Acta Psychologica 169 (2016) 119–132

Contents lists available at ScienceDirect

Acta Psychologica

journal homepage: www.elsevier.com/locate/actpsy

Establishing the situated features associated with perceived stress

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ARTICLE INFO

Article history:
Received 8 June 2015
Received in revised form 17 May 2016
Accepted 19 May 2016
Available online xxxx

Keywords:
Stress
Perceived stress
Categorization
Stress categorization
Situated cognition
Appraisal

ABSTRACT

We propose that the domain general process of categorization contributes to the perception of stress. When a situation contains features associated with stressful experiences, it is categorized as stressful. From the perspective of situated cognition, the features used to categorize experiences as stressful are the features typically true of stressful situations. To test this hypothesis, we asked participants to evaluate the perceived stress of 572 imagined situations, and to also evaluate each situation for how much it possessed 19 features potentially associated with stressful situations and their processing (e.g., self-threat, familiarity, visual imagery, outcome certainty). Following variable reduction through factor analysis, a core set of 8 features associated with stressful situations—expectation violation, self-threat, coping efficacy, bodily experience, arousal, negative valence, positive valence, and perseveration—all loaded on a single Core Stress Features factor. In a multilevel model, this factor and an Imagery factor explained 88% of the variance in judgments of perceived stress, with significant random effects reflecting differences in how individual participants categorized stress. These results support the hypothesis that people categorize situations as stressful to the extent that typical features of stressful situations are present. To our knowledge, this is the first attempt to establish a comprehensive set of features that predicts perceived stress.

1. Introduction

1.1. The importance of perceived stress

The distinction between stressful life events vs. perceived stress has played a central role in the measurement of stress (e.g. Cohen, Kessler, & Gordon, 1995; Monroe, 2008). From an environmental perspective, an individual's stress can be measured as the number of stressful life events that he or she encounters in the world, using instruments such as the Social Readjustment Rating Scale (Holmes & Rahe, 1967) and the Life Events and Difficulties Schedule (Brown & Harris, 1978). From a psychological perspective, an individual's stress can be measured as how much stress he or she perceives in their experience, using instruments such as the Perceived Stress Scale (Cohen, Kamarck, & Mermelstein, 1983) and the Perceived Stress Questionnaire (Levenstein et al., 1993). Although both environmental and psychological measures predict the negative consequences of stress, such as illness (e.g., Cohen, Tyrrell, & Smith, 1993), we focus here on the psychological contribution.

Since the advent of appraisal theory (e.g., Lazarus & Folkman, 1984), the importance of perceived stress for mental and physical wellbeing has become well established. Depending on how the same life event is interpreted psychologically, its affective and bodily consequences can vary. Whereas one person might appraise an opportunity for public speaking as a threat, another might appraise the same event as a challenge (e.g., Blascovich, Mendes, Hunter, & Lickel, 2003). Perceived stress is associated with negative health outcomes (e.g., Cohen & Williamson, 1988), and also with various biological markers of stress, such as telomere shortening (Epel et al., 2004) and reduction in hippocampal gray matter (e.g., Gianaros et al., 2007).

The negative health consequences of neuroticism further implicate the importance of perceived stress in health. Neuroticism is typically defined as high stable levels of negative emotion, reflecting the fact that some individuals respond more negatively to negative life events than do others. As much research shows, neuroticism is associated with considerable reductions in both mental and physical wellbeing (Lahey,

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http://dx.doi.org/10.1016/j.actpsy.2016.05.012
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2009). Importantly, for our purposes here, individuals who score high on neuroticism tend to experience classic markers of stress, being more likely to perceive threat and less likely to believe that they can cope with threat effectively (Gunthert, Cohen, & Armeli, 1999). As a result, these individuals tend to experience more stress in response to negative events (Suls, Green, & Hillis, 1998). Finally, perceived stress and neuroticism share common genetic contributions (Rietschel et al., 2014) and are closely related psychometrically (Morgan, Umberson, & Hertzog, 2014). The strong affective responses associated with individual differences in neuroticism further implicate the importance of psychological factors in the stress that an individual experiences.

1.2. Adopting a categorization perspective on stress perception

To date, research has predominantly examined perceived stress as a predictor, specifically, as a predictor of negative health outcomes (for a brief review, see Monroe, 2008). Conversely, it is important to understand the factors that predict perceived stress, with these factors potentially including cognitive, affective, and bodily processes. Once these predictive factors are established, they can inform how the perception of stress originates, and can be used to motivate interventions that decrease it.

Appraisal theory offers one account that informs the perception of stress (e.g. Lazarus, 1993; Lazarus & Folkman, 1984; Moors, Ellsworth, Scherer, & Frijda, 2013; Roseman, 2011; Scherer, 2001). When difficult life events occur, people often make certain kinds of appraisals about them (e.g., a threat is present, coping ability is low). In turn, these appraisals can cause bodily and affective responses associated with stress (e.g. McEwen, 2007; McEwen & Sapolsky, 1995). In other words, making these appraisals can cause stress responses (but see Moors, 2013; Parkinson, 1997). Once appraisals and stress responses have been produced, the perception of stress results.

We explore a related but different perspective here, drawing on categorization research in cognitive science (e.g., Barsalou, 2012; Barsalou & Hale, 1993; Murphy, 2002; Pothos & Wills, 2011). From this perspective, perceived stress is the result of categorizing the current situation as the kind of situation that has previously been experienced as stressful. Specifically, when the current situation contains features similar to the features of previous situations experienced as stressful, it is categorized as stressful, too. When it is not similar to the features of these situations, it is categorized in some other way (e.g., a boring event, a fulfilling experience). Once the current situation is categorized as a stressful experience, it becomes perceived as stressful. In the Discussion, we address the relations between stress categorization and stress perception further.

Over time, as experiences of stressful situations accumulate and become integrated in an individual's memory, a category of stressful experiences develops. The representation of this category could be a prototype, a collection of exemplars, a connectionist network, a Bayesian model, etc., or some combination of these representational structures. Although this is an important and interesting issue, the specific kinds of structures representing the category of stressful experiences do not bear on the work reported here. Instead, as described next, we simply focus on *features* of stressful situations that could be incorporated into *any* of these representational approaches.

Once an individual has established a category of stressful situations in memory, it is used to categorize new situations as stressful. Because individuals can differ significantly in the life situations they encounter, together with the resources available for coping with these situations, they are likely to differ in the stressful situations that they experience and establish in memory. As a consequence, the content and organization of stress categories varies between individuals, in turn causing variability in how they categorize future situations as stressful. Situations that one individual categorizes as stressful might not be stressful for another individual, and vice versa. From this perspective, stress perception results from the same basic cognitive mechanisms that underlie all other kinds of categorization (cf. Sanislow et al., 2010).

1.3. Adopting a situated perspective on stress categorization

From the categorization perspective, the features associated with a category play central roles in its processing (e.g. Barsalou, 2012; Murphy, 2002). The category of birds, for example, is associated with features such as feathers, wings, flies, chirps, and nests (McRae, Cree, Seidenberg, & McNorgan, 2005; also see Wu & Barsalou, 2009; Santos, Chaigneau, Simmons, & Barsalou, 2011). During categorization, these features can be used to identify perceived entities as category members. If an entity is perceived as having feathers, wings, and flying, it might be categorized as a bird; alternatively, if it has wheels, an engine, and a trunk, it might be categorized as a car.

What features are associated with that category of stressful experiences? To the extent that we can establish these features, we can better understand how the perception of stress originates. When people perceive situations as having these features, they are likely to categorize and perceive these situations as stressful.

Certainly, the primary and secondary appraisals associated with stress offer likely features used to categorize stressful situations (e.g., Lazaraus & Folkman, 1984; Lazarus, 1993). When situations are associated with a threat (primary appraisal) and poor ability to cope with the threat (secondary appraisal), they are likely to be categorized as stressful. Because threat and poor coping ability are often associated with experiencing stress, these features become associated with the category of stressful situations. Indeed, from the perspective of appraisal theories, these are the defining features of stressful experiences.

Importantly, however, a major theme of categorization research is that the features associated with a category are not merely its defining features, but also typical features and contextual features (e.g. Hampton, 1979; Medin & Schaffer, 1978; Rosch & Mervis, 1975; Smith & Medin, 1981). Important features of birds, for example, do not simply include defining features, such as feathers, but also typical features such as small and sings, and contextual features such as live in nests (cf. Lebois, Wilson-Mendenhall, & Barsalou, 2015).

More recently, much research indicates that category knowledge is situated (e.g., Barsalou, 2003, 2008, 2009, 2016; Yeh & Barsalou, 2006). When people represent the category of hammers, for example, they don't simply represent defining features (e.g., handle, head), they also represent features of relevant background situations (e.g., woodshops, nails, boards, hammering actions). In experiments that ask people to produce the features associated with concepts, large numbers of situational features are typically produced (e.g. Barsalou & Wiemer-Hastings, 2005; McRae et al., 2005; Santos et al., 2011; Wu & Barsalou, 2009). In particular, people produce features for settings, other agents and objects present, actions and events likely to occur, and a wide variety of internal states experienced, including goals, evaluations, emotions, and interoceptions. In general, considerable evidence has existed for some time that the features associated with a category, not only represent the features of category members, but also the situations in which category members are experienced.

If we generalize this basic finding to the category of stressful experiences, it follows that situational features become associated with the category of stressful experiences, just as for any other category. As a consequence, situational features contribute to stress categorization. To the extent that a situation shares features with situations previously experienced as stressful, it too is categorized as stressful.

1.4. Establishing the features associated with stressful situations

To our knowledge, no previous work has attempted to comprehensively establish the features of situations that predict perceived stress. Thus, the study reported here attempted to do so. We adopted two heuristics for identifying features that people might typically associate with

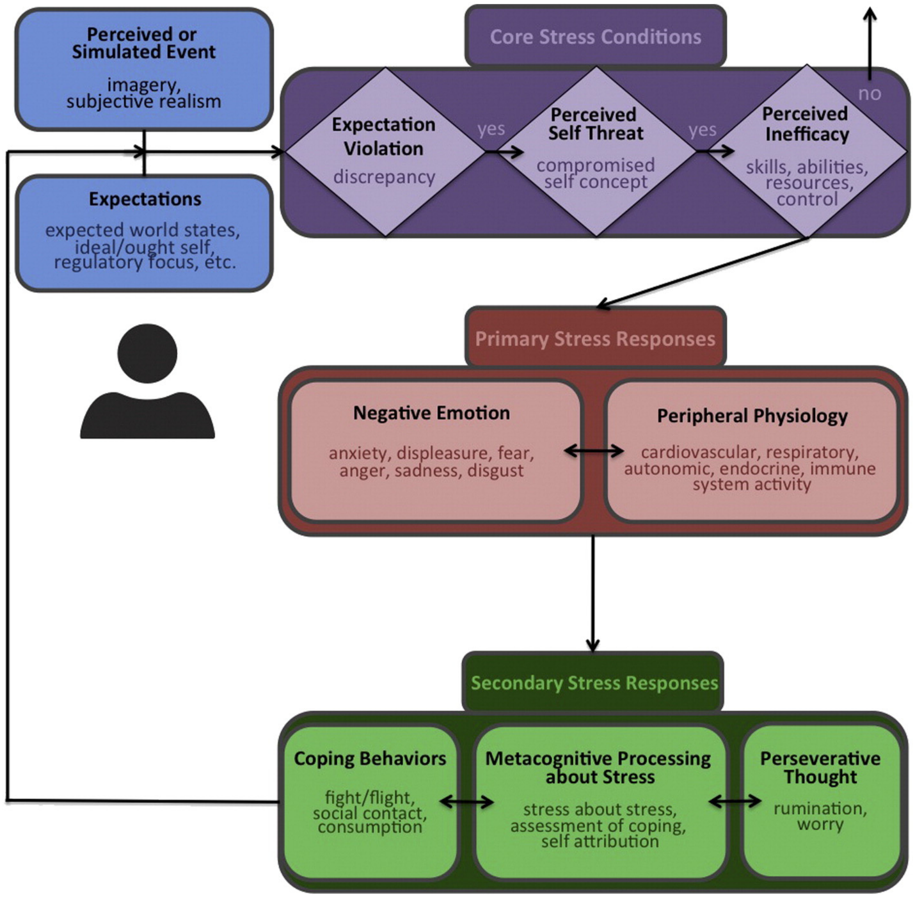

Fig. 1. Features predicted to be associated with stressful situations, shown with the global structure that integrates them.

stressful situations. First, we examined the diverse literatures on stress, searching for well-documented features of stressful experiences (e.g., Lazarus, 1993). To the extent that a feature has been frequently associated with stressful experiences in the literature, it is likely to be a typical feature (e.g., features associated with primary and secondary appraisals). Second, we examined the stressful situations catalogued in life events inventories and extracted features that appeared typical of these situations (Adrian & Hammen, 1993; Almeida, 2005; Almeida, Wethington, & Kessler, 2002; Brown & Harris, 1978; Slavich & Epel, 2010). From assessing these situations, we attempted to establish other features besides appraisals that occur regularly during stressful experiences.

Fig. 1 summarizes the features that we identified using these two heuristics, integrated into a global conceptual structure likely to represent stressful situations. As Fig. 1 illustrates, we propose that a situation is perceived as stressful when three core conditions are satisfied: (1) an expectation violation exists, namely, a discrepancy between an expectation and an actual or simulated situation (e.g., Higgins, 1989),[1] (2) a threat to self is experienced (e.g., Lazarus, 1993), and (3) a perceived lack of efficacy exists for acting to remove the expectation violation and the associated threat, which could reflect control, power, self-efficacy, available coping strategies, etc. (e.g. Bandura, 1997; Lazarus, 1993; Roseman, 2011; Scherer, 2001). We assume that these three features of a situation are each necessary for perceiving an experience as stressful, and that, together, they are typically sufficient for producing an experience of psychological stress. Indeed, we would argue that they are defining features of stressful situations.

As Fig. 1 further illustrates, once the three basic conditions for perceiving a situation as stressful occur, they produce other important features of stressful situations, in particular, the primary stress responses of negative emotion and peripheral physiological states. Appraisal theories similarly assume that initial appraisals can produce other aspects of affective episodes, including motivational, somatic, motor, and affective components (e.g., Moors et al., 2013). The realization that one cannot act to remove a threat increases negative emotion (Lazarus, 1999), and produces activity in peripheral physiological systems (Kemeny, 2003; McEwen & Sapolsky, 1995). From the situated perspective, emotion and peripheral physiology are central aspects of situated activity that become associated with the category of stressful experiences (cf. Barrett, 2006, 2013; Barsalou, 2016; Lebois, Wilson-Mendenhall, Simmons, Barrett, & Barsalou, 2016; Wilson-Mendenhall, Barrett, Simmons, & Barsalou, 2011). During a stressful experience, negative emotion could take the form of anxiety, displeasure, fear, anger, sadness, or a combination thereof, depending on the specifics of the situation. Associated peripheral physiology occurs in the cardiovascular, respiratory, autonomic, endocrine, and immune systems.

Finally, as Fig. 1 illustrates, secondary stress responses are likely to occur in stressful situations while attempting to manage the core causes of stress and the immediate affective and bodily responses that follow. Because these secondary responses play central roles in experiencing and coping with stress, they, too, constitute important situated features

[1] An expectation violation (discrepancy) can potentially take numerous forms, including: (1) an unexpected or "surprise" event (e.g., a pop quiz in a course), (2) an unexpected outcome for an expected event (e.g., unexpectedly receiving a poor grade on an expected quiz), (3) an *expected* violation of a desirable outcome that one would prefer to not see violated (e.g., receiving a poor grade as expected on an exam that violates the aspiration to receive good grades), and (4) the violation of a social norm (e.g., a friend wearing pajamas and a bathrobe in class).

of stressful situations. In particular, rumination and worry about the stressful situation are likely to persist, as long as the self-threat, action inefficacy, and associated physiological arousal remain (e.g. Brosschot, Gerin, & Thayer, 2006; Nolen-Hoeksema, Wisco, & Lyubomirsky, 2008; Watkins, 2008). We assume that this type of perseverative thought typically results from experiencing the stressful situation, together with the inability to cope effectively. To the extent that coping behaviors occur, they too may become established as situational features, along with their consequences (e.g., Lazarus, 1993, 1999). Finally, a wide variety of metacognitions about one's stress responses, regulatory activities, and coping abilities are also likely to occur as situational features (e.g. Beer & Moneta, 2010; Dragan, Dragan, Kononowicz, & Wells, 2012; Wells, 2008).

In summary, Fig. 1 integrates features of stressful situations abstracted from the stress literature that are compatible with viewing these situations from the situated perspective. Statistically speaking, we assume that an individual's category of stressful experiences is likely to include these features. Certainly, variations on this feature structure occur, with features varying across situations and individuals. Nevertheless, we propose that Fig. 1 includes features that are typically present in situations that people find stressful.

1.5. Overview and predictions

If Fig. 1 represents the situated structure of the experiences that an individual has previously categorized as stressful, then this structure should determine people's categorizations of whether situations are stressful or not. To the extent that a situation matches this feature structure, the situation should be categorized as stressful; to the extent that the situation does not match, it should categorized as not stressful.

To test this general hypothesis, we presented participants with 572 brief descriptions of stressful and non-stressful situations that could occur in their daily lives (e.g., “Your professor just accused you of cheating on an exam”). We then asked participants to judge the perceived stress of each situation, without specifying what we meant as stress, leaving it open-ended. To assess whether the specific features in Fig. 1 are associated with stressful situations, we also asked participants to evaluate how much each situation they evaluated contained an expectation violation, self-threat, action inefficacy, negative affect, arousal, and perseverative thought.

If the situated features of stress in Fig. 1 provide a good account of the experiences that an individual has categorized as stressful, then memories of stressful situations should contain the features embedded in this structure. Moreover, prototypical memories of stress should tend to have high values for these features (e.g., high threat, high inefficacy, high arousal), whereas atypical memories should tend to have low values (e.g., low threat, low inefficacy, low arousal: cf. Barsalou, 1985; Wilson-Mendenhall, Barrett, & Barsalou, 2014). As a result, participants should judge situations with high values as stressful, and situations with low values as non-stressful. Furthermore, we predicted that these features would be highly inter-correlated, together constituting a unitary construct of stress. When people experience a situation as stressful, all these features should tend to be present as a group; analogously, when a situation is not stressful, these features should tend to be absent as a group.

Four additional kinds of features noted in various literatures could also potentially influence the perceived stress of a situation: familiarity, imagery, realism, and certainty. Notably, these additional features generally constitute cognitive aspects of how representations of stressful situations are processed, rather than being features of stressful situations themselves. First, familiarity and past experience with a stressor could be correlated either positively or negatively with its perceived stress (Bandura, 1997). The more often people fail to effectively manage a stressor, the more stressful it may seem. Alternatively, increased familiarity with a stressor may enhance one's belief that it can be handled effectively, making it seem less stressful. Second, imagery could be related to perceived stress (D'Argembeau & Van der Linden, 2006). As visual imagery, auditory imagery, motor imagery, and bodily experience increase while imagining a stressor, the stress experienced could increase as well.[2] Third, the plausibility and subjective realism of an imagined stressor could be related to its perceived stress (Lebois et al., 2015b; Papies, Barsalou, & Custers, 2012; Papies, Pronk, Keesman, & Barsalou, 2015). Specifically, as an imagined stressor becomes increasingly realistic, perceptions of threat and action inefficacy may seem increasingly compelling. Fourth, uncertainty could potentially be associated with perceived stress. As people become more uncertain about the causes, consequences, or ability to cope with a stressful situation, perceived stress may increase. Relative to the features in Fig. 1, we hypothesized that these other kinds of features would be relatively peripheral, playing a more minor role in predicting perceived stress, given that they appear less central to stressful situations.

Finally, we predicted that individual differences in judgments of perceived stress would occur. Because people differ in their experiences with stressors, they should establish different features in their respective categories of stressful situations (or perhaps different emphases on these features). As a consequence, these different categories should produce individual differences in perceived stress. Overall levels of perceived stress might differ across individuals, as might the range of stressfulness they perceive.

2. Methods

2.1. Participants

Because this exploratory study is the first to provide a comprehensive assessment of the features that predict perceived stress, we assessed a non-clinical sample in the laboratory. Furthermore, we focused on the detailed processing of stress in a relatively small sample, an approach similar to detailed psychophysical analysis of a few individuals in a vision experiment. Over 37 to 51 days, each participant provided 20 ratings for each of 572 situations, for a total of 11,440 ratings per participant. As described in the Discussion, once we understand how a non-clinical sample categorizes stress, we can extend our methods and model to clinical populations under a variety of real-world conditions. Thus, our participants were 12 Emory University students (6 females), ranging in age from 23 to 38 ($M = 27.5$), predominately Caucasian (66.7%), with 25% Asian and 8.3% Hispanic. All were native English speakers with normal or corrected vision, and received $100 compensation.

2.2. Design

Each participant performed 20 ratings on Likert scales for each of 572 situations in a repeated-measures design with no grouping variables. Participants received each situation a total of 6 times, once in each of 6 rating groups (see the Procedure section for details). For a given rating group, each participant received the 572 situations in a different random order. However, the order of the six rating groups, and also the sequence of ratings within each group, followed a set order to prevent certain ratings from being affected by earlier ratings. Experience and Familiarity ratings, for example, were completed first to ensure that viewing the situations previously for other ratings did not produce carry-over effects on these memory judgments. Other ratings were grouped and positioned sequentially for similar reasons. Additionally, the fixed order of ratings within each group made the task easier for

[2] We include bodily experience as a form of imagery because previous memories of a stressful situation could be associated with imagery of bodily states experienced at the time. When, however, this situation is later imagined, the associated bodily imagery is experienced as the *current* bodily state. For this reason, we refer to it here as “bodily experience” instead of as “bodily imagery.”

Table 1
Mean responses for rating questions (standard deviations), and correlations with perceived stress.

Question	M (SD)	Pearson r
Group 1. Experience		
Experience (Exper)	0.12 (0.95)	−0.49*
Familiarity (Fam)	3.19 (2.20)	−0.43*
Vicarious familiarity (VicFam)	3.83 (1.91)	−0.09*
Group 2. Perceived stress and plausibility of experience		
Perceived stress (PrcStr)	3.07 (2.07)	–
Being there (BeTh)	4.66 (1.35)	−0.06*
Plausibility (Plaus)	3.85 (2.01)	−0.46*
Group 3. Basic conditions for stress and perseveration		
Expectation violation (ExpVio)	2.56 (1.99)	0.67*
Self threat (SlfThr)	2.76 (2.05)	0.78*
Efficacy (Effic)	5.91 (1.50)	−0.72*
Perseveration (Persev)	2.94 (2.24)	0.82*
Group 4. Imagery and bodily experience		
Visual imagery (VisIm)	4.22 (1.58)	−0.15*
Bodily experience (BodExp)	3.24 (1.96)	0.62*
Action imagery (ActIm)	3.73 (1.76)	−0.05*
Verbal imagery (VrbIm)	3.93 (1.82)	0.01
Group 5. Valence and arousal		
Positive valence (PosVal)	1.89 (1.28)	−0.46*
Negative valence (NegVal)	3.20 (2.08)	0.85*
Arousal (Arous)	3.98 (1.65)	0.63*
Group 6. Certainty		
Situation certainty (SitCer)	5.44 (1.70)	−0.46*
Coping certainty (CopCer)	5.33 (1.71)	−0.65*
Outcome certainty (OutCer)	4.96 (2.00)	−0.65*

Note. For the complete rating questions and rating scales, please see the Supplementary Materials.

participants, allowing them to settle into a response rhythm as they performed the ratings for a group in a constant order across the 572 situations. Table 1 presents the order of the six groups, together with the order of ratings within each.

2.3. Materials

We constructed one-sentence descriptions of 572 situations likely to be familiar in the participant population. Of these situations, 286 were stressful and 286 were non-stressful. To enhance the ecological validity of the stressful situations, two sampling strategies were used. First, stressful situations were drawn from Almeida et al.'s (2002) nation-wide sample of stressful life events. Second, student research assistants helped to develop a set of stressful situations relevant to an undergraduate student population. See the Supplmentary Materials (SM) for all 572 situations.

All of the stressful situations involved interpersonal tensions occurring in college life (e.g., "Your professor just accused you of cheating on an exam"). For each stressful situation, a matched non-stressful situation was constructed that included similar characters and settings, but that focused on a non-threatening interpersonal interaction (e.g., "Your professor just passed out lecture notes in preparation for the next class"). Each sentence describing a situation contained second person ("you") references to promote participant engagement. Including a broad range of stressful and non-stressful situations provided sufficient variability to establish whether the features in Fig. 1 predict perceived stress. The Linguistic Inquiry and Word Count database was used to ensure that stressful and non-stressful situations were comparable on irrelevant variables, such as sentence length and tense (Tausczik & Pennebaker, 2010).

2.4. Procedure

As Table 1 indicates, participants performed the six groups of ratings in the following order: (1) experience and familiarity, (2) perceived stress and plausibility of experience, (3) basic conditions for stress and perseveration, (4) imagery and bodily experience, (5) valence and arousal, and (6) certainty. Before beginning each group, the experimenter first read participants detailed instructions about the ratings. During these instructions, participants were shown the ratings and associated rating scales, illustrated with an example situation. Participants then received one practice situation, evaluating it on all the rating scales for the group, and discussing the rating scales with the experimenter, if necessary. See the SM for the specific rating scales used.

Participants received additional instructions relevant to particular ratings. For the experience and familiarity group, participants could indicate that they had experienced a particular situation even if their experience was not identical to the situation described. For the imagery and bodily experience group, participants were told that bodily experience is anything going on in one's body (e.g., sensing your heart beat, your face getting red), whereas verbal imagery is hearing people talking in the situation. For the valence and arousal group, participants were told: (1) valence is the degree of pleasantness or unpleasantness in a situation, (2) arousal is the degree to which one feels awake and reactive during the situation, (3) a distinct difference exists between them (e.g., high arousal can be both pleasant or unpleasant; Wilson-Mendenhall, Barrett, & Barsalou, 2013).

Once participants understood the instructions for a particular rating group, they received the 572 situations in random order and evaluated them on the rating scales for that particular group in a fixed order. On each trial, a sentence describing a situation appeared at the top of the computer screen, with the first rating question and scale directly below it. Participants had as much time as needed to read the sentence and make a rating. Once the participant entered a rating, the next question appeared immediately, while the same situation remained at the top of the screen. This process continued until the participant had made all the ratings in the current group for the situation. At this point, participants had two options: (1) If they felt they had made an error, they could press the SPACE bar, go back, and change their responses, or (2) if they were ready to perform the same ratings on the next situation, they pressed the ENTER key and moved on. After judging situations for 15–20 min, participants had the option to continue with another 15–20 min batch of ratings, to take a break, or to stop for the day.

Participants took a total of 10 to 19 sessions to complete the experiment, with the total period ranging from 37 to 51 days. The time spent on a given day ranged from 30 min to 120 min. Participants always completed the final 15–20 min batch of ratings before stopping for the day. This procedure continued for every group of ratings until each participant had completed all 20 ratings for each of the 572 scenarios (11,440 ratings total). Table 1 presents the mean and standard deviation for each of the 20 ratings.

2.5. Statistical method

First we assessed whether the hypothesized perceived stress-related features in Fig. 1 could be reduced into a smaller number of latent variables. Treating situations as the unit of analysis, we used exploratory factor analysis to establish the number of distinct dimensions underlying the features in Fig. 1. A common factor analysis was run on the matrix of ratings for the 19 relevant indicator variables across all participants, excluding perceived stress (which would later serve as the dependent variable in regression models).[3] Unweighted least squares factor extraction indicated that 4 factors underlay the 19 predictors (by visual inspection of a scree plot for the correlation matrix eigenvalues). The four factors were transformed by an oblique (correlated factors) promax rotation with Kaiser normalization to make them

[3] We opted not to run more complex exploratory multilevel factor models that treated each participant's covariance matrix of ratings separately, generating a solution for each individual. Such an approach would have avoided potential aggregation bias but at the expense of a far more complicated sets of results, further creating difficult issues related to generating scores on rating dimensions across participants. Because our principal research questions were not about between-person heterogeneity in factor structure, we chose to assume invariance of factor structures across participants so as to focus on the question of how equivalently-defined dimensions of situation features predicted perceived stress.

more interpretable.[4] Each variable was assigned to the factor on which it loaded most heavily. We then generated factor scores for the four factors using the standardized regression method, and used these derived variables as predictors of the perceived stress for each situation.

Specifically, we used multilevel regression models (e.g., Snijders & Bosker, 2012) to assess how well the four derived factors predicted variation in perceived stress. These models estimated the proportion of variance that reflected between-situation differences in perceived stress, while also evaluating fixed and random effects associated with the four factors from the factor analysis. In these models, situation was treated as the Level 1 unit of analysis, and the fixed effects estimated the average influence of each derived factor on perceived stress, aggregated across situations. Participant served as the Level 2 unit of analysis in models that used maximum likelihood estimation in the SPSS Mixed Procedure (version 20; see Heck, Thomas, & Tabata, 2014). The covariance structure for random effects was specified as orthogonal variance components. Significance tests on random effects for regression slopes and intercepts were evaluated by likelihood-ratio χ^2 tests and also by the normal-deviate Wald test (ratio of the variance estimate to its estimated standard error).

We began with two preliminary models not of substantive interest, but necessary for later computing proportion of variance estimates in the critical models. The first model (Model 0) included a fixed intercept (Model 0; RES-I) and estimated the aggregate variance of the residuals (i.e., the variance of the perceived stress ratings). Model 0 was used later to calculate a residual variance for any model attempting to explain variance in perceived stress (i.e., the dependent variable, RES-M), generating a pseudo-R^2 statistic: (RES-I – RES-M)/RES-I (Snijders & Bosker, 2012). A second preliminary model (Model 00) estimated both a fixed intercept together with random intercepts for participants, disaggregating consistent participant variance from situation and situation X participant variance. The variance estimates from Models 0 and 00 were used later to assess how much variance the individual intercepts for participants explained in perceived stress.

Five nested models were used to evaluate predictors of perceived stress, and to generate the likelihood-ratio tests for random effects (with the difference in −2LL fitting functions for the maximum likelihood estimation being asymptotically distributed as a χ^2 variate, with *df* equal to the number of parameters added to the model). First, Model 1 added the fixed effect of Situations to Model 00, assessing the ability of the 572 situations to predict perceived stress. Using derived covariates for the four factors from the factor analysis, Model 2 estimated the fixed effects of these four covariates on perceived stress (without the fixed effect of Situations or any random effects). This model assumed that each covariate contributed to perceived stress in the same way across participants. Model 3 added the random intercepts for participants back into Model 2, offering a first assessment of whether individual differences occurred in predicting perceived stress. Model 4 additionally included the random effect of the individual slopes for the most important predictive factor in Model 2, further assessing individual differences. Model 5 added Situations as a fixed effect back into Model 4, assessing the relationship between Situations and the derived factor covariates, while continuing to assess individual differences for intercepts and slopes.

3. Results

3.1. Correlation analysis

We hypothesized that the features of the situated structure in Fig. 1— expectation violation, self-threat, action inefficacy, negative emotion, peripheral physiology, bodily states, perseveration, and coping certainty—would be related to ratings of perceived stress. As the correlations in Table 1 illustrate, all of these features correlated significantly with perceived stress (see SM Table 1 for the full correlation matrix).

Self-threat, negative valence, and perseveration were most strongly associated with perceived stress and were also highly inter-correlated with each other. As situations appeared more threatening, they became more negative and stressful, and were more likely to be associated with perseveration (Dickerson, Gruenewald, & Kemeny, 2004; Watkins, 2008).

Greater lack of efficacy in managing a situation and greater expectation violation were both associated with greater perceived stress. Consistent with existing literature, when participants believed that they lacked the ability to effectively manage an interaction described in a situation, they reported greater overall stressfulness (e.g. Bandura, 1997; Cooper & Dewe, 2004; Lazarus, 1993). The role of expectation violation in stress may reflect the disruption that results from challenges to one's plans, goals, values, and aspirations for the future (e.g., Brown & Harris, 1989). Additionally, when a situation violated expectations, participants reported less experience with the situation and less belief in their capacity to cope with it effectively (see SM Table 1). In contrast, the more certainty participants experienced, the less stress they perceived. Perhaps greater certainty indicates, more generally, believing that a coping solution can be achieved in the imagined situation.

Higher arousal and bodily experience were associated with more perceived stress. Higher arousal is a well-documented response to stressful situations, often related to activation of the hypothalamic-pituitary-adrenal axis (e.g., Ganzel, Morris, & Wethington, 2010). Among the imagery and bodily experience predictors in our dataset, bodily experience was much more strongly correlated with perceived stress than were the related imagery variables (i.e., visual, action, verbal). Bodily experience may be especially important because it is frequently associated with stressful experiences, whereas other types of imagery may vary more widely, often not being salient.

Greater experience and familiarity with the situation were both associated with less perceived stress, perhaps because participants had dealt successfully with similar situations previously. Indeed, experience and familiarity were positively correlated with certainty about one's ability to cope with the situation (SM Table 1). Additionally, as situations became more plausible, they also became less stressful, perhaps because plausibility was positively correlated with experience, coping, and efficacy (SM Table 1).

Greater positive valence was related to lower perceived stress. Interestingly, the negative correlation between positive valence and perceived stress was much smaller than the positive correlation between negative valence and perceived stress. This pattern most likely reflects the fact that our stressful situations were written to be unpleasant and stressful, and did not include positive situations that are also stressful (e.g., planning a wedding). Additionally, as much research shows, positive and negative valence are often not perfect inverses of one another, given that a situation can have both positive and negative aspects (e.g., Wilson-Mendenhall et al., 2013). Although we designed our stressful situations to have negative valence, some of them may have inadvertently had positive features as well. Another possibility is that range restriction drove the difference in predictability for positive and negative affect (*SD*s of 1.28 and 2.08, respectively). Still another possibility is that positive emotion is not generally predictive of stress, whereas negative emotion is.

Not all the features assessed were highly, or even moderately, correlated with perceived stress. Vicarious familiarity, being there, visual imagery, and action imagery were either weakly or negatively correlated with perceived stress, and verbal imagery was unrelated. Vicarious familiarity and perceived stress were related in the expected direction: More vicarious familiarity was associated with less perceived stress. This correlation, however, was very small, implying that personal experience and familiarity are more important than vicarious familiarity. The

[4] We allowed for oblique factors because it seemed possible that some of the dimensions would be correlated, and we wished to evaluate this empirically. Forcing orthogonal factors on data actually generated by correlated factors would have absorbed factor correlations into the columns of the factor pattern matrix, which could have resulted in uninterpretable intermediate loadings.

small negative and non-significant correlations for being there, and also for visual imagery, action imagery, and verbal imagery most likely reflect the brevity of the stimuli. Because each description of a situation only contained as much detail as would fit in a single sentence, these descriptions may not have contained enough detail to generate the imagery necessary for relations between these variables and perceived stress to emerge. Perhaps longer more detailed descriptions, or actual life events, would produce significant relations. A median split on stressfulness ratings indicated that the correlation between being there and the most stressful 50% of scenarios was in the expected positive direction ($r = 0.22$, $p < 0.001$). For these situations, the more participants experienced "being there," the more stressful they found them. This suggests that "being there" may only play a role in experiencing stress when strong affect is present (cf. Lebois et al., 2015b; Papies et al., 2015).

With the exception of some imagery variables and vicarious familiarity, all of the hypothesized variables—expectation violation, self-threat, action inefficacy, emotion, perseveration, bodily states, and coping certainty—were related to stressful cognition in the expected directions. This pattern is consistent with our account of stress categorization: All of the central features for stressful situations in Fig. 1 were associated with perceived stress.

3.2. Data reduction through factor analysis

As described in the Methods section, we conducted an exploratory factor analysis on the full matrix of rated features for the purpose of generating a reduced set of variables to predict perceived stress. The four-factor solution explained almost 60% of the variance in the rated features. Table 2 reports the factor loadings and communalities. Some of the communalities were relatively low (e.g., for verbal imagery, positive valence). Our evaluation of the eigenvalues and some higher-dimensional solutions, however, suggested that adding additional factors would not improve the solution, resulting in so-called 'singleton' or feature-specific factors, with only one feature loading on a factor. Although we could have deleted features with low communalities from the solution, all factors were determined empirically by at least moderate loadings for some features (furthermore, low loadings in factor analysis are not atypical). After considering our choices, we opted to include all features in estimating the factor scores for later regressions, allowing whatever variance was available for each feature to contribute to estimating these scores.

Table 2
Factor loadings and communalities.

Rating	Factors				
	Core stress	Experience	Certainty	Imagery	Communality
Self threat	0.97				0.83
Perseveration	0.96				0.88
Negative valence	0.85				0.83
Efficacy	−0.81				0.67
Bodily experience	0.76			0.27	0.61
Expectation violation	0.71				0.66
Positive valence	−0.58				0.27
Arousal	0.53				0.44
Familiarity		0.99			0.93
Experience	−0.20	0.76			0.69
Plausibility	−0.27	0.57			0.59
Vicarious familiarity	0.22	0.52			0.30
Being there		0.43		0.31	0.33
Coping certainty			0.81		0.83
Outcome certainty			0.77		0.82
Situation certainty			0.69		0.55
Action imagery				0.79	0.58
Visual imagery				0.51	0.30
Verbal imagery				0.37	0.15

Note. Values are the pattern matrix coefficients, representing the variance in a measured variable explained by a factor's *unique* contributions. Values < 0.2 are suppressed. Communality is the variance in a given variable explained by all the factors (reliability). These are the extraction communalities, not the initial values.

The four factors were well-defined and easily interpreted. Factor 1, labeled Core Stress Features, was most important, accounting for 40% of the item variance. Key features of stressful situations in Fig. 1—expectation violation, self-threat, action inefficacy, negative valence, arousal, and perseveration—all loaded on this factor (along with closely related features of bodily experience and positive valence). Factor 2 (Experience) appeared to capture participants' prior and present experience with the situations, including judgments of familiarity, experience, plausibility, vicarious familiarity, and being there, accounting for 11% of the total item variance. Factor 3 (Certainty) was defined by loadings of the three certainty judgments for situation, coping, and outcome, accounting for 5% of the total item variance. Factor 4 (Imagery) was defined by loadings for rated imagery of action, vision, and verbalization, accounting for 3% of the total item variance[5].

A potential methodological concern was that we had participants rate groups of features together (to minimize carry-over effects across ratings), which could have caused features in these groups to be correlated. The factor analysis indicates that this possible source of method variance was not a significant problem for three reasons. First, features rated in the same group often loaded on different factors. In Group 4, for example, bodily experience primarily loaded on Core Stress Features, whereas the other imagery factors loaded on Imagery. Second, features in different groups sometimes loaded on the same factor. Features from Groups 3, 4, and 5 loaded on Core Stress Features. Features from Groups 1 and 2 loaded on Experience. Features from Groups 2 and 4 loaded on Imagery. Third, the overall loadings that resulted generally followed our predictions. Whereas the core features of stress loaded together, the more peripheral features for experience, certainty, and imagery loaded on separate factors.

3.3. Predicting perceived stress with multilevel regression models

Our primary goal was to establish the situated features that most strongly predict the perceived stress of situations. If the features of stressful situations in Fig. 1 provide a good account of stress categorization, then these situated features should be strong predictors of a situation's perceived stress. Thus, we hypothesized that a situation's value on the Core Stress Features factor should strongly predict its perceived stress, with the other three factors for Experience, Certainty, and Imagery being less important.

3.3.1. Preliminary models

Table 3 first reports results from two preliminary multilevel models that evaluated variation in the stressfulness ratings for the 12 participant × 572 situation matrix. Model 0 was a null-model with a fixed intercept across participants used to estimate overall variance in perceived stress. Model 00 was a random-intercept model used to establish consistent individual differences in mean stressfulness ratings. In this model, the 12 participants differed in the average levels of stressfulness that they perceived in the events (Estimated Variance $= 0.27$, $SE = 0.11$, Wald $Z = 2.39$, $p = 0.017$). Notably, however, these stable individual differences only accounted for 6% of the total variance in perceived stress, indicating that individual differences in intercepts did not explain much of its variance.

[5] Two additional factor analyses were performed on the stressful events alone and on the non-stressful events alone. The same four factors emerged first in each analysis, explaining 55% and 49% of the explainable variance, respectively, with the ordering of the four factors differing slightly in the two solutions (stressful events: core stress features, experience, certainty, imagery; non-stressful events: experience, certainty, imagery, core stress features). Thus, the factor solutions that held across stressful and non-stressful events together generally occurred within stressful events and non-stressful events alone.

Table 3
Percent of variance in perceived stress explained with multilevel modeling including fixed and random effects estimates.

				Measures of model fit	
Model	Coeff	SE	% Variance explained	−2LL	Residual variance
Model 0. Fixed intercept only			–	29,493.58	4.30
Intercept	3.07*	(0.15)			
Model 00. Fixed intercept & random intercepts			6.3	29,091.11	4.03
Intercept	3.07*	(0.15)			
Model 1. Fixed intercept, random intercepts, & situations			76.0	17,729.70	0.77
Intercept	1.42*	(0.30)			
Situations	⌘*				
Model 2. Fixed intercept & covariates			75.1	19,936.98	1.07
Intercept	3.07*	(0.01)			
F1 core stress features	1.76*	(0.02)			
F2 experience	−0.01	(0.02)			
F3 certainty	−0.10*	(0.02)			
F4 imagery	−0.09*	(0.02)			
Model 3. Fixed intercept, covariates, & random intercepts			81.4	18,030.63	0.80
Intercept	3.07*	(0.15)			
F1 core stress features	1.82*	(0.02)			
F2 experience	−0.05*	(0.01)			
F3 certainty	0.00	(0.02)			
F4 imagery	0.04*	(0.02)			
Model 4. Fixed intercept, covariates, random intercepts, & random F1 slopes			84.0	17,093.68	0.69
Intercept	3.09*	(0.15)			
F1 core stress features	1.86*	(0.11)			
F2 experience	−0.01	(0.01)			
F3 certainty	−0.01	(0.02)			
F4 imagery	0.03	(0.02)			
Model 5. Fixed intercept, covariates, random intercepts, random F1 slopes, & situations			88.0	15,238.83	0.53
Intercept	2.43*	(0.26)			
F1 core stress features	1.16*	(0.10)			
F2 experience	0.03	(0.01)			
F3 certainty	−0.04	(0.02)			
F4 imagery	0.08*	(0.02)			
Situations	⌘*				

Note. "Covariates" refers to the four factors from Table 2. F1 is Factor 1, etc. Coeff is coefficient. SE is standard error. ⌘ Indicates that the situations factor was significant, and that, due to space, the 571 freely estimated values for the 572 situations are not reported. Please see Table 4 for a sampling of these values and for additional information.
* $p < 0.05$.

3.3.2. Modeling the effect of situations

The first substantive model, Model 1, again included participant intercepts as a random effect but also included Situations as a fixed effect with 572 levels, one for each situation. Although we could have estimated a random variance component for Situations, we opted to estimate fixed effects so that we could examine the specific deviation scores of different situations, rather than absorb all these effects into an aggregate random variance component. As reported in Table 3, Model 1 explained 76% of the variance in the perceived stress ratings. The 572 situations differed considerably (on average) in perceived stress, $F(571, 6852) = 50.99$, $p < 0.001$, explaining about 70% of its total variance (the increment from Model 00). Finally, the model residuals accounted for the remaining 18% of the total variance, pooling Situations X Participants interaction variance and random measurement error variance (the Situations X Participants interaction variance cannot be separated from measurement error and hence is not uniquely estimable).

Table 4 provides a sense of how much the situations varied in perceived stress, presenting situations from the low end, middle, and high end of the perceived stress distribution (together with their regression coefficients and standard errors from Model 1). As will be seen next, the factors for Core Stress Features and Imagery were most important for explaining variance in perceived stress. For this reason, Table 4 also presents the average values for the features that loaded on these two factors, to further provide a sense of how the situations varied.

3.3.3. Multilevel models with covariates

As we just saw, situations constituted an important source of variance in explaining perceived stress. Situations varied substantially in perceived stress, with this variation being highly consistent across participants. This outcome justified evaluating whether covariates on the four derived factors in Table 2 explain how situations vary in perceived stress. If our original predictions are correct, then scores on the Core Stress Features factor should explain much of this variance. As we proceed through the final four models, we will assess this we issue.

In each of the four models to follow, perceived stress ratings made by the 12 participants for the 572 situations were regressed onto covariates for the 4 factors from the factor analysis in Table 2 (Core Stress Features, Experience, Certainty, Imagery). Each covariate was the estimated value of the respective factor for the specific situation for each participant. Because all factor scores were standardized by the factor score estimation method, they were effectively scaled in the same units of measurement. To assess how well the four covariates explained perceived stress, Model 2 only included these covariates, excluding random participant intercepts and Situations. Model 3 added the random effect of participant intercepts into Model 2. Model 4 further added the random effect of participant slopes for the Core Stress Features factor. Model 5 further added the fixed effect of Situations. Table 3 presents the goodness-of-fit statistics for each model.

For Model 2, the factors of Core Stress Features, Certainty, and Imagery significantly predicted perceived stress, whereas Experience did not. As Table 3 shows, Core Stress Features had a much higher fixed effect on perceived stress than did Certainty and Imagery, consistent with our hypothesis. Because the Certainty and Imagery coefficients were very small, they may not represent reliable relationships with perceived stress (as assessed in subsequent analyses). Overall, the pseudo-R^2 statistic indicated that the four covariates explained 75% of the variance in perceived stress.

In Model 3, all four fixed effects were again included as in Model 2, along with the random effect of participant intercepts for perceived stress. Again, this random effect can be conceptualized as participants varying in their average levels of perceived stress across the 572

Table 4
For Model 1 in Table 3, the situations that had the five lowest, the five most average, and the five highest values of perceived stress. For each situation, its regression coefficient in Model 1 and the standard error of the coefficient are shown, followed by its average value for perceived stress and its average values for the features loading on the Core Stress Features factor (self-threat, perseveration, negative valence, efficacy, bodily experience, expectation violation, positive valence, arousal) and on the Imagery factor (action imagery, visual imagery, verbal imagery).

				Core stress features								Imagery		
Scenario	Coeff	SE	PrcStr	SlfThr	Persev	NegVal	Effic	BodExp	ExpVio	PosVal	Arous	ActIm	VisIm	VrbIm
Lowest values of perceived stress														
You watch a mother and child walk past you as you wait for the bus.	−0.42	0.36	1.00	1.00	1.50	1.17	7.00	1.92	1.00	2.33	2.67	2.08	6.00	2.33
Your mother buys you a magazine for the trip, and you pack it in your bag.	−0.42	0.36	1.00	1.00	1.00	1.25	6.92	1.42	1.08	3.50	3.00	5.25	5.25	2.50
Your friend asks a mutual friend if they can borrow their pen for a second.	−0.42	0.36	1.00	1.50	1.00	1.50	7.00	1.25	1.00	1.50	2.08	2.25	4.08	4.00
You catch another driver's eye as you turn left at a green light on the way home.	−0.42	0.36	1.00	1.50	1.00	1.17	7.00	2.25	1.00	2.25	2.67	6.08	6.17	2.58
Your roommate gives you the cleaning supplies they bought to put under the sink in the kitchen.	−0.42	0.36	1.00	1.50	1.00	1.25	7.00	2.00	1.08	2.00	2.50	5.17	5.25	3.25
Most average values of perceived stress														
You're in the infirmary, and the nurse insists on lights out even though you have to continue working.	1.75	0.36	3.17	3.67	3.42	4.25	5.83	3.92	4.00	1.25	4.50	4.50	4.83	5.00
The electric bill is due today, but your roommate doesn't receive their paycheck until next week.	1.75	0.36	3.17	3.00	3.50	3.58	6.25	3.33	2.42	1.17	4.00	3.42	3.00	3.33
Your roommate borrowed some of your favorite clothes, wore them to a smoky party and now they reek.	1.75	0.36	3.17	2.33	3.08	3.75	6.08	3.75	3.83	1.25	3.33	4.08	5.17	4.08
You overhear your significant other laughing with their friend about what a poor driver they think you are.	1.83	0.36	3.25	4.58	4.00	4.33	5.00	3.92	4.17	1.33	4.58	3.33	4.08	5.42
Your friends insist on going to the one movie you don't want to spend $12 on.	1.92	0.36	3.33	2.67	2.58	3.58	5.50	3.08	3.33	1.67	3.67	3.50	3.75	4.17
Highest values of perceived stress														
A stranger bursts out of your apartment, and you realize you've been robbed.	5.08	0.36	6.50	6.76	6.58	6.33	3.25	6.00	6.33	1.00	6.83	4.92	5.50	3.67
Your dad tells you that he has just been diagnosed with cancer.	5.08	0.36	6.50	5.58	7.00	6.83	3.83	6.00	1.83	1.00	6.33	2.83	4.17	5.08
You have to tell your best friend that both their parents passed away in a car accident.	5.17	0.36	6.58	5.08	6.75	6.58	3.67	5.67	2.42	1.00	5.75	3.67	3.25	4.42
Your significant other says they're breaking up with you because you hardly make time for them.	5.17	0.36	6.58	5.75	6.33	6.42	3.83	5.58	3.92	1.08	5.75	3.58	3.83	5.33
You swerve to avoid a pedestrian and get in a head-on car crash.	5.25	0.36	6.67	6.67	6.33	6.50	3.67	6.25	3.67	1.08	6.75	5.17	5.67	3.17

Note. The coefficients are relative to the arbitrary fixed-zero intercept coefficient. Coeff, regression coefficient for the situation in Model 1; SE, standard error of the regression coefficient; PrcStr, perceived stress; SlfThr, self-threat; Persev, perseveration; NegVal, negative valence; Effic, efficacy; BodExp, bodily experience; ExpVio, expectation violation; PosVal, positive valence; Arous, arousal; ActIm, action imagery; VisIm, visual imagery; VrbIm, verbal imagery.

situations, with some individuals having higher average levels than others, while controlling for the covariates. This random effect was significant, with a likelihood-ratio of $\chi2 = 1906.35$, $df = 1$, $p < 0.01$.

Including the random effect of participant intercepts in Model 3 altered the pattern of fixed effects observed in Model 1, with Experience now becoming a significant predictor, and Certainty dropping below significance. Consistent with Model 1, Core Stress Features still had the largest regression coefficient, whereas Experience and Imagery played much smaller roles. Adding the random effect of stress intercepts for participants increased the estimated R^2 from 75% to 81%.

Model 4 included all parameters from Model 3, while adding a random effect for participants' slopes on the Core Stress Features factor. This random effect can be conceptualized as allowing participants to vary in the slope that regresses perceived stress onto the Core Stress Features covariate (i.e., for some participants, this regression coefficient could be high, whereas for other participants it could be low). Adding the random effect for slopes improved fit, rejecting the null hypothesis of fixed slopes across individuals, LR $\chi^2 = 36.95$, $df = 2$, $p < 0.01$. Both Wald tests of random variance components were significant for Model 4, specifically, the random effect of participant intercepts for perceived stress (Estimated Variance = 0.29, $SE = 0.12$, Wald Z = 2.44, $p = 0.015$), and the random effect of Core Stressor Features slope (Estimated Variance = 0.13, $SE = 0.06$, Wald Z = 2.42, $p = 0.015$). Fig. 2 plots the individual differences in intercepts and slopes for the Core Stress Features factor from Model 4.

Including random effects for both the intercepts and slopes again changed the pattern of fixed effects that explained perceived stress. In Model 4, only the Core Stress Features factor explained significant

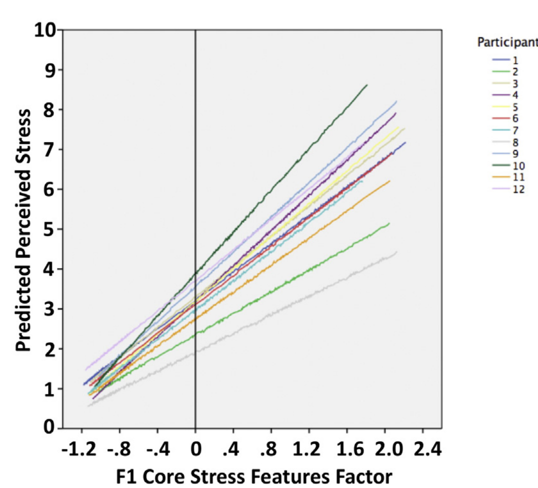

Fig. 2. In the regression functions for individuals, individual intercepts for perceived stress judgments (at X = 0), and individual slopes for these judgments as a function of F1 Core Stress Features (across the F1 values of the 572 events).

variance, whereas all other fixed effects failed to achieve statistical significance. According to Model 4, the features loading on Core Stress Features (expectation violation, perceived self-threat, action inefficacy, negative valence, positive valence, arousal, bodily experience, and perseveration) account for all the explainable variance in perceived stress ratings (i.e., when all fixed and random factors associated with this factor were included). Adding the second random effect of Core Stress Features slopes significantly increased the explained variance from 81% to 84%.

Similar to Model 1, Model 5 added Situation back into the model as a fixed-effects factor, while including the covariates and random effects in Model 4. Of interest was whether the covariates fully explained the situation variance originally observed in Model 1, or whether the 572 situations explained additional variance in stressfulness not accounted for by the covariates. As Table 3 shows, the effect of Situations in Model 5 was significant ($F(571, 6840) = 3.73$, $p < 0.001$), with Situations explaining additional variance in perceived stress beyond the covariates. We address the implications of this finding in a moment. An additional finding associated with Model 5 is that the Imagery covariate re-emerged as a significant predictor of perceived stress (see Table 3). Once variance associated with Situations was controlled, the perceived stress of a situation was again associated with increased imagery (as in Models 1 and 2). Adding Situations in Model 5 significantly increase the explained variance in perceived stress from 84% to 88%.

As we saw earlier for Model 1, Situations explained a substantial 70% of the variance in perceived stress without the covariates. Including Situations in Model 5 with the covariates, however, only increased the explained variance by 4%, relative to Model 4 when Situations wasn't included. This pattern indicates that the covariates explained most (but not all) of the Situations-related variance in perceived stress. Specifically, the covariates explained about 95% of the variance in perceived stress that Situations originally explained (i.e., 80% / 84%). Furthermore, because participants only explained 6% of the variance in Models 00, 1, and 3, it follows that variance across the situations associated with the covariates accounted for most of the explained variance in perceived stress. Because the Core Stress Features factor was by far the most important covariate, variance on the core stress features was primarily responsible for situation variance, although variance on the imagery features also played a minor role.

Finally, when controlling on Situation, the covariates uniquely explained 12% of the total variance in perceived stress (the difference in R^2 from Model 1 to Model 5), again illustrating the close relationship between variance associated with the Situations and the covariates. Additionally, the covariates accounted for some of the variance in the Situations X Participants interaction for Model 1, explaining 32% of it (i.e., the proportional reduction in residual variance from Model 1 to Model 5 (0.77 − 0.53) / 0.77).

3.3.4. Further analysis of the Core Stress Features factor

Can the features that load on the Core Stress Features factor be differentiated, with subsets of these features being differentially related to perceived stress? Perhaps only a few of these features are important, with the others being less important or not important at all. To test this hypothesis, a common factor analysis on the eight core features was performed, analogous to the factor analysis described earlier. An arousal factor emerged that differed from a factor for the remaining seven core features (expectation violation, self threat, action inefficacy, bodily experience, negative valence, positive valence, perseveration,) with these two factors being highly correlated ($r = 0.78$).

Next these two factors were used to predict perceived stress in a multilevel regression model. Importantly, both factors explained significant unique variance, even when random effects for intercepts and slopes were entered as in Model 4. Based on these analyses, we conclude that all features loading on the original Core Stress Features factor are important for explaining perceived stress, and again that they are highly related to one another, approaching a unitary construct. These analyses further confirm our prediction that a core set of features underlies how people conceptualize stressful experiences.

3.3.5. Further analysis of individual differences

Individuals varied in the overall levels of stress that they perceived (random intercepts) and in how strongly their scores on the Core Stress Features factor predicted perceived stress (random slopes). In a final analysis, we explored individual differences in the stress intercepts and slopes for the Core Stress Features factor. As the X-axis in Fig. 3 illustrates, individuals varied widely in the standard deviations of their perceived stress judgments (from about 1.4 to 2.4). In other words, participants varied in the granularity of these judgments, with some participants drawing finer distinctions than others. As the left panel of Fig. 3 illustrates further, this granularity was positively correlated with individual intercepts for stressfulness ($r = 0.76$, $p = 0.005$). As participants' overall average or baseline for perceived stress ratings increased (i.e., higher intercepts), the granularity of their stress judgments became finer. One possible interpretation is that higher levels of perceived stress lead to greater differentiation (and therefore greater variability) in perceiving degrees of stress.

Finally, as the right panel of Fig. 3 illustrates, the granularity of perceived stress ratings was also positively correlated with individual

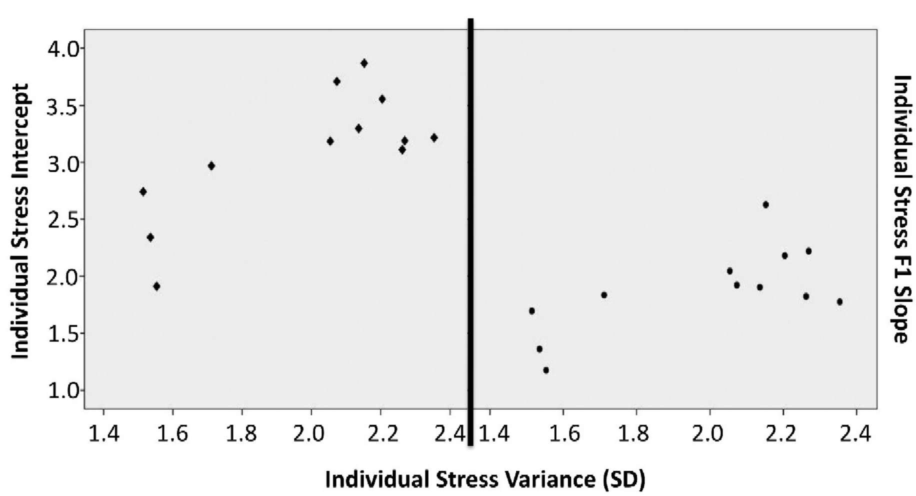

Fig. 3. Scatter plots of individual variance (SD) in perceived stress, first, with individual intercepts for perceived stress, and second, with individual slopes for perceived stress as a function of the Core Stress Features factor (F1). The scale on the Y axis is the same for both panels.

slopes for the Core Stress Features factor ($r = 0.67$, $p = 0.017$). As the Core Stress Features factor explained increasing variance in perceived stress (steeper slopes), the granularity of perceived stress ratings again became finer. A possible interpretation is that greater variability in perceived stress ratings enabled greater prediction through greater range. Alternatively, greater use of the Core Stress Features produced greater variability in judgments of perceived stress.

4. Discussion

The experiment reported here focused on establishing the features that predict perceived stress, in contrast to previous research that has primarily focused on perceived stress as a predictor of health outcomes. To our knowledge, this experiment is the first to establish a comprehensive set of features that predicts perceived stress. Because perceived stress is related to health outcomes (e.g., Monroe, 2008), it is important to understand the factors that predict it, such that it can be better understood, and so that informed interventions can be developed to reduce it.

We developed an account of situated stress categorization that motivated our experiment. From this perspective, we predicted that when a situation possesses features associated with stressful experiences, the situation should be perceived as stressful; conversely, situations lacking these features should be perceived as non-stressful. Furthermore, if individuals vary in the features associated with their respective stress categories, they should exhibit individual differences in stress perception.

To test these predictions, we assessed the extent to which 19 features predicted perceived stress. As predicted, all the critical features that we hypothesized as central to categorizing situations as stressful in Fig. 1 were highly correlated with perceived stress, including expectation violation, self-threat, action inefficacy, negative valence, arousal, and perseveration, along with the closely-related features of positive valence and bodily experience (Table 1). Furthermore, all these features loaded on a Core Stress Features factor that captured a relatively unitary construct of what constitutes a stressful experience (Table 2). Most importantly, the Core Stress Features factor was consistently the most important factor in explaining perceived stress, across a variety of multilevel models (Table 3). Not only did it enter into every critical model, it played by far the largest explanatory role.

Across the critical models, the other three factors for Imagery, Experience, and Certainty also contributed to explaining perceived stress, with Imagery being the most consistent. Although Imagery's contribution was relatively modest compared to Core Stress Features, its presence suggests that the perceived stress increases with how vividly a situation is imagined. Clearly, causality could go in either direction: Increasing imagery could amplify stress, or increasing stress could intensify imagery. A related possibility is that increasing imagery increases the subjective realism of imagined situations, further contributing to their perceived stress (cf. Lebois et al., 2015; Papies et al., 2012, 2015). Regardless, the importance of imagery is consistent with the perspective of grounded cognition, which assumes that modality-specific processing underlies the representation of situations (Barsalou, 2008, 2009, 2016).

Perceived stress also varied systematically with both situations and participants. In an analysis when covariates for the four factors were not included, situations explained 70% of the variance in perceived stress, whereas participants only explained 6%. Thus, variability in situations played a much larger role in perceived stress than did variability in participants. Furthermore, the Core Stress Features factor explained nearly all the variance associated with situations. Consistent with our original prediction, the situated features in Fig. 1 were primarily responsible for how perceived stress varied across situations.

Finally, individual differences consistently contributed to perceived stress. As random effects across the critical models demonstrated, participants differed significantly in their overall levels of perceived stress, and in how well the Core Stress Features factor predicted their perceived stress (Table 3, Figs. 2 and 3).

To our knowledge, no previous work has attempted to comprehensively establish the features that predict perceived stress. In the results reported here, the fixed and random effects across the critical models explained 75% to 88% of its variance (Table 3). In the best fitting Model 5, fixed effects for Core Stress Features, Imagery, and Situations, together with random effects for participant intercepts on perceived stress and participant slopes on Core Stress Features, explained 88% of the variance in perceived stress.

These results indicate that the perspective of grounded cognition offers a potentially useful way of understanding the categorization of stress. On the one hand, situational features associated with stressful experiences played the central role in explaining perceived stress. On the other, increasing imagery was associated with increased perceptions of stress as well, although playing a minor role. Perhaps in other contexts, when people immerse themselves more deeply in stressful events for longer durations, imagery may play more important roles.

Additionally, these results indicate that perceived stress doesn't simply reflect the basic appraisal features of self-threat and action inefficacy. If only these basic appraisal features were associated with perceiving stress, they alone should have accounted for the explainable variance in perceived stress. As we saw, however, additional features of stressful situations loaded on the same Core Stress Features factor as threat and action inefficacy, including expectation violation, negative valence, positive valence, arousal, bodily experience, and perseveration. Because these latter features occur frequently during stressful situations, they become typical features of the category and contribute to categorizing situations as stressful.

As Fig. 1 suggests, when an individual perceives a situation as exhibiting basic conditions for stress (an expectation violation, a threat, and action inefficacy), these conditions in turn produce primary stress responses (negative emotion, arousal), followed by secondary stress responses (rumination). Over the course of a stressful experience, all these features are likely to occur, such that they become associated with the category of stressful experiences. As future situations match this feature set, they, too, are categorized as stressful. An important goal for future work is to assess whether the process model that Fig. 1 implies is correct. Does processing proceed as Fig. 1 suggests? Clearly, the features in Fig. 1 are important for categorizing situations as stressful, but the additional processing assumptions remain to be tested.

Finally, it is important to note the similarities and differences between our account of situated stress categorization and appraisal theories (e.g., Moors et al., 2013). First, appraisal theories would be very comfortable with our results. The features here that predicted perceived stress are highly similar to those associated with the appraisal, motivational, somatic, motor, and feeling components of emotional episodes in appraisal theories. In some sense, both approaches have attempted to identify the features of emotional situations, understand the relations between features, and establish relations of these features to various outcomes, such as perceived stress and emotion. As a result, both approaches have converged on similar features, while theorizing about them in different ways. Whereas appraisal theory is primarily interested with how appraisal features activate the motivational, somatic, motor, and feeling components of emotional episodes, situated categorization theory focuses more on the categorization processes that underlie situated action. As a consequence, situated categorization theory views perceived stress as utilizing the same basic processes of categorization in general, rather than being a specialized process only associated with stress and emotion.

As a further consequence, we assume that many situated aspects of stressful experiences can become part of the categorization process, not just appraisal features and the other components of emotion that they influence. Perhaps one example that illustrates this emphasis is the importance of rumination in explaining perceived stress found here. Because rumination is an important part of many stressful situations, it becomes part of how the category of stressful experiences is represented, and contributes to categorizing future situations as stressful. In appraisal theories, however, rumination tends not to be included because it is relatively peripheral to the appraisal process (although it could in principle result as an activated outcome).

4.1. Further exploring individual differences in stress categorization

To establish the features that underlie stress categorization, we examined how a small sample of relatively homogenous individuals evaluated the stressfulness of imagined situations in a laboratory setting. Our methods and results can be readily extended, however, to a wide variety of clinical populations in everyday contexts (e.g., using briefer instruments that focus on only a few critical features for a small set of real-life events). Within such studies, various individual difference measures from our methods could be utilized, including an individual's overall level on the Core Stress Features factor, their slope for this factor, and their intercept for perceived stress.

Correlations between these individual difference measures and various personality types could then be assessed to establish how people with different personality types perceive stress. Analogously, individual variability in perceived stress could be examined in individuals who live and work in different environments, who have different developmental histories, who have different cultural backgrounds, who are embedded in different social networks, who have different psychopathologies, and who receive different therapeutic treatments. Finally, perceived stress could be examined in groups having different genetic profiles, exploring relations between relevant genes and core features of stress cognition (e.g., Conway, Slavich, & Hammen, 2014).

Although the core features of stress loaded on a single factor in the study reported here, it is important for future work to examine whether these features remain integrated or disassemble as individual differences are examined more closely. In certain individuals or sub-groups of individuals, these core features may pattern differently than observed here, reflecting how different groups and individuals adapt the perception of stress to the life events that they encounter, utilizing the resources available for managing them.

As we also saw earlier, individuals explained a modest 6% of the total variance in perceived stress, varying significantly in their intercepts on this measure. Because the 12 participants in this study constituted relatively homogenous sample, it is not surprising that variability between them played a relatively minor role in explaining perceived stress. In future studies that sample individuals more broadly, the role of participants could increase substantially.

In contrast, variability in situations played a much larger role in perceived stress. Within individuals, situations varied considerably in perceived stress from stressful to non-stressful situations, with different individuals perceiving this variability similarly. This finding fits well with emerging arguments in the stress literature that, on a daily basis, a given individual experiences considerable variability in stress, ranging from minor daily hassles to major life events (e.g., Almeida, 2005). It may be fruitful to regard this intra-individual variability as reflecting fluctuations in the particular situations that individuals experience over the course of a day. Our results here further suggest that different individuals may often perceive this variability in stressful situations similarly. To the extent that different individuals perceive the situated features of situations similarly, they may perceive stress similarly.

We also saw, however, that individuals varied in their perceptions of stress, suggesting that important differences in stress perception exist as well. Such differences may well become increasingly apparent when more heterogeneous samples of individuals are assessed, together with the specific situations that they find stressful in their daily lives. A related possibility is that the same situated features consistently produce stress responses across individuals, with individuals varying in how they experience these features.

4.2. Stress cognition originates in general cognitive mechanisms

We proposed initially that general cognitive mechanisms associated with categorization play a central role in stress perception. As many stress theorists have suggested, stress is a natural response to difficult life events (e.g. Almeida, 2005; McEwen & Sapolsky, 1995; Monroe & Slavich, 2007). To the extent that stress is a natural response, it is not surprising that general cognitive mechanisms play central roles in producing it (Sanislow et al., 2010).

As we also proposed, however, perceived stress, as a category, has unique features, analogous to how other categories are associated with unique features (e.g., animals, artifacts, foods, emotions). Our findings here confirm that these features are indeed strongly associated with perceived stress. We suspect, however, that these features are not *individually* unique for perceived stress, but are relevant for many other categories as well. Similar to how the features of emotion occur across many categories (Lebois et al., 2016; Wilson-Mendenhall et al., 2011), so may the features of stressful experiences occur across many categories. We simply propose that these features tend to be relatively unique *as a set* for stressful experiences (Fig. 1), relative to non-stressful experiences.

Finally, we assume that as stress becomes increasingly dysfunctional, mechanisms underlying stress categorization operate in increasingly aberrant manners (Sanislow et al., 2010). In some individuals, for example, undue emphasis on high threat and action inefficacy could increase neuroticism, anxiety, and rumination, thereby increasing the attribution that one is experiencing much stress (cf. Bandura, 1997; Blascovich et al., 2003; Higgins, 1989; Watkins, 2008). Similarly, during the categorization of situations, an individual's stress category may generalize too broadly beyond situations typically perceived as stressful (e.g., the dysfunctional generalization that characterizes Posttraumatic Stress Disorder; e.g., Oyarzún & Packard, 2012).

In general, the methods we have developed for assessing a person's category of stressful experiences could be extended to studying the effects of extreme stressors on health. By characterizing how individuals process core stress features, researchers and clinicians could differentiate various populations in terms of how they experience major and traumatic life events. This approach could also be used to assess treatment effectiveness and to tailor treatments to individuals as a function of how they conceptualize stress in terms of core stress features.

4.3. The relation between stress categorization and stress perception

To this point, we have been relatively vague about how stress categorization produces stress perception. We have simply argued that categorizing a situation into the category of stressful experiences produces the perception of stress. Here we speculate in more detail about the nature of this process, with this account requiring future investigation.

Stress perception could simply result from assigning a situation to the category of stressful experiences. Once this categorization is made, it follows that the situation is the kind of situation that has been stressful in the past, such that it, too, must be stressful. Once the categorization comes to characterize the situation, it makes the situation appear stressful.

The process of categorical inference could further contribute to stress perception. In general, theories of categorization assume that the purpose of categorization is to produce useful inferences (e.g. Barsalou, 2012; Murphy, 2002). Rather than being an end in itself, categorization provides access to rich inferential knowledge that guides understanding and action. When categorizing something as a hammer, for example, inferences follow about its origins, weight, and use. Similarly, when categorizing something as a single malt whisky, inferences follow about its taste and psychological effects. By categorizing the world around us, we access expert knowledge that guides sophisticated goal-directed action in the environment (e.g., Barsalou, 2009, 2016).

The same general principles apply to stress categorization as well. Once a situation is categorized as stressful, inferences about the situation are likely to follow. From the situated perspective, these inferences could take many forms, including emotion, bodily responses, and action (e.g., Barsalou, Niedenthal, Barbey, & Ruppert, 2003). When encountering a particular person, object, or event that has caused stress in the past, the category of stressful experiences might become active, which in turn, could activate related emotions, bodily responses, and/or actions likely to follow. Seeing a difficult co-worker from the distance at the grocery store, for example, might activate the category of stress experiences, producing negative emotion, arousal, and rumination. Once these inferences occur, they are perceived in experience, thereby contributing to the perception that the current situation is stressful. We further assume that these inferences vary systematically across specific kinds of stressful situations, such that the stress response takes a different form tailored to each one (e.g. Barsalou, 2016; Lebois et al., 2016; Wilson-Mendenhall et al., 2011).

In summary, the perception of stress could result both from categorizing a situation as stressful and from inferences that follow from this categorization. As the categorization and inferences are experienced together, the perception of stress results. Again, further work is required to establish these proposed relations between stress categorization and stress perception.

4.4. Relations between stress cognition, neural activity, and peripheral physiology

Another direction for future work is to explore relations between features associated with perceived stress and other dimensions of the stress response. As these features vary, what corresponding dimensions of neural and peripheral physiology covary? Because we found that a set of situational features all loaded on a common Core Stress Features factor, this question can be framed as examining the neural and peripheral activity that covaries with this factor across stressful situations.

Analogously, individual differences in overall Core Stress Features scores, Core Stress Feature slopes, and perceived stress intercepts could also be correlated with neural activity and peripheral physiology. As these individual difference measures vary, how do neural activity and peripheral physiology covary with them (e.g., Slavich, Way, Eisenberger, & Taylor, 2010)? By examining such issues, it may become possible to develop an increasingly articulated and integrated account of stress cognition, its neural bases, and its bodily manifestations.

Author contributions

LAML and LWB developed the study concept and design. LAML played the primary role in implementing, running, and analyzing the experiment in the Barsalou Lab at Emory University. CH played the leading role in developing and implementing the analyses. LWB played central roles in implementing the experiment, analyzing the results, and managing the project. GMS played a leading role in relating the research to the stress literature. All authors contributed to interpreting the results. LAML, LWB, GMS, and CH drafted the manuscript, and all authors contributed to revising it. This project grew out of a related neuroimaging project developed by LAML, Esther K. Papies, LWB, and LFB. LWB and LFB are joint senior authors. All authors approved the final version for submission.

Acknowledgments

Work on this article was supported by an NIH NRSA award to Lauren (McDonough) Lebois at Emory University, and by an NIH Director's Pioneer Award DPI OD003312 to Lisa Feldman Barrett at Northeastern University, with a sub-contract to Lawrence Barsalou at Emory University. We are grateful to David Almeida for sharing his stressor database, Taryn Colton, Hailey Friedman, and Bridget Warren for assistance with sampling the stressful life events, and to Christine D. Wilson-Mendenhall for assistance with the valence and arousal instructions.

Supplementary Materials

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.actpsy.2016.05.012.

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