Emotion

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Many models of emotion assume that the emotional response is preceded by an assessment of a stimulus' relevance to the perceiver's goals. Although widely assumed, experimentally controlling and, hence, empirically testing the effect of a stimulus' relevance on the emotional response has proven challenging. In this study, we used stimuli with high ecological validity and manipulated their relevance while holding constant the perceptual features of the stimuli. In the experiment, participants were given the result of their Israeli Psychometric Entrance Test (PET). The PET score is highly relevant to most participants, as, at the time of the experiment, it is the only unknown about whether they shall be admitted to their major of choice at the university. Relevance of the information was experimentally controlled both binarily by manipulating whether the presented score is the participant's or belongs to another unfamiliar participant and parametrically by manipulating the probability that a presented score is their actual PET score. We found a substantial effect for manipulated relevance on self-report, electrodermal activity, and heart rate. The results provide evidence that information about a stimulus' relevance modulates the emotional response to it.

Keywords: appraisal, emotion, relevance

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We are exposed to numerous objects and events in various contexts, yet few of them initiate an emotional response. Why and how does our brain decide to selectively elicit emotions? One way to reframe these questions is by asking what the stimuli or event dimensions that are evaluated in the decision to generate an emotional response are. These questions are exactly the ones traditionally addressed by appraisal theories. Appraisal theories regularly assume that, at least one evaluation stage—in which specific dimensions of an event are appraised—precedes the emotional response. Evaluation, in turn, determines the type and/or the intensity of the emotional response (e.g., Clore & Ortony, 2000; Frijda, 2007; Lazarus, 1991; Reisenzein & Spielhofer, 1994; Roseman & Smith, 2001; Scherer, 2001; but see also Parkinson, 1997).

Critical to appraisal theories is the assumption that the evaluation phase(s) involve(s) the assessment of the stimulus' relevance to the perceiver's well-being (Moors & De Houwer, 2001; Scherer, 2013). Yet although the effect of relevance on the emotional response is assumed and supported by empirical findings, it has proved to be challenging to control and manipulate (Roseman & Evdokas, 2004). Especially challenging is ensuring that the phys-

ical properties of the stimulus remain constant while changing the appraisal. This experimental element is crucial because the moment a stimulus' appearance changes together with the appraisal, there is no way to differentiate the effect of its appraisal from the effects of the stimulus itself. The current study's primary goal is, thus, to experimentally manipulate the relevance of stimuli and keep its physical properties unchanged.

Working Definitions

Emotional Response

Emotion is defined as a response profile that indexes the occurrence of an event as pleasant or unpleasant (Dolan, 2002), with arousal being a secondary dimension (e.g., Russell, 1980, 2003, but see also Kron, Goldstein, Lee, Gardhouse, & Anderson, 2013). The activation of an emotional response profile is usually short in duration, event-related (see Beedie, Terry, & Lane, 2005, for a review), and composed of different levels of activation of various components (Russell, 2003), such as nonverbal signals, action tendencies, autonomic changes, core affect, affective quality, cognitive factors (e.g., attribution and appraisal), and feelings.

Appraisal

Appraisal is defined here using a minimal set of two invariant features that, together, distinguish it from other processes involved in the emotional response and do so without committing to many other, currently debated features (Moors, Ellsworth, Scherer, & Frijda, 2013):

1. Appraisal involves assigning a value to a stimulus on a certain dimension; with "dimension" being the property

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that is being appraised. For example, some theories assume the appraisal of novelty (e.g., Scherer, 2009).[1] In this case, *novelty* is the dimension that is appraised.

2. Appraisal affects the type and/or intensity of the emotional response (e.g., Clore & Ortony, 2000; Frijda, 2007; Lazarus, 1991; Reisenzein & Spielhofer, 1994; Roseman & Smith, 2001; Scherer, 2001).

Note that this two-feature set is silent on whether appraisal is "cognitive" or not and on whether it is a controlled or a fully automatic process. Importantly, this definition of appraisal does not assume any model of emotion—only that the appraisal should causally affect the entity specified by the model, be it the type of emotion (e.g., fear, disgust, happiness—if one holds a discrete view of emotion) or the emotion dimension (e.g., changes in arousal or valence—if one holds a dimensional-continuous view of emotion).[2]

Relevance

Relevance is defined here in terms of a stimulus' informativeness to a goal. Specifically, a stimulus' relevance is proportional to the degree that the information it carries should modify the expectancy of achieving the goal. This definition of relevance can be cast in terms of deviation from statistical independence and formally defined as follows: information is relevant to a focal goal if it changes the probability of achieving the goal (see SOM1 of the online supplemental materials for a more formal definition of relevance). For example, the relevance of seeing a snake in one's garden to the end goal "maintaining my well-being" is proportional to the degree the snake can affect the probability of one maintaining their well-being.[3] This probabilistic interpretation of relevance is compatible with recent formulations of goal relevance (Tanner & Itti, 2017) and very similar to previous definitions of relevance detection. For example, Sander (2013) defines *relevance appraisal* as following: an "object or situation is appraised as relevant for an individual if it increases the probability of satisfaction or dissatisfaction toward a major concern of the individual" (p. 22). The definition of relevance in terms of a change in probability of goal attainment (see also SOM1) underlies the operationalization of degree of relevance of information as its potential of changing the probability of achieving the goal.

Appraisal of Relevance

There are two ways in which a stimulus' relevance, is incorporated into appraisal theories: the first is as a property of a theory of appraisal and the second is as a dimension that is appraised.

Appraisal of relevance as a property of a theory of appraisal. In this usage of the term, *relevance* is an abstract label of what the appraisal process does, but it is not a dimension that is directly appraised (i.e., actually assessed). For example, in his sequential check theory, Scherer (2001) uses the term *relevance detection* to describe an initial evaluation stage that assesses the stimulus on two dimensions: novelty (e.g., the degree to which an event is unexpected; appraisal of novelty) and intrinsic valence (whether the stimulus is likely to result in pleasure and/or pain; appraisal of valence). These two appraisals are assumed to serve, from the

perspective of theory of appraisal (the sequential check theory; Scherer, 2001), as "relevance detectors." Yet "relevance" is used here to refer to the actual process of appraisal of two other dimensions (see also Footnote 1).

Relevance as a dimension that is appraised. In its second meaning, the term *relevance* is the dimension that is being assessed by the appraisal processes. Here, the dimension of appraisal is the assessment of the extent to which information is relevant to a goal[4] (see also SOM1 for a formal definition). One example of relevance as a dimension that is appraised is probability appraisal (Roseman, 1984; Roseman & Smith, 2001; Sander, 2013). Probability appraisal is assumed to evaluate whether the occurrence of "motive-relevant" aspects of a situation is "merely possible or definite." Thus, in contrast to the first case, when novelty and valence were the dimensions of appraisal and *relevance* was used to refer to their assessment, relevance is the actual dimension being assessed. This second meaning of the relevance appraisal is also closely related to the concept of primary appraisal of motivational relevance—that is, that the relevance of an event to one's own goals and needs is appraised (Lazarus, 1991; Smith & Kirby, 2009) and the notion of relevance to concern, on which the relevance of stimulus to the perceiver's concerns is assessed (e.g., Frijda, 1986; Pool, Brosch, Delplanque, & Sander, 2016). For the purposes of the current study, we adopted this second meaning of relevance in which relevance was the dimension of appraisal.

The Experimental Investigation of Appraisal

There are two main challenges that complicate the experimental study of appraisal processes (Roseman & Evdokas, 2004). One such challenge lies in manipulating the dimension to be appraised while creating minimal (and ideally no) change in the physical appearance of the stimuli. Maintaining the physical properties of the stimulus is crucial because the moment a stimulus' appearance changes, there is no way to differentiate between the effects of its appraisal from the effects the stimulus itself may have on the emotional response. In the case of the appraisal of a stimulus' relevance, this would entail the manipulation of the relevance of stimuli without changing their physical appearance. The second

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[1] A dimension (such as novelty) may be a combination of a number of separate dimensions.

[2] In this section, we use the terms *dimensional* and *discrete* structures as general models of emotional experience and not in reference to a specific theory. Specifically, we do not suggest that Russell's (2003) theory of core affect, or Ekman's (1992) or Panksepp's (2004) discrete emotion theories, hold that appraisals are the cause of changes in core affect, but rather that our definition of appraisal is not restricted to a specific structure, dimensional or discrete.

[3] Interestingly, this definition of relevance immediately brings to mind the question of why individuals respond emotionally to the (obviously currently irrelevant) image of a snake. Although we do not develop this point further here, relevance can be thought of as being *transient* (contextualized) or *chronic* (cross-situational; Eitam & Higgins, 2010), and it is conceivable to think that (irrelevant) images of highly relevant real-world stimuli are used in experiments precisely because they carry the latter—chronic—type of relevance.

[4] The relevance of information (I) to an end goal (EG) could be generalized to more complicated processes in which multiple end goals are assessed, such as the relevance I to an EG within the context of multiple goals or goal hierarchy, for example, closely related to the term *goal relevance* used by Scherer (2001).

challenge concerns the use of self-report data to estimate stimulus relevance. We do not assume that participants necessarily have conscious access to the output of the appraisal process, and even less so to the process itself (see Roseman & Evdokas, 2004, for related argument). The fact that participants can answer questions regarding a specific dimension, even reliably, does not mean that their response is based on the output of a process of appraisal (Nisbett & Wilson, 1977). Consequently, self-report of stimulus relevance is weak evidence that such a process even occurs when spontaneously processing an emotion-inducing stimulus and ideally will be supported by data that does not rely on self-report.

In summary, strong evidence that an appraisal (of relevance) affected the emotional response would require (a) keeping the physical properties of the stimulus constant, (b) directly manipulating the dimension to be appraised (relevance), and (c) demonstrating that the dimension to be appraised affected the type or intensity of the emotional response.

Empirical Evidence for the Appraisal of Relevance

Initial evidence that the appraisal of relevance affects the emotional response comes from studies that rely on self-reports—participants provided self-reports about both the emotional response and the relevance of information to the participants (e.g., De Leersnyder, Koval, Kuppens, & Mesquita, 2017; Scherer, Dan, & Flykt, 2006). A second type of evidence comes from studies that show a "beyond valence" effect (i.e., similar effect for positive and negative stimuli, with both differing from neutral stimuli). This pattern of results is sometimes interpreted as reflecting the underlying mechanism of the appraisal of relevance (Brosch, Sander, Pourtois, & Scherer, 2008; Grandjean & Scherer, 2008; Walentowska, Moors, Paul, & Pourtois, 2016). The logic of such interpretation is that what is shared by a response to positive and negative stimuli, but not to neutral stimuli, is their relevance to well-being. For example, Brosch et al. (2008) showed that when stimuli are selected to be biologically relevant, positive stimuli (and not exclusively fear-inducing stimuli) also produce an automatic spatial orientation toward the location of a stimulus.

A third line of evidence comes from studies about the effect of gaze direction on emotion perception. According to the gaze direction hypothesis (N′Diaye, Sander, & Vuilleumier, 2009; Sander, Grandjean, Kaiser, Wehrle, & Scherer, 2007), an angry face is predicted to be more relevant to an observer if the expresser's gaze is directed toward the observer rather than averted from him. This assumption considers that directed gaze increases the probability that the observer is the target of the expressed anger. Following the same logic, an expresser's fearful face is assumed to be more relevant to the observer if his gaze is turned away, again focusing on the target (potentially dangerous) stimulus. The gaze direction hypothesis was supported by experiments using measures of semantic categorization and judgments of perceived emotional intensity (Sander et al., 2007; but not for low intensity [N′Diaye′et al., 2009]); further evidence comes from the level of activation of the human amygdala, which has been argued to process the significance of stimuli (N′Diaye′et al., 2009; see also Cunningham & Brosch, 2012; Sander, Grafman, & Zalla, 2003).

These studies do suggest that relevance is appraised and that it influences the emotional response. Yet the condition of keeping the stimulus constant was not satisfied. That is, the relevance manipulation also changed the physical properties of the stimuli (e.g., changing gaze direction also changes the facial expression). Roseman and Evdokas (2004) examined the probability component of relevance without changing the stimulus. Using an elaborate design (simplified here), participants were led to believe that they were about to have pleasant-tasting or unpleasant-tasting drinks with two levels of probability: certain or uncertain. Participants then provided self-reports of various discrete feelings (joy, relief, hope, sadness, anger, and fear) while waiting for their drink. The results supported the hypothesis that the degree of certainty had an effect on the emotional response of participants that were waiting for the bad-tasting drink but not for the tasty one. Specifically, participants that were manipulated to believe that they had definitely avoided the bad-tasting drink reported a higher degree of relief. Although these results provide some evidence for the effect of the appraisal of the emotional response, they are inconclusive regarding the questions of interest. This is largely because Roseman and Evdokas (2004) collected the self-reported feelings before the stimulus (the drink) was actually experienced (i.e., tasted). That is, the probability was manipulated in regard to a future perception of the stimuli (of tasting the drink). Consequently, it is not clear whether the effect that probability had on expectancy can be generalized to the instance of actually experiencing (and processing of) the stimulus itself—which is the focal question of appraisal theory.

The Current Study

The current study has three objectives—first, to develop an experimental paradigm for investigating the effect of appraisal of relevance on the affective response; second, to manipulate the appraised dimension while keeping the perceptual features of the stimuli constant; and third, to examine the hypothesized influence of relevance on emotion generation with stimuli that are clearly connected to people's goals and, thus, are of high ecological validity.

In the experiment, participants were to face their Israeli Psychometric Entrance Test (PET) score for the first time during the experimental session while facial electromyography (EMG), heart rate (HR), electrodermal activity (EDA), and reported experience were monitored. The Israeli PET score is equivalent to the SAT and ACT tests in the United States. It is of major importance for most university candidates, as it is a cardinal determinant of acceptance into university programs. At the time of testing, the PET score was the only unknown factor regarding the fate of their academic plans. Thus, when arriving at the experiment, participants did not know what their PET score was and understood that they would find out at the end of the experiment.

Relevance appraisal was manipulated by controlling the probability that the presented score was indeed the participant's final PET score. Probability was manipulated in two ways: parametrically and binarily. In parametric manipulation, participants were exposed to the same test scores, appearing in three probabilities. In each of the probabilities, participants were told that one of the presented scores was indeed their final score: 1/12, 1/6, and 1/3. In the binaric manipulation, we compared conditions in which participants knew that one of the scores was their real score with conditions in which participants knew all the scores belonged to another participant (i.e., nearly zero relevance). Note that "para-

metric" versus "binaric" can be a feature of both the input (the available information is either parametric or binaric) and/or a feature of the appraisal process itself (e.g., it may be that regardless of whether the available information is parametric or binaric, the output of the process computing the relevance of stimuli is binaric). Manipulating the input probability in both ways (i.e., binarily and parametrically) offers the possibility of examining whether the process of relevance appraisal is sensitive to parametric changes.

Perceiving the PET score for the first time is assumed to be highly relevant and to induce strong achievement-related emotional responses (Pekrun, 2016). The effect of relevance appraisal on the emotional response was estimated by changes in four indexes: facial expressions—specifically, surface EMG from the areas above the corrugator supercilii and zygomaticus major muscle; HR acceleration in response to highly relevant stimuli; and electrodermal change and reports about feelings. The first index, EMG measures, was collected from the area above the zygomaticus major and corrugator supercilii muscles. The zygomaticus major pulls the corners of the mouth back and activates a smile. The corrugator supercilii draws the brows medially into a frown. In response to emotional stimuli that elicit moderate intensity, such as emotional pictures, zygomaticus activation is associated more with positive emotional reactions than with negative reactions, and corrugator activation is associated more with negative reactions and attenuates below baseline during positive reactions (e.g., Larsen, Norris, & Cacioppo, 2003). In more intense real-life situations, this differentiation is not always present, and sometimes both the zygomaticus and corrugator muscles are activated in negative and in positive responses (Aviezer, Trope, & Todorov, 2012). The second index, cardiac changes, reflects autonomic activation during emotional responses. Cardiac deceleration is observed for 2 to 3 s after the onset of complex visual stimuli (Bradley, Codispoti, Cuthbert, & Lang, 2001); this effect is usually interpreted as part of the orienting response (Graham & Clifton, 1966; Sokolov, 1963) and thought to be linked to allocation of attention during "stimulus intake" (Lacey & Lacey, 1978). Cardiac acceleration is thought to be related to stronger affective responses and observed in tasks that involve the imagination or real-life emotional events from the past (Gollnisch & Averill, 1993; Vrana, Spence, & Lang, 1988; Witvliet & Vrana, 1995). In light of the nature of stimuli that will be used in this study (i.e., stimuli are assumed to be highly relevant, elicit strong emotional responses and to be very simple in terms of perceptual complexity), cardiac acceleration (and not deceleration) is expected.

The third index we used was electrodermal activation. Electrodermal activation is modulated by sympathetic activation and assumed to be part of orienting responses (Maltzman & Boyd, 1984). The affective modulation of the skin conductance response to novel stimuli is manifested by an increase in the skin conductance magnitude in response to high-arousing positive and negative stimuli (e.g., Bradley et al., 2001; Kron, Pilkiw, Banaei, Goldstein, & Anderson, 2015; Lang, Greenwald, Bradley, & Hamm, 1993).

Finally, the fourth index is self-reports of emotional experience. Self-reports can be more of a proxy for emotional feelings (e.g., "I feel strong negative feelings looking at this video of a car accident") or reflect semantic knowledge (e.g., "car accidents are negative events, but this video did not elicit strong negative feelings"; Itkes, Kimchi, Haj-Ali, Shapiro, & Kron, 2017; Levenson,

2003; Robinson & Clore, 2002). Self-reports were collected using special instructions developed and validated in our lab (Itkes et al., 2017; Kron et al., 2015). The special instructions (named "feelings-focused instructions") directly communicate to the participant the distinction between reports that reflect affective versus semantic aspects. The feelings-focused instructions encourage participants to report about their actual feelings and not semantic knowledge about the content of the stimulus.

In summary, in this study, appraisal of relevance was manipulated by keeping the stimulus constant and controlling the probability that the presented score was indeed the participant's final PET score. The effect of manipulating relevance appraisal was tested on four indexes of the emotional response: facial EMG, HR acceleration, electrodermal change, and self-report on feelings.

Method

Ethical Considerations

The current research received approval from University of Haifa research ethics committee. Approximately a month and half before the PET exam, potential participants were recruited from PET preparation classes. Participants were briefed about the exact content, procedure, and design of the experiment, and they signed a consent form. This procedure—full disclosure of the details of the experiment and signing a consent form—was performed twice, during recruitment stage and again on the day of the experiment.

To enable removal of movement artifacts from the facial EMG data, a hidden video camera recorded the participants' faces. At the end of the experiment, participants were informed about the video recording and the reason it was hidden. Then, they were asked for their signed consent to use the video recordings. If they refused, the video was deleted.

Participants

Forty (26 females)[5] preuniversity participants in a PET preparation course (M_{age}= 21.55, SD = 1.48) were recruited and completed the experiment for monetary compensation (~$100). Participants were recruited before taking the PET exam, approximately a month and a half before the experiment. They all gave their permission for their PET scores to be sent to a designated e-mail address that we created specifically for this purpose, instead of to their personal e-mail address. Data from six participants was not analyzed because of malfunctioning of the recording equipment.

Stimuli

A total of 24 different scores were computed according to an in-house algorithm using three preknown parameters: "simula-

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[5] Because we did not find a similar manipulation in the literature, we used a sample size of 30 participants in the current study. The same sample size is usually used in studies run in our lab that involve effects of affective pictures on physiological measure and self-reports (e.g., Kron et al., 2015, 2013). Furthermore, because the current experiment was done in a "one shot" during 2 days (the day the test scores were published and the day after) with a fixed number of participants that were registered and prepared in advance, we a priori decided to run an additional 10 participants, in cases of equipment malfunctions, participant withdrawal, or other unexpected problems.

tion," "required," and "actual" scores. The simulation score is the participant's score obtained at the final simulated test taken before the actual PET exam (a standard practice in all PET preparation courses). The simulated test was used as a proxy for participants' realistic expected score. The required score is the minimal PET score that the participant would need in order to be admitted to the university major and school chosen as first priority. Finally, the actual score is what the participant actually obtained on the PET exam.

The experimenter had access to the three scores (simulation, required and actual) prior to the experimental session. Positive scores were operationally defined as being higher than both the simulation and required scores; negative scores were defined as being lower than the simulation and requested scores; all scores lying between the simulation and required scores were considered undefined. For each participant, the algorithm automatically selected four negative, four positive, and four undefined scores. All grades were presented on a white background, in black Times New Roman font, size 28.

Design

The experiment consisted of three within-participants blocks (Figure 1, Part I): one "own scores" block (i.e., OWN), one "other's scores" block (i.e., OTHER), and one "final score" block (i.e., FINAL).

OWN scores block. In the OWN scores block, participants were told that one of the presented scores was their actual PET score. In addition, this block consisted of three subblocks (Figure 1, Part II). In the first subblock, participants viewed 12 scores, one after the other (including the participant's actual PET score). In the second subblock, six of the 12 scores that were presented in the

first subblock (including the participant's actual PET score) were again presented. In the third subblock, three of the scores presented in the second block (including the participant's actual PET score) were presented for the third time. In summary, in the OWN scores block, participants were presented with three different probabilities and were instructed that one of them was their current own PET score (1/12, 1/6, and 1/3). Each probability block consisted of scores from the three valence conditions: positive scores (above "expected score" and "required score"), negative scores (below "expected score" and "required score"), and undefined scores (between "expected score" and "required score").

OTHER scores block. This block is almost identical to the OWN scores block. The only difference is that participants were told that one of the scores that they would see was another participant's actual PET score (i.e., not their own). To maximize similarity to the OWN scores block, the scores in the OTHER block were computed for each participant based on their 12 OWN scores list generated by the algorithm, by subtracting or adding 1 point from each score.

Procedure

Participants performed the experiment individually in a dimly lit room. Before completing the experiment, they provided consent (see Ethical Considerations section) and were connected to measuring devices (EMG, electrocardiogram [ECG], and EDA). Participants were seated approximately 60 cm from the computer monitor and were asked to not make extensive movements or touch their face. Then, instructions for the rating scales (see Itkes et al., 2017) were delivered and a short practice followed (three trials). Participants then went through the three experimental blocks: OWN, OTHER, and FINAL score blocks (counterbalanc-
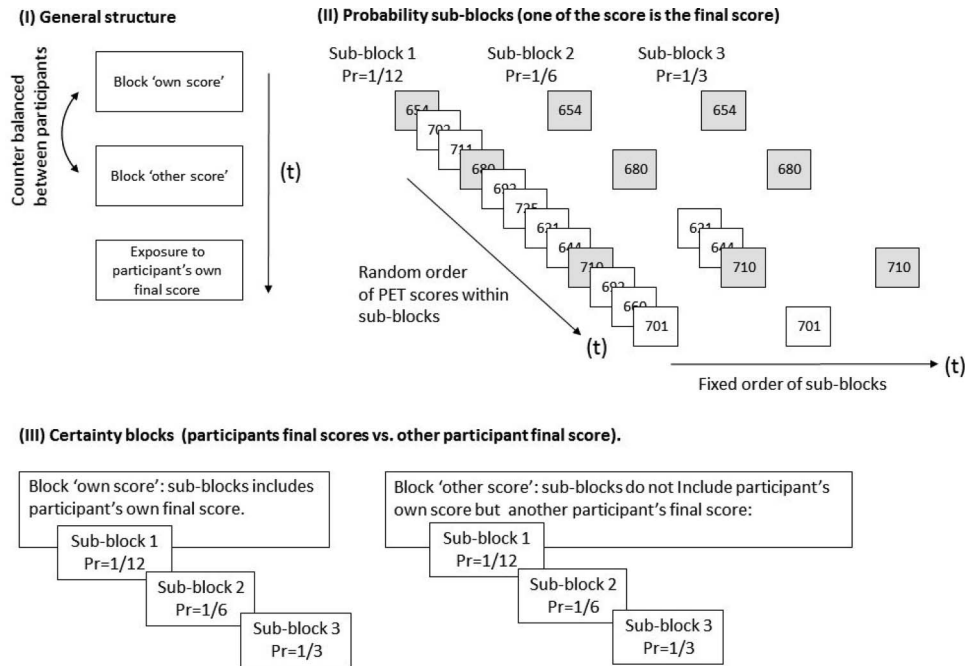

Figure 1. Experimental design: (I) experimental blocks; (II) probability subblocks; (III) OWN versus OTHER conditions.

ing the order of OWN and OTHER blocks is detailed in Figure 1). A hidden video camera recorded the participants' faces to enable removal of movement artifacts from the EMG signals (see Ethical Considerations section).

Measures

Self-report scales. Following the presentation of each score, three scales of feelings-focused self-reports were presented (Itkes et al., 2017; Kron et al., 2015). The instructions for the feelings-focused self-report scales acquainted participants with the difference between reporting their actual feelings (which are what they are required to report), their beliefs or expectations, and the social norms about what one "should" feel while seeing the score. Participants were then asked to rate their feelings using three scales: a General Feelings scale, a Pleasant Feelings scale, and an Unpleasant Feelings scale. Each scale ranges from 0 (*no feelings*) to 8 (*very strong feelings*). On the general Feelings scale, participants were instructed to indiscriminately detect and report any type of feeling they had by rating its intensity (e.g., arousal, sadness, displeasure, or any other feeling). On the Pleasant Feelings scale, participants were asked to rate the intensity of any pleasant feeling they had (e.g., pleasure, happiness, or any other pleasant feeling). Similarly, on the Unpleasant Feelings scale, the participants were asked to rate the intensity of any unpleasant feeling they had (e.g., feelings of displeasure, sadness, or any other unpleasant feeling).

Physiological data acquisition. Physiological data was recorded and amplified with a multichannel BioNex 8-slot chassis (MindWare Technologies, Grahanna, OH) equipped with a two BioNex 4-channel bio-potential amplifier (Model 50 −371102–00). All data were sampled at 1,000 Hz and transmitted to a computer for viewing and storage using MindWare acquisition software BioLab 2.4. The experiment was programmed using E-Prime 2 (Schneider, Eschman, & Zuccolotto, 2002) and run on an HP PC and a 23-in. color monitor.

Facial electromyography. Surface EMG was recorded from the zygomaticus major and corrugator supercilii muscles on the left side of the face (Cacioppo, Petty, Losch, & Kim, 1986) using 4-mm miniature Beckman Ag/AgCl electrode pairs filled with designated gel.

Heart rate. The HR was extracted from the ECG signal that was recorded using two Silver EKG/ECG Electrodes (Model 93–0100-00), placed on the right collarbone and the 10th left rib.

Electrodermal activity. The EDA signal was collected using two disposable electrodes that were attached to the palmar surface of the middle phalanx on the index and middle fingers of the nondominant hand.

Data Reduction

Subjective feelings. Two feelings scales (Pleasure and Displeasure) were transformed into a single bipolar valence score by subtracting negative from positive (positive minus negative; see Itkes et al., 2017; Kron et al., 2015; Larsen et al., 2003).

Physiological measures. For all physiological indexes, activation during stimuli presentation was not compared with baseline ("event related") but to the other experimental conditions ("tonic"). The reason is that the effect of the probabilistic relevance manipulation was so strong that activation before stimuli

were even presented was high, rendering the use of the baseline suboptimal. SOM1 presents all results when the analyses are done in an event-related manner.

Facial electromyography. Experimenters unfamiliar with the experimental conditions removed the EMG artifacts (scratching, lip licking, biting, yawning, and other unrelated movements) by inspecting the video recordings. Data preprocessing was done using MATLAB R2014a (MathWorks Inc.). EMG signals were rectified and fed into a 20–450 Hz Butterworth bandpass filter (Butter, filtfilt, MATLAB). Tonic EMG scores for each stimulus were computed as the mean activation of the zygomaticus and the corrugator during 4 s after the onset of a score on the screen.

Heart rate. Analysis was performed using MindWare Technologies HRV 3.0.25 software. Signal was fed into a 5-Hz high-pass filter and HR tonic score was computed as the mean HR during the first 4 s after a score's onset.

Electrodermal activity. Analysis was performed using Mind-Ware Technologies EDA 3.0.25 software. The electrodermal signal was subjected to a 2-Hz Low Pass filter. EDA tonic score was computed as the mean of skin conductance level during the 4 s after a score's onset.

Analysis Strategy

A key feature of this study is the experimental control over the probability that the presented PET score was indeed the participant's final PET, which enabled examining its unique influence on the emotional response. Two contrasts test the effect of probability: parametric modulation of probability, that is, comparing three probabilities (1/12, 1/6, and 1/3), and binary modulation of probability, that is, comparing a condition in which information is relevant to the participant (one of the presented scores belongs to that participant) with a condition in which the relevance information is negligible, as the presented score belongs to another, unfamiliar participant.

Parametric modulation of probability. The parametric modulation of probability was estimated by computing the linear trend of the emotional response's intensity, to the same stimulus, when it appeared in each of the three probability conditions: 1/12, 1/6, and 1/3. Specifically, the linear trend was estimated by comparing these two simple slopes: the trend of intensity of the three probability conditions in the OWN condition (one of the scores belongs to the participant) and the same trend in the OTHER condition (one of the scores belongs to another, unknown participant). Importantly, in both conditions, participants knew that they would receive their own PET score in the last block of the experiment. The resulting interaction effect enables estimating the parametric effect of probability while controlling for two key alternative explanations: (a) that the effect is only an artifact of the participants gradually approaching the point in time in which they will learn their actual PET score, and (b) that the effect is an outcome of a confound between the decrease in (sub)block size and the probability condition—as the probability that one of the scores is the participant's increases, fewer stimuli (scores) are presented; a sequence's length can potentially affect the emotional response. Finally, this design enables us to control for any other unspecified psychological effects of "climax building" or "countdown," which may operate independently of whether the presented scores belong to the participant or to an unknown another.

Thus, comparing the trends of the OWN versus OTHER conditions substantially strengthens the claim that the source of any modulation of the emotional response (if one is found) associated with the increasing probability that one of the scores belongs to the participant is related that factor alone.

Binary modulation of probability. The effect of comparing relevant information (OWN) to near absence of relevance (OTHER) is estimated by the main effect of own score versus another participant's score on the intensity of the emotional response, over and above the interactive effect of probability.

Manipulation check. The manipulation check analysis examines the effect of positive and negative PET scores (as defined by "expected" and "required" scores). This analysis was performed only in the OWN condition.

Statistical model. Binary and parametric modulation of probability were analyzed in the context of a linear mixed model (SAS, proc mixed), with probability (1/12, 1/6, 1/3), ownership (OWN vs. OTHER), and score valence (negative vs. positive) as fixed factors, and subject as a random effect. The manipulation check was analyzed with valence ratings as a dependent variable, PET score valence as a fixed factor, and subject as a random effect.

Results

Self-Reports: Undifferentiated/General Feelings Scale

Parametric modulation of relevance. The positive linear trend of participant's self-report of general feelings in response to participants' OWN scores (positive and negative) that appeared in three probabilities (1/12, 1/6, and 1/3) was significant, $t(231) = 6$, $p < .0001$. The positive linear trend of participant's self-report of general feelings in response to OTHER participants' scores (positive and negative) that appeared in three probabilities (1/12, 1/6, and 1/3) was not significant, $t(211) = 0.57$. Importantly, the linear trend for probability was stronger in the OWN condition compared with the OTHER condition, providing support for a probabilistic relevance appraisal, $t(477) = 4.01$, $p < .0001$ (see Figure 2). This effect was not significantly different between the three valence conditions, $F(4, 471) = 0.54$.
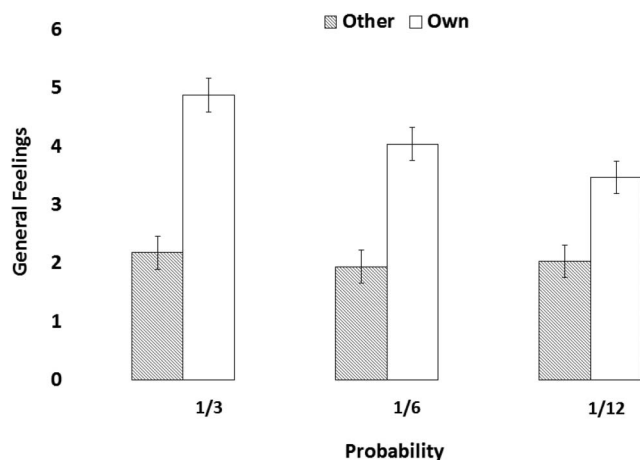

Figure 2. The effects of parametric and binaric modulations of probability on self-reported general feelings.

Binary modulation of relevance. Supporting the effect of an appraisal of binaric relevance on the emotional response, scores presented in the OWN condition resulted in stronger self-reported general feelings compared with scores presented in the OTHER condition, $F(1, 471) = 137$, $p < .0001$ (see Figure 2). The interaction between ownership factor (OWN vs. OTHER) and valence of score (positive, negative) was also significant, $F(1, 471) = 3.8$, $p < .052$, with negative and positive scores both demonstrating a significant effect of ownership, $F(1, 255) = 147$, $p < .0001$, and $F(1, 178) = 36$, $p < .0001$, respectively.

Self-Reports: Valence Scales

Valence of scores was defined relative to participants "expected score" (the final simulated test taken before the actual PET exam) and the "required score" (the minimal PET score required in order to be admitted to the university major and school as first priority; see also Stimuli section). Positive scores were defined as scores above both "simulation" and "required" scores, and negative scores were defined as scores below both "simulation" and "required" scores.

Valence manipulation check. The valence manipulation check examines the effect of positive and negative PET scores (as defined by "simulation" and "required" scores) in the OWN condition on self-reports of valence (see also Analysis Strategy section for the exact statistical model). Self-reports of valence in response to positive PET scores were significantly higher ($M = 2.5$) than self-reports in response to negative PET score ($M = -1.9$), $F(1, 481) = 274$, $p < .0001$.

Parametric modulation of probability. First, we examined whether the influence of parametric modulation of probability on self-reports of valence was sensitive to whether the PET score was positive or negative. To this aim, we compared the effect of parametric modulation of probability on positive versus negative scores. Parametric modulation of probability of positive scores resulted in a linear increase of valence score (reports become more positive with higher probability), whereas the opposite pattern was observed in negative scores (reports become more negative with higher probability); the difference between the trends was significant, $t(477) = 4.50$, $p < .01$.

Next, we performed two analyses for negative and positive PET scores. In the first analysis, we examined whether the linear trends of negative (or positive) scores were different between the OWN condition and the OTHER condition—this contrast aims to control for potential confound of the "countdown effect," or nearing the receipt of the actual PET score. In the second analysis, we examined the effect of binary manipulation of probability for negative and positive PET scores.

Negative Scores

Parametric modulation of probability. The positive linear trend of participant's self-report of valence in response to OWN negative scores that appeared in three probabilities (1/12, 1/6, and 1/3) was significant, $t(114) = 4.8$, $p < .0001$. The positive linear trend of OWN self-report of valence in response to OTHER negative scores that appeared in three probabilities (1/12, 1/6, and 1/3) was not significant, $t(106) = 24$. Supporting the parametric appraisal of relevance, the contrast of interaction between the two

linear trends of probability and the ownership factor (OWN vs. OTHER) was significant, $t(255) = 3.25$, $p < .001$ (see Figure 3).

Binaric modulation of probability. Supporting the categorical appraisal of relevance, scores that were presented in the OWN condition resulted in lower (more negative) self-reports than those presented as belonging to the OTHER condition, $F(1, 255) = 57.85$, $p < .0001$ (see Figure 3).

Positive Scores

Parametric modulation of probability. The positive linear trend of participant's self-report of valence in response to OWN positive scores that appeared in three probabilities (1/12, 1/6, and 1/3) was significant, $t(77) = 2.2$, $p < .03$. The positive linear trend of OWN self-report of valence in response to OTHER negative scores that appeared in three probabilities (1/12, 1/6, and 1/3) was significant, $t(69) = 2.4$, $p < .02$. No significant interaction between probability trend and ownership was found, providing no support for the probabilistic appraisal of relevance in the case of positive feelings, $F(1, 178) = 0.24$ (see Figure 4).

Binary modulation of probability. Supporting the binary appraisal of relevance, OWN scores resulted in stronger positive feelings compared with OTHER scores, $F(1, 178) = 26$, $p < .0001$ (see Figure 4).

Heart Rate

Parametric modulation of probability. No interaction was found between HR and valence of PET scores $F(1, 194) = 0.9$. The positive linear trend of HR in response to OWN scores that appeared in three probabilities (1/12, 1/6, and 1/3) was significant, $t(268) = 9.88$, $p < .0001$. The positive linear trend of HR in response to OTHER negative scores that appeared in three probabilities (1/12, 1/6, and 1/3) was significant, $t(268) = 6.69$, $p < .0001$. Importantly, a significant contrast of interaction between the linear trend for probability and the ownership factor on HR activity provides support for a parametric appraisal of relevance, $F(1, 570) = 5.7$, $p < .02$ (see Figure 5).
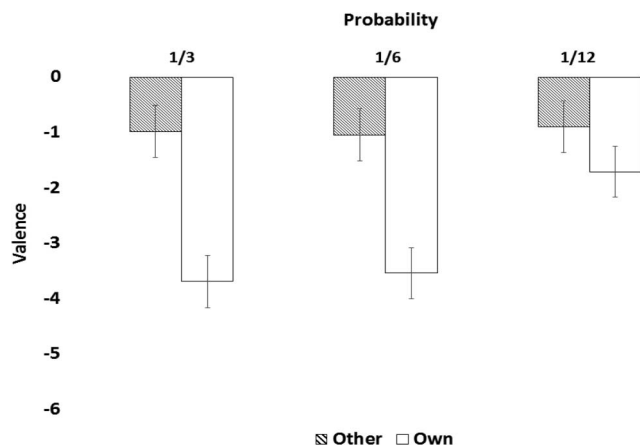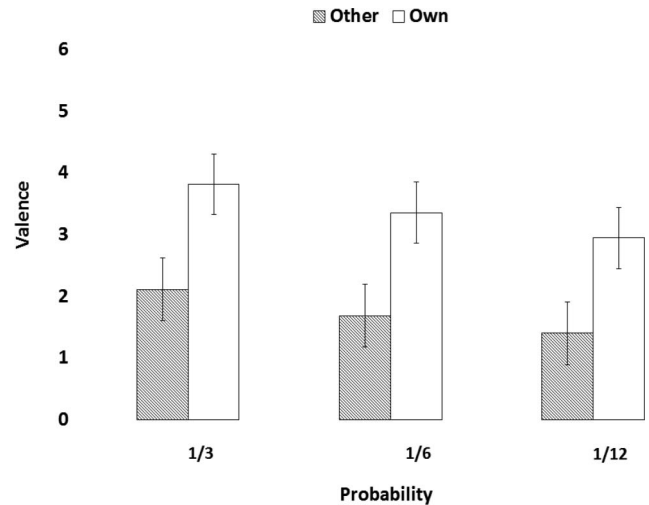

Figure 4. The effects of parametric and binaric modulations of probability on self-reported valence in response to positive Psychometric Entrance Test (PET) scores.

Binary modulation of probability. Supporting a binaric appraisal of relevance, OWN scores resulted in higher HR activity compared with OTHER scores, $F(1, 569) = 97$, $p < .0001$ (see Figure 5). The interaction between binaric relevance and valence of the scores was not significant $F(2, 557) = 2.18$.

Electrodermal Activity

Parametric modulation of probability. No interaction was found between HR and valence of PET scores $F(1, 196) = 1.53$. The positive linear trend of HR in response to OWN scores that appeared in three probabilities (1/12, 1/6, and 1/3) was significant, $t(270) = 3.68$, $p < .0003$ (Figure 6). The negative linear trend of HR in response to OTHER negative scores that appeared in three

Figure 3. The effects of parametric and binaric modulations of probability on self-reported valence in response to negative Psychometric Entrance Test (PET) scores.
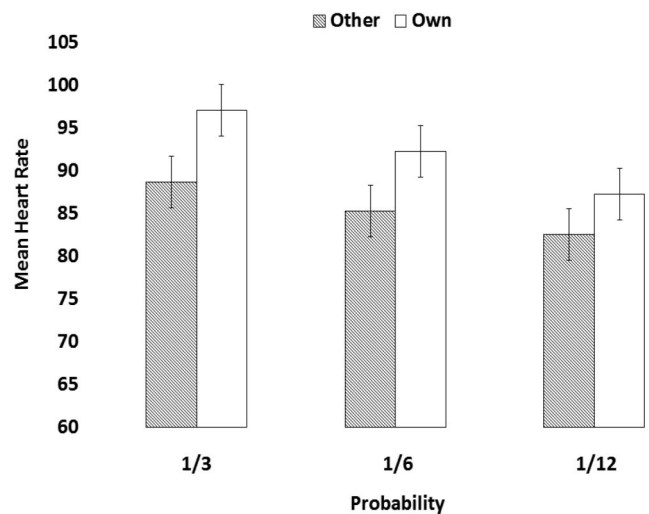

Figure 5. The effects of parametric and binaric modulations of probability on heart rate in response to positive and negative Psychometric Entrance Test (PET) scores.
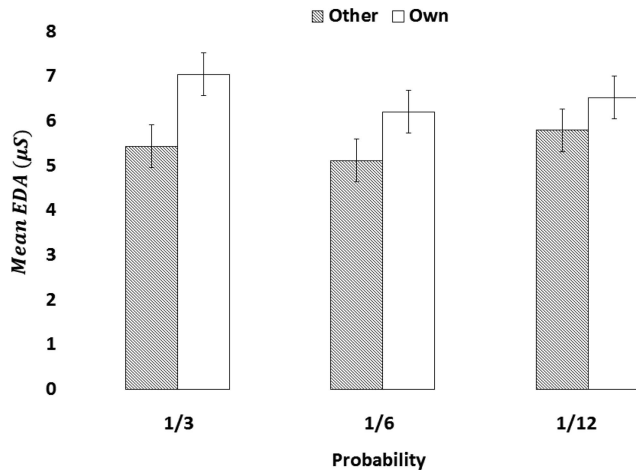
Figure 6. The effects of parametric and binaric modulations of probability on mean electrodermal activation in response to positive and negative Psychometric Entrance Test (PET) scores.

probabilities (1/12, 1/6, and 1/3) was significant, $t(270) = 2.67$, $p < .008$. Importantly, a significant contrast of interaction between the linear trend for probability and the ownership factor on EDA provides support for a parametric appraisal of relevance, $t(573) = 3.68$, $p < .0003$.

Binary modulation of probability. Supporting the binaric appraisal of relevance, OWN scores resulted in increased EDA compared with the one measured in the OTHER scores, $F(1, 573) = 138$, $p < .0001$. Interaction of binaric relevance with valence of scores was not significant $F(2, 561) = 0.76$.

Facial Electromyography

Intriguingly, no EMG activation of the zygomaticus or corrugator were found in response to the presentation of the scores—no parametric or binaric relevance effects, no differences between "positive" and "negative" scores, and none for probability beyond absolute relevance was found.[6]

Discussion

The current study examines the influence of information about stimulus' relevance on the generation of emotional response. To this aim, we used stimuli that relate to an important personal goal and manipulated relevance while keeping the stimulus constant. The effect of relevance was examined on four indexes of the emotional response: facial expressions, HR acceleration, electrodermal change, and self-report of feelings.

Relevance was operationalized by controlling the probability that the presented score was indeed the participant's final PET score. Probability was manipulated in two ways: binarily (one of the presented scores was the participant's own score vs. another participant's score) and parametrically (by presenting the PET score under three probabilities: 1/3, 1/6, and 1/12). Regarding the binaric manipulation of relevance, a series of scores, including the actual PET score of the participant, elicited stronger feelings, HR responses, and EDA than a series of scores that was presented as belonging to another participant. In regard to parametric manipu-

lation, effect of relevance was found for self-reported of general feelings, unpleasant feelings, HR, and EDA. No significant effect was found for parametric modulation of self-report of pleasant feelings.

In addition to the effect on emotional intensity, relevance is often conceived as goal conductive and goal obstructive. That is, with respect to the definition of relevance (e.g., a stimulus' relevance is proportional to the degree that the information it carries should modify the expectancy of achieving the goal; see Working Definitions section), appraisal of relevance can be more specific in regard to how it affects the probability of achieving a goal: Is it reducing or increasing the probability of achieving the goal? The results of the current study support such a distinction: Positive PET scores showed stronger effect of probability on self-reports of positive feelings than on negative feelings, and vice versa—negative PET scores showed stronger effect of probability on self-reports of negative feelings than on positive feelings.

These findings are consistent with appraisal theories assuming that relevance appraisal can influence the type or intensity of the emotional response (e.g., Clore & Ortony, 2000; Frijda, 2007; Lazarus, 1991; Reisenzein & Spielhofer, 1994; Roseman & Smith, 2001; Scherer, 2001). Previous findings support the existence of appraisal of relevance by using self-reports that directly asked about relevance (De Leersnyder et al., 2017; Scherer et al., 2006), by showing "beyond valence effect" (similar effect for positive and negative but not for neutral) that is interpreted as reflecting an underlying relevance appraisal mechanism (Brosch et al., 2008; Grandjean & Scherer, 2008; Walentowska et al., 2016), by gaze direction manipulation (e.g., N′Diaye′et al., 2009, Sander et al., 2007), and effect of relevance of expectancy (Roseman & Evdokas, 2004). The results of our study provide strong support for this line of research in two ways: the first potential contribution is that, in this study, we kept the stimuli constant and only changed their relevance. One of the challenges in appraisal research is keeping the stimulus constant and manipulating only the appraisal. Otherwise, changing both, appraisal and stimulus leaves it unclear whether the effect of interest is caused by changing the stimulus or changing its appraisal. By keeping the stimulus constant, we controlled for this alternative. A second potential contribution of this study is asking if appraisal detection is sensitive to parametric changes in probability. That is, the distinction between binaric versus parametric manipulation is relevant to two distinct features: as a feature of the input (the available information is either parametric or binaric) and/or as a feature of the appraisal process itself (e.g., regardless of whether the available information is parametric or binaric, the output of the process computing the relevance of stimuli is binaric). The results suggest that the output of the appraisal of relevance (the process) is sensitive to parametric changes in probability.

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[6] Surprisingly, additional analyses found no activity of the zygomaticus or corrugator during exposure to the final score (not presented here), suggesting the zygomaticus and corrugator are not activated in this specific emotional context. Additional examination of video clips ensured that the lack of effect was not a result of problems with the EMG signals, that is, arbitrary movements of facial expression were recorded, and coding of facial expressions from the video clips were consistent with the EMG showing no effect.

Interestingly, facial EMG of the area above corrugator/zygomaticus showed no influence of relevance manipulation. Facial EMG did not show any effect (neither positive vs. negative scores) or differences in intensity between the OWN scores condition and the OTHER scores condition. By examining the video and the signal, we verified that this lack of change in the corrugator and zygomaticus EMG signals are not related to problems with the EMG equipment (see also Footnote 6). Consequently, we conclude that zygomaticus and corrugator activation are not part of the emotional response profile in this specific context. These findings were added to previous results that show different, undifferentiated patterns of facial expressions when it comes to real-life, highly intense emotional responses (Aviezer et al., 2012). However, in contrast to Aviezer et al. (2012), who showed undifferentiated strong facial expressions, we showed no facial response.

Finally, self-reports of pleasant feelings showed an increase with probability and strong significant effect of binaric contrast but did not show a difference in slopes between the OWN scores versus OTHER scores conditions. Future research should determine whether the insignificant small effect of parametric modulation of probability in the case of positive stimuli is meaningful. Specifically, it should be determined whether the absence of this parametric modulation is replicated or it reflects random fluctuation; and if replicated, whether it is specific to this affective context, or it is more general to parametric modulation of positive stimuli.

To conclude, in accord with previous literature, the current research provides strong evidence for the role of relevance appraisal in the generation of emotional reactions. The appraisal of relevance was found to influence the intensity of the emotional response as reflected in self-reported and autonomic responses. Moreover, the emotional response was demonstrated to be sensitive to both binaric and parametric manipulation of probability and showed specificity according to the valence of the stimuli (negative, positive, or unspecified).

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