror, like some poisonous fog bank roll in upon my mind, *forcing me into bed*. *There I would lie for as long as six hours, stuporous and virtually paralyzed, gazing at the ceiling and waiting* for that moment of evening when, mysteriously, the crucifixion would ease up just enough to allow me to force down some food and then, like an automaton, seek an hour or two of sleep again (1990, pp. 33–34, emphasis ours).

From a behavioral and bodily viewpoint the subjects affected by major depression are stuck in this horrifying trance, where standing still or lying in bed are often regarded as the only possible alternatives. Another important component of major depression emphasized in first-person accounts is the altered or distorted perception of time. More specifically, patients who are in the grip of a depressive episode appear significantly *stuck* from a temporal perspective, as they seem to lose the ability to project themselves in the future and imagine a more positive outcome. In his book *Experiences of Depression* (2015), Ratcliffe collected several reports that illustrate this point: "In the middle of a depressive episode, *it is impossible to believe it will pass*" (Burnard 2006, p. 244, emphasis ours); "I am in a *time-locked place, where the moment I am in will stretch on, agonizingly, forever*" (Lott 1996, pp. 246–7, emphasis ours. For another recent work investigating the distortion of temporality in major depression, see Maiese 2018). Following our initial hypothesis, we therefore characterize major depression as a condition where a subject is *stuck* in a combination of low arousal and negative valence. Notably, given the suggested modulatory effect of arousal on valence, these subjects experience a pathological inability to

move along the valence axis, which might explain why depressive episodes extend over long periods of time and are particularly hard to overcome.[6]

Our hypothesis may also help us to better understand the mechanisms underlying affective disorders characterized by high levels of arousal, such as the manic states within *bipolar depression*. Again, first-person accounts of patients affected by this disorder highlight some of the features that we have described as typical of high arousal conditions. For instance Jamison (1995) vividly reports feelings of bodily and affective imminence – to say it with Marañon – and hypersalience:

> With vibrissae twinging, antennae perked, eyes fast-forwarding and fly faceted, *I took in everything around me*. I was on the run. Not just on the run but fast and furious on the run, darting back and forth across the hospital parking lot trying to use up a boundless, restless, manic energy (1995, p. 3, emphasis ours).

Interestingly, Jamison also connects these high levels of arousal with an inclination towards impulsivity and excess. In other words, when in a manic state she experiences the world as being full of salient stimuli that demand to be acted upon immediately. As a result, she cannot help but restlessly jumping from one thing to the next without being able to complete a single task (1995, p. 42. See Sass & Pienkos 2013 for a similar account of mania). Another first-person account of manic states that forcefully stresses this point has been recently offered by the philosopher Paul Lodge:

[6] While here we characterize major depression as the inability to disengage from a negative state due to low arousal levels, our hypothesis also applies to the opposite (arguably non-pathological) scenario. Given a very low level of arousal combined with a positive valence state, a subject should find it difficult to experience a shift toward negatively valenced states. Indeed, this might be what happens in calm yet positive affective conditions such as meditation.

> It is important to recognize that during at least some manic and hypomanic episodes, there is a sense of an exponential *increase in objects of attention*. And this brings with it an *exhilarating sense of being exposed to an unlimited number of objects and their interconnections all at onc*e, and a sense that one is being offered a window into the true nature of reality (2020, emphasis ours).

Besides being characterized by (abnormally) high levels of arousal, manic phases also exhibit a markedly positive valence. As these authors put it: "I felt great. Not just great, I felt really great. I felt I could do anything, that no task was too difficult" (Jamison 1995, p. 36); "But this need not be experienced as unpleasant. Indeed, it may be experienced as just the opposite—for instance, as an ecstatic sense of the meaningfulness of existence" (Lodge 2020).

These intense but short-lived manic episodes, characterized by the combination of high arousal and positive valence, are usually followed by longer depressive phases that closely resemble the ones experienced in major depression. Patients often describe this change as being abrupt, overwhelming, and terrifying. Notably, the transition to negative valence is also accompanied by a dramatic decrease in the subject's sense of salience. As Jamison puts it: "I lost all interest in my schoolwork, friends, read-ing, wandering, or daydreaming. (...) I would wake up in the morning with a profound sense of dread that I was going to have to somehow make it through another entire day (1995, p. 44). In this respect, bipolar depression seems therefore characterized by the problematic *oscillation* between two extremes: either too many things, objects, and events

are perceived as significant (manic phase) or everything appears unimportant and uninteresting to the subject (depressive phase).[7]

This discussion of first-person reports helps us to reframe the standard view of depressive disorders. Rather than focusing on negative valence – e.g. low mood – we propose to see depression primarily as a *disorder of arousal* (or of its underlying mechanisms). On the one hand, when arousal levels are *too* low patients appear "stuck in a rut" and thus unable to disengage from a negative mood (Holtzheimer & Mayberg 2011, p. 2). On the other hand, when arousal levels are *too* high patients tend to oscillate abruptly between positive and negatively valenced states. The pathological nature of depression – as we see it – should thus be connected with a subject's *inability to disengage from negatively valenced states.*

This conceptual revision may also carry some important consequences with respect to treatment. Indeed, current antidepressant medications tend to focus on valence regulation – e.g. mood uplifting – through their action on monoaminergic neurotransmitters. Yet, these treatments have shown very limited success rates over time – i.e., 60% for best available therapies – with high percentages of patients being treatment-resistant (Holtzheimer & Mayberg 2011, pp. 3–6. See also McIntyre *et al.* [2014] for some recent data on treatment-resistant forms of depression). Moreover, some researchers have pointed out that current antidepressant medications are usually successful in shifting patients out of the low-valenced state but often have trouble *preventing their re-entry into that state* (Holtzheimer & Mayberg 2011, p. 8). Designing treatments acting

[7] Although our account tells us something interesting about the interaction between arousal and valence in manic and depressive states analyzed separately, we do not aim to provide a full-blown explanation of why manic states result in depressive ones (e.g., within bipolar disorder). The mechanisms underlying such transition are undoubtedly complex and multi-factorial in nature, and we cannot fully explore the matter in this paper. Our focus here is rather on how arousal modulates valence within discrete emotional episodes, and any discussion on long-term arousal changes lies outside the scope of our discussion.

more directly on arousal may prove more successful in the long run thanks to the suggested modulatory effect. Indeed, if arousal levels influence valence variability, being able to intervene (pharmacologically or through psychotherapy) on a patient's degree of arousal may play an important role in stabilizing mood. In cases of major depression, we might want to work on *increasing* arousal levels so that we can facilitate the shift to more positively valenced states. By contrast, in manic phases it would be key to *stabilize* arousal levels against problematic oscillations.

One possible objection to our view concerns the well-known comorbidity between depressive and anxiety disorders (see Hirschfeld [2001] for a review). Indeed, it seems *prima facie* contrary to our hypothesis that a subject would simultaneously experience low and high arousal, for instance anhedonia and anxiety. However, this objection stems from a confusion between being clinically anxious and subjectively experiencing an anxious state. While the former comprises a complex set of symptoms, including bodily and cognitive manifestations (e.g., muscle soreness, trouble sleeping, impaired concentration - see American Psychiatric Association [2013]), the latter consists in a more straightforward combination of high arousal and negative valence (e.g., the state of tension upon encountering a stranger in a dark alley). As we mention above, we follow Russell & Carroll (1999) in assuming that one can only stand at *one* point on the Affect Circumplex at a given time: in this sense, high and low arousal states cannot be experienced *simultaneously*. However, the coexistence of more complex affective phenomena, such as clinical depression and anxiety, unfolding over time is surely possible (and in fact extremely common).

5. Testing the hypothesis and concluding remarks

We conclude by offering a few suggestions on how to test our hypothesis empirically. In order to understand whether intervening on arousal states (or their underlying mechanisms) *actually* plays the stipulated modulatory effect on valence, we need to find effective ways to modulate and measure both dimensions in the lab and in real-life conditions. What we predict, to recap, is that in high arousal conditions, the experienced (un)pleasantness of a stimulus and (thus) subjective valence variability would increase, with positive and negative states being triggered more easily. By contrast, in low arousal conditions we expect valence variability to be reduced: in response to the same stimulus, subjects should have a harder time switching from negative to positive states and vice versa. But how can we effectively manipulate and measure arousal and valence?

Some potentially useful data-gathering techniques in real-life settings include the vast array of Experience Sampling Methods or ESM (see Csikszentmihalyi & Larson [2014] for a review). In these studies, subjects are interviewed about their moods or emotional state at various times of the day thanks to customized applications or specifically designed devices. ESM thus allows experimenters to collect data outside the lab and better investigate the complexity of moods waxing and waning over time. Moreover, assuming that physiological signals such as skin conductance may work as indirect indicators of affective arousal, modern wear-on devices can provide continuous measurements over longer and more significant time spans. An important challenge in this respect concerns *sampling frequency*. Indeed, if sampling frequency is too low we risk missing out on some significant relationships that may go undetected: in our case, we may overlook some important ways in which arousal modulates valence over time. On the contrary, a too high sampling frequency may render the study unnecessarily burdensome and complicated for participants thus causing higher dropout rates or constraining the time span. In

our case, this might be problematic because to test our hypothesis we would need both an adequate number of participants and a sufficiently long time span to measure significant changes. Moreover, as it emerges from the first-person accounts discussed above, *timescale considerations* would be particularly important in designing such experiments. On the one hand, depressive disorders develop and exacerbate over long periods of time and go through phases of acute suffering, remission, and relapse (see Verhoeven *et al.* 2017). Longitudinal studies focusing on affective changes may thus be an effective way to explore the nature of these pathological conditions. On the other hand, the best way to capture the influence that arousal levels exercise on subjective valence would be to focus on micro-scales, that is on specific moments within emotional episodes (see Hurlburt 2011). Obviously, ESM can afford ecological validity only at the expense of experimental control.

Therefore, in future work we aim to design complementary laboratory experiments focused on the interaction between arousal and valence over time. One way to do it might be to study populations already exhibiting high arousal conditions (be them natural or induced) and measure their proneness to valence variability. Laboratory studies could also take advantage of the experimental protocols developed by Itkes and colleagues (2017), who explicitly instructed subjects to focus either on their own inner states (feeling-focused reports) or on the stimulus' qualities (knowledge-focused reports). This would allow us to check an important prediction following our hypothesis, namely that experienced subjective valence may change despite the stability of perceived valence quality.

Taking stock: the vast literature on arousal-valence interactions (notably Kuppens *et al.* 2013; Mattek *et al.* 2017), as well as the phenomenological evidence from pathological cases, offer grounds for optimism. Yet, it is obviously possible for our hypothesis to be falsified by studies

explicitly designed to test it. But even that would be an important outcome, as it would advance our understanding of the interaction between valence and arousal (or lack thereof). By contrast, if our hypothesis gets some traction, i.e. if arousal states are found to play (or at least to signal) a modulatory role in the experience of affective stimuli, this result may contribute to trace new paths in the understanding and treatment of serious psychopathological conditions such as depressive disorders.

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