Running head: DIFFERENTIAL AND SEQUENTIAL APPRAISAL EFFECTS

First Evidence for Differential and Sequential Efferent Effects

of Stimulus Relevance and Goal Conduciveness Appraisal

Tatjana Aue, Anders Flykt, and Klaus R. Scherer

University of Geneva, Switzerland

Address correspondence for all authors to:
Tatjana Aue
Geneva Emotion Research Group
FPSE
Université de Genève
40, Boulevard du Pont d'Arve
1205 Genève
Switzerland
Tatjana.Aue@pse.unige.ch

Abstract

In the context of a memory task, participants were presented with pictures displaying biological and cultural threat stimuli or neutral stimuli (*stimulus relevance manipulation*) with superimposed symbols signaling monetary gains or losses (*goal conduciveness manipulation*). Results for heart rate and facial electromyogram show differential efferent effects of the respective appraisal outcomes and provide first evidence for sequential processing, as postulated by Scherer's (2001) component process model of emotion. Specifically, as predicted, muscle activity over the brow and cheek regions marking the process of relevance appraisal occurred significantly earlier than facial muscle activity markers of goal conduciveness appraisal. Heart rate, in contrast, was influenced by the stimulus relevance manipulation only.

First Evidence for Differential and Sequential Efferent Effects

of Stimulus Relevance and Goal Conduciveness Appraisal

Most of the past work on the physiological response characteristics of emotional

experiences has been motivated by the attempt to find consistent, specific patterns for a small

number of presumably "basic" or "fundamental" emotions. The results of these research activities

have thus far been inconsistent. A number of reviews and meta-analyses of the empirical studies

in this area (Cacioppo, Berntson, Larsen, & Poehlmann, 2000; Cacioppo, Klein, Berntson, &

Hatfield, 1993; Stemmler, 1989, 1992, 1996) have shown that, at most, differences between anger

and fear are consistently replicated for a small number of physiological parameters (mostly

related to cardiovascular activity).

Alternatives to basic emotions theory include, amongst others, psychophysiological

activation theory (Cacioppo, Berntson, & Crites Jr., 1996) and Obrist's (1976, 1981) work on

active and passive coping. This paper addresses still another alternative. Rather than adopting the

idea that affect programs produce a small number of fundamental emotion categories with

characteristic response patterns or that responses vary on only two dimensions, one can assume

that physiological response organization is driven by more molecular mechanisms. Those

molecular mechanisms are supposed to link the results of cognitive appraisal or evaluation

directly to small-scale adaptations of the central, autonomic, and somatic nervous systems in the

service of immediate local adaptations. In other words, bodily responses should vary as a

function of cognitive appraisal. The overall patterns of emotional experience, labeled in social

communication by terms such as anger, fear, or joy, would result from a sequential accumulation

of the molecular, appraisal-driven local effects. Suggestions of this kind have been made by

Scherer (1984, 2001) and Smith (1989) in the context of appraisal theory (see also Smith & Scott,

1997).

Scherer's (1984, 1986, 1987, 2001) component process model (CPM) defines emotion as a sequence of state changes in all of five functionally defined organismic subsystems: (a) the *cognitive* system (appraisal), (b) the *autonomic* system (arousal), (c) the *motor* system (expression), (d) the *motivational* system (action tendencies), and (e) the *monitor* system (feeling). At first, the organism appraises events on the basis of a series of sequential stimulus evaluation checks. These checks concern the *relevance detection* of an event (comprising novelty, intrinsic pleasantness, and goal relevance checks), its *implication assessment* (with causal attribution, outcome probability, discrepancy from expectation, goal/need conduciveness, and urgency checks), the individual's *coping potential determination* (including control, power, and adjustment checks), and finally the *normative significance evaluation* of the event (comprising internal and external standards checks). The result of each check is supposed to modify the state of all the other organismic subsystems described above in the direction of adaptation to the event. The pattern of an emotional reaction is therefore considered as the cumulative result of all these appraisal-driven state modifications and the ensuing feedback and feedforward interactions between the subsystems. These responses can, in turn, lead to modifications of the ongoing appraisals (see Scherer, 1984, 1986, 2001).

The outcome of one evaluation often depends on the information generated by a preceding appraisal. Thus, the assessment of the available coping potential requires information about the degree of goal conduciveness and the urgency of a reaction as an input. Given this differential delay, the efferent effects of the stimulus evaluation checks on the other subsystems are supposed to be sequential as well. Importantly, Leventhal and Scherer (1987) claim that each appraisal check can be performed on three different processing levels: the sensory-motor, the schematic, and the conceptual processing level. Thus, appraisal in the CPM comprises highly automatic as well as more effortful information processing.

The general utility of the appraisal approach in predicting physiological changes as a function of cognitive evaluations has been demonstrated in several experiments. Smith (1989) showed that the *anticipated effort* appraisal, as manipulated by different imagery scripts, was positively related to participants' heart rate. Furthermore, activity over the brow region (M. Corrugator supercilii) varied as a function of perceived *goal obstacles*. Pope and Smith (1994) replicated the latter finding in another experiment dealing with imagery tasks. Activity over the cheek region (M. Zygomaticus major), in contrast, was associated with the appraisal dimension *subjective pleasantness*, indicating that the experience of pleasant events led to more smiling than did the experience of unpleasant events.

Pecchinenda and Smith (1996) investigated the relation of skin conductance and *problem-focused coping potential* as defined by Lazarus (1991). Coping potential was varied via the manipulation of the difficulty of anagrams, which had to be solved by the participants, as well as the available resolution time. The authors concluded that increasing difficulty at first led to increased task engagement, but later to decreased engagement for the most difficult anagrams (perception of low coping potential). Thus, maximum skin conductance response amplitude and spontaneous response rate were positively related to the level of task engagement (comparable results are reported by Wright, Contrada, & Patane, 1986; Wright and Dill, 1993, for systolic blood pressure). This is in line with the general idea that autonomic nervous system responses, including heart rate and temperature changes, ought to represent mobilization effects for adaptive action preparation (e.g., Hamm, Schupp, & Weike, 2003; Jänig, 2003; Levenson, Ekman, & Friesen, 1990; Obrist, 1981).

Finally, Van Reekum, Johnstone, Banse, Etter, Wehrle, and Scherer (2004) manipulated appraisals of *intrinsic pleasantness* (pleasant versus unpleasant sounds) and *goal conduciveness* (attaining the next level or losing a spaceship) in a computer game. The intrinsic pleasantness

appraisal had only relatively weak effects on physiological responding. On the contrary, participants displayed greater skin conductance amplitudes and activity measured at the M. Extensor digitorum site as well as higher heart rate and shorter pulse transit time after having lost a spaceship than after having reached the next level. This result suggests stronger mobilization for the obstructive event as compared with the conducive event.

While the general appraisal approach has turned out to be promising, the proposed sequential nature of the appraisal process in Scherer's (1984, 1986, 1987, 2001) CPM has not yet been studied systematically in the context of psychophysiological responding. The major aim of the current experiment is to empirically test CPM predictions on differential latencies of different stimulus evaluation checks. The question is whether the presumed sequence of appraisals (in our case, goal or stimulus relevance preceding goal conduciveness) can be demonstrated through a sequential onset of physiological responses. Thus, this work has a pioneering character. We used an experimental design that combines a typical paradigm from Öhman's (1988, 1993, 1997) research on threat with a standard conduciveness manipulation (win/lose money). As, to our knowledge, testing predictions on the *sequential aspect* of appraisal with psychophysiological measures has never been attempted before, we could not rely on earlier data or paradigms.

Stimulus relevance was manipulated by confronting participants with biological (very high relevance) and cultural threat stimuli (high relevance) and with neutral stimuli (low relevance).[1] According to Öhman's (1988, 1993, 1997) preparedness theory, threats that have a long history from the evolution of humankind (i.e., dangerous animals) ought to elicit fear responding without any involvement of conscious awareness and to lead to remarkable mobilization of bodily resources for adaptive action preparation. Biological threat stimuli (e.g. snakes and spiders) are thought to be processed very rapidly on a preattentive level, activating hard-wired schemata of high relevance almost instantaneously. Cultural threat (e.g., guns and

tanks), in contrast, having appeared later in human history, should be a less effective trigger of automatic relevance schemata, possibly requiring more effortful processing at higher levels. Indeed there is some evidence (e.g., Flykt, 1998; Hugdahl & Johnsen, 1989; Hugdahl & Kärker, 1981), showing larger skin conductance amplitudes (as an index of mobilization) for biological as compared with cultural threat stimuli. Arguably, neutral stimuli are by definition less relevant to survival goals. There is no need for enhanced processing and no urgency for action preparation. Therefore, there should be virtually no mobilization effects.

In consequence, we expected physiological mobilization (as indicated by heart rate and temperature changes; e.g., Hamm, Schupp, & Weike, 2003; Jänig, 2003; Levenson, Ekman, & Friesen, 1990) to be more pronounced for biological threat stimuli than for cultural threat stimuli. Least changes were predicted for neutral stimuli. The expected differences in mobilization were supposed to be reflected in level or amplitude differences of the proposed physiological changes.[2] Also, we predicted stronger and more persistent activity over the brow region (M. Corrugator supercilii) for cultural in comparison with biological threat stimuli and also with respect to neutral objects, because the M. Corrugator supercilii is known to reflect ongoing cognitive processing (Darwin, 1872/1965; Scherer, 1992).

Goal conduciveness is expected to be processed later in the appraisal process than stimulus relevance. In the present experiment, goal conduciveness was operationalized by participants' expectations to win or lose money, based on the overwhelming evidence that obtaining rewards and preventing losses (or failure) constitute two central goals of any organism (e.g., Gray & McNaughton, 2000; Plutchik, 1980).

Based on Scherer's CPM (see Scherer, 1987, 2001, p. 110) and associated studies (e.g., Van Reekum, Johnstone, Banse, Etter, Wehrle, & Scherer, 2004), we postulated that heart rate would be most elevated in a goal obstructive condition and lowest in a neutral condition with a

goal conducive condition in between. This is because goal obstructive situations are generally characterized by a strong need to change existing circumstances and consequently also by higher personal engagement or effort. Task engagement, in turn, has been observed to be positively related to sympathetic nervous system activity (e.g., Pecchinenda & Smith, 1996; Wright, Contrada, & Patane, 1986; Wright and Dill, 1993). Furthermore, we expected an increase in activity over the cheek region (presumably caused by the innervation of the M. Zygomaticus major, action unit [AU] 12, Ekman & Friesen, 1978) in response to a goal conducive event, generalizing from the automatic reactions to intrinsic pleasantness (Pope & Smith, 1994; Steiner, 1977).[3] The anticipated response to a goal obstructive event comprised a pronounced increase in activity over the brow region (mostly due to innervation of the M. Corrugator supercilii, AU 4). The latter prediction is based on the common assumption, as well as some empirical evidence, that circumstances that impede progress toward reaching an important goal call for increased mental effort in order to find an adequate solution to overcome the obstacle (Darwin, 1872/1965; Pope & Smith, 1994; Smith, 1989; Waterink & van Boxtel, 1994).[4]

Our main hypothesis concerned the question whether there is evidence for onset differences of efferent appraisal effects manifest in physiological responding with stimulus relevance before goal conduciveness effects. As a consequence, differences between the stimulus relevance conditions were thought to be reflected earlier in bodily responses than differences between the goal conduciveness conditions.

Method

Participants

Forty-four (38 female) University of Geneva undergraduates, mainly psychology students, were recruited in the context of a course requirement or via ads posted in a university building.

Because of apparatus failure, 2 female participants had to be excluded from all analyses. The remaining 42 participants were aged between 19 and 40 years ($M = 22.1$, $SD = 4.55$). Another female participant was excluded from the heart rate analyses because of abnormal arrhythmia. On the basis of a random procedure, students were paid an amount between 3 and 12 CHF for their participation (independently of the goal conduciveness manipulation described below).

Experimental Design

A $3 \times 3 \times 2$ within-subjects design resulted from the manipulation of three factors:

1. Stimulus Relevance (manipulated by different picture contents)

Fifty-four pictures displaying either biological threat (i.e., snakes and spiders, angry human faces), cultural threat (i.e., tanks and guns), or neutral stimuli (i.e., mushrooms and chairs) were chosen from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 1999; $n=45$) and the Internet ($n=9$). Biological and cultural threat stimuli stemming from the IAPS were matched for Lang et al.'s (1999) valence and arousal ratings (for a list of the selected IAPS pictures and the respective valence and arousal ratings, see Appendix).

2. Goal Conduciveness

Purportedly losing 2 CHF, purportedly neither winning nor losing money, and purportedly winning 2 CHF were indicated by different symbols superimposed on the pictures (§, %, and &). Specifically, attention was called to the iconic character of the symbols included in this study. Participants were informed that (a) the § symbol was related to law, signifying penalty; (b) the % symbol included zeros, indicating that the participant neither won nor lost money; and (c) the & symbol implied that something was added. These superimposed, slightly transparent symbols covered the entire picture and were thus even larger than most objects displayed on the pictures. Because of their transparency, the symbols did not impede the recognition of the picture content.

3. Color Scheme

In order to control for the relative prominence of the picture content and the superimposed symbol as well as attention recruitment, the 54 pictures were presented in the form of two different color schemes: 27 colored pictures with gray symbols superimposed and 27 gray-scale pictures with colored symbols superimposed. Clearly, if the picture content had always been presented in color and the symbols always in gray scale, picture content would probably have systematically caught more attention than the superimposed symbol (because of the attraction effect of color).

Participants were presented with three blocks of 18 pictures each, separated by two short relaxation periods to prevent fatigue. Each block consisted of nine gray-scale and nine colored pictures. Picture contents and goal conduciveness symbols were balanced within the blocks. In total, 324 different combinations of Stimulus Relevance, Goal Conduciveness, and Color Scheme were included in the experiment, establishing six different versions of 54 pictures, which were systematically varied over participants.

Setting and Apparatus

Participants were seated comfortably in a reclining position, facing a computer screen at a distance of approximately 1.4 m (picture size: 16 cm × 24 cm) in a sound attenuated room (3.50 m × 4 m). Physiological signals were assessed with the TEL 100 Remote Monitoring System of Biopac Systems (Santa Barbara, CA) with separate settings for the electrocardiogram, electromyogram (EMG), and temperature channels. Signals were transferred from the experimental room to the MP100 Acquisition Unit (16 bit A/D conversion) in an adjacent room and stored on computer hard disc. Experimental control, like picture presentation and synchronization, was performed by the Experimental Run Time System (version 3.28; BeriSoft Cooperation, Frankfurt am Main, Germany) running on a second computer.

Procedure

Participants were told that they were taking part in a memory experiment. After having signed a consent form, they were informed that the aim of the study was to investigate the effects of gains or losses (as indicated by symbols superimposed on pictures) on memory and physiological responses. Gains consisted of purportedly adding 2 CHF to their total credit for the presentation of the symbol "&" and losses of purportedly subtracting 2 CHF for the presentation of the symbol "§." The symbol "%" indicated that money was neither subtracted nor added. The starting value was zero. Participants were also informed that the symbols appeared randomly and that they were not related to the picture content. Each picture was displayed for 5 s.

Following each picture, participants were asked to indicate via vocal response (a) the kind of object they had seen on the picture, and (b) whether they purportedly lost money, won money, or neither lost nor won money. These two questions were presented in random order and served as a manipulation check for (a) stimulus relevance (picture content) and (b) goal conduciveness. All trials in which the depicted object or symbol had not been identified correctly were excluded from subsequent statistical analyses. Vocal responses were spoken into a microphone, digitized via an A/D converter, and recorded on hard disk. They were also written down by the experimenter. A training block preceded the real experiment in order to familiarize the participants with the task and especially the symbols.

Participants were asked in a postinterview whether they had experienced any harm by the picture presentation and whether they suffered from a specific form of phobia. This was done in order to ensure that results could not be attributed to such influences. Before leaving the laboratory, participants were debriefed and received an amount between 3 and 12 CHF for their participation. Different amounts were paid in order to prevent manipulation failure due to students communicating the amount of money they had won to their fellow students who were to

participate in the experiment at a later date. If, for example, a given participant had the

information that all of his fellow students had won 8 CHF, he or she would surely have guessed

that the frequency of occurrence of each of the different symbols appearing on the screen was

predefined and consequently would have doubted the cover story of the study.

Dependent Variables

As our main focus concerned small differences in timing of response onset, we preferred

to measure physiological variables like heart rate and muscle activity, which are characterized by

relatively short latencies (especially EMG measures) and therefore optimally suited to examine

sequential effects of appraisal on efferent responses. Additionally, temperature measures were

included to provide an additional indicator for mobilization effects, as indexed by heart rate

changes. The following physiological signals were recorded continuously with a sampling rate of

1000 Hz.

Heart rate. Heart rate was assessed by the use of Biopac pre-gelled disposable electrodes

fixed under the left and right armpits. A third electrode was placed on the neck and served as

ground. The signal was amplified by 1,000 and low-pass filtered (45 Hz).

Facial muscle activity at two different sites ((a) activity over the cheek region, measured

over the M. Zygomaticus major; (b) activity over the brow region, measured over the M.

Corrugator supercilii). Skin was first cleansed with PDI (Orangeburg, Canada) electrode prep

pads consisting of 70% alcohol and pumice. Two 4-mm Biopac Ag/AgCl surface electrodes per

site were placed according to the guidelines of Fridlund and Cacioppo (1986). The conducting

medium was Signa Gel of Parker Laboratories, Inc. (Fairfield, NJ). An electrode fixed near the

midline of the forehead served as ground. Raw EMG was amplified by 2,000 and high-pass

filtered (30 Hz). Signals were then rectified and smoothed by a moving average (length: ± 20

ms).

Finger and arm temperature. Finger temperature was measured by using the Biopac Smart Sensor 18 Digit Surface Temperature Probe, placed on the distant phalanx of the little finger of the nondominant hand. Arm temperature was assessed via the Biopac Smart Sensor 7 Skin Surface Temperature Probe, fixed on the M. Extensor digitorum. Both signals were amplified by 1,000 and low-pass filtered (10 Hz).

Data Analysis

All analyses of the physiological signals were performed with PPP 6.11 (2003; eXtra Quality Measurement Systems, Frankfurt am Main, Germany).

Heart rate. Heart rate during the 2 s before picture onset served as baseline. Five heart rate task scores were computed, one for each of the 5 s following stimulus presentation (0-1 s, 1-2 s, 2-3 s, 3-4 s, and 4-5 s, respectively). Thus, there are five different heart rate task scores for each picture, representing heart rate changes with respect to baseline at different times after stimulus onset.[5]

Facial muscle activity. A logarithmic transformation was undertaken to normalize the distribution, as the EMG measures were characterized by positive skewness. (a) Similarly to heart rate task scores, EMG task scores constituted mean muscle activity during each of the five 1-s intervals following stimulus onset (overall picture presentation time). The time interval of 1 s before picture onset to picture onset was used as baseline. (b) Given that muscle activity is a short latency signal and changes rapidly over time, and given our need for high time resolution to discover subtle sequence effects of appraisal-generated responses, we analyzed the first 1-s interval following picture onset in greater detail. Five micro task scores were computed for each 200-ms period during the first 1-s interval after stimulus onset (0-200 ms, 200-400 ms, 400-600 ms, 600-800 ms, 800 to 1,000 ms).

Finger and arm temperature. Because temperature, in general, changes relatively slowly and is often not reliable for short time segments, mean arm and finger temperatures were calculated for the whole picture presentation time (5 s). Mean arm and finger temperatures during the 2 s preceding picture onset were taken as baselines.

Outliers (deviating more than three standard deviations from the mean value of a given participant during a particular time interval) and artifacts were eliminated from all physiological data (making up approximately 1% of all data). Baseline scores were then subtracted from task scores to obtain difference scores describing physiological changes resulting from the presentation of the different stimuli.

Analyses of variance (ANOVAs) for repeated measures (SPSS 12.0) were computed for the 3 (Stimulus Relevance) × 3 (Goal Conduciveness) × 2 (Color Scheme) within-subjects design. For variables, which were assumed to capture temporal aspects of the appraisal process (heart rate and EMG), we added a fourth factor: Time (five levels). In describing the results, we refer to these analyses when describing results of the three-factorial ANOVA and the four-factorial ANOVA, respectively. An alpha level of .05 was used for all statistical tests. In the case of nonsphericity, effects were Greenhouse-Geisser corrected.[6] If, for EMG and heart rate data, the four-factorial ANOVA yielded a significant interaction effect for either Time × Stimulus Relevance or Time × Goal Conduciveness, (a) a priori specified contrasts were calculated for every time interval for the above-described hypotheses concerning Stimulus Relevance and Goal Conduciveness, and (b) three-factorial ANOVAs with the factors Stimulus Relevance, Goal Conduciveness, and Color Scheme were performed on each time interval, when no a priori hypotheses had been established. All reported effect sizes are partial η^2 and simply noted as η^2. Only main effects and interactions directly related to our research questions are described in the Results section. For better visualization of the results, we include figures instead of tables.

Results

Manipulation Check

Participants remembered the picture content (stimulus relevance manipulation) very well and made virtually no mistakes (<1%). They had more difficulties recalling which symbol had been superimposed on the picture (indicating the degree of goal conduciveness). Of the answers concerning the goal conduciveness manipulation check, 5.8% were incorrect and the respective trials were excluded from further analyses.

Heart Rate

The four-factorial ANOVA revealed an interaction effect of Time × Stimulus Relevance, $F(8, 320) = 2.33$, $p < .05$, $\eta^2 = .06$ (see Figure 1). Planned contrasts comparing biological threat and neutral objects achieved significance for the third, fourth, and fifth time intervals, $Fs(1, 40) = 2.96, 7.39$, and 12.70, $ps < .05, .05$, and $.001$, $\eta^2 s = .07, .16.$, and $.24$, respectively. For the fourth time interval, there was furthermore, a trend for the difference between biological and cultural threat stimuli, $F(1, 40) = 1.95$, $p = .09$, $\eta^2 = .05$, and for the last time interval, cultural threat could be distinguished from neutral objects, $F(1, 40) = 3.21$, $p < .05$, $\eta^2 = .07$. All observed differences are in accordance with predictions, though the difference between biological and cultural threat did not pop up as strongly as expected. Taken together, biological threat stimuli provoked most heart rate acceleration. Least acceleration resulted from the presentation of neutral stimuli. Contrary to predictions, we found neither a significant main effect for Goal Conduciveness, $F(2, 80) = 0.83$, *ns*, $\eta^2 = .02$, nor a significant interaction effect of Time × Goal Conduciveness, $F(8, 320) = 0.82$, *ns*, $\eta^2 = .02$ in the four-factorial ANOVA.

Insert Figure 1 about here

Facial Muscle Activity

Activity Over the Cheek Region

Intervals of 200 ms (during first 1-s interval of picture presentation). The four-factorial ANOVA showed only a significant interaction of Time × Stimulus Relevance, $F(8, 328) = 5.13$, $p < .001$, $\eta^2 = .11$ (see Figure 2). Five three-factorial ANOVAs (one performed for each time interval) showed an effect of Stimulus Relevance only for the fifth time interval describing activity over the cheek region from 800 to 1000 ms following stimulus onset, $F(2, 82) = 4.57$, $p < .05$, $\eta^2 = .10$, where cultural threat was characterized by lower activity over the cheek region than either biological threat or neutral situations. Post hoc tests revealed that the differences between cultural threat, on the one hand, and neutral situations and biological threat, on the other hand, were significant, Fs$(1, 41) = 8.17$ and 4.89, ps $< .01$ and $.05$, η^2s $= .17$ and $.11$, respectively.

Insert Figure 2 about here

The results may indicate that our participants displayed more grimacing in response to biological threat as compared with cultural threat. The four-factorial ANOVA did not display a significant main effect for Goal Conduciveness, $F(2, 82) = 0.13$, *ns*, $\eta^2 = .00$, or a significant interaction effect of Time × Goal Conduciveness, $F(8, 328) = 0.63$, *ns*, $\eta^2 = .02$.

Intervals of 1 s (over entire period of picture presentation). The four-factorial ANOVA showed a highly significant main effect of Stimulus Relevance, $F(2, 82) = 8.79$, $p < .001$, $\eta^2 = .17$. Whereas the presentation of biological threat led to an increase in activity over the cheek region, cultural threat was accompanied by a decrease ($M_{biological} = 0.059$; $M_{cultural} = -0.027$; $M_{neutral} = 0.008$).[7] Post hoc contrasts showed that biological threat could clearly be distinguished from both cultural threat and neutral situations, Fs$(1, 41) = 14.58$ and 7.38, ps $< .001$ and $.05$, η^2s $= .26$ and $.15$, respectively.

This main effect was qualified by a significant Time × Stimulus Relevance interaction, $F(8, 328) = 3.77$, $p < .01$, $\eta^2 = .08$ (see Figure 3). Three-factorial ANOVAs, performed separately for each time interval, revealed no difference between different types of picture content during the first 1-s interval, $F(2, 82) = 0.24$, ns, $\eta^2 = .01$. In contrast, there was a significant main effect of Stimulus Relevance for the four remaining time intervals, Fs$(2, 82) = 8.86$, 9.53, 5.80, and 3.77, ps $< .001$, $< .001$, $< .005$, and $< .05$, η^2s $= .18$, $.19$, $.12$, and $.08$, for the second, third, fourth, and fifth time intervals, respectively. Post hoc tests showed that responses toward biological threat differed from cultural threat for all time intervals concerned, Fs$(1, 41) = 12.35$, 15.95, 10.39, and 4.74, ps $< .001$, $.001$, $.005$, and $.05$, η^2s $= .23$, $.28$, $.20$, and $.10$, for the second, third, fourth, and fifth intervals, respectively. Biological threat could be distinguished from neutral objects in these periods as well, Fs$(1, 41) = 4.35$, 6.21, 4.63, and 6.24, all ps $< .05$, η^2s $= .10$, $.13$, $.10$, and $.13$, for the second, third, fourth, and fifth intervals, respectively. Finally, differences between cultural threat and neutral stimuli were observed for the second and third time intervals, Fs$(1, 41) = 7.11$ and 4.37, both ps $< .05$, η^2s $= .15$ and $.10$, respectively.

Insert Figure 3 about here

There was a trend for the influence of Goal Conduciveness on activity over the cheek region (1-s intervals) in the four-factorial ANOVA, $F(2, 82) = 2.81$, $p = .07$, $\eta^2 = .06$. As expected, greatest activity was observed for the trials in which participants thought that they were winning 2 CHF ($M_{lose} = 0.011$; $M_{neutral} = -0.012$; $M_{win} = 0.039$). Planned contrasts attained significance only for the difference between the winning and the neutral condition, $F(1, 41) = 5.84$, $p < .05$, $\eta^2 = .13$. However, there was a trend for the difference between the losing and winning condition as well, $F(1, 41) = 1.79$, $p = .09$, $\eta^2 = .04$.

The main effect of Goal Conduciveness was qualified by the significant interaction effect of Time $\times$ Goal Conduciveness, $F(8, 328) = 3.23$, $p < .01$, $\eta^2 = .07$ (see Figure 4). Planned comparisons for Goal Conduciveness performed on each time interval already revealed trends for the differences between the winning sign and the neutral sign for the second and third time intervals, Fs$(1, 41) = 2.20$ and 2.57, ps $= .07$ and $.06$, η^2s $= .05$ and $.06$, respectively. The same comparison was significant for the fourth and fifth time intervals, Fs$(1, 41) = 10.69$ and 7.52, both ps $< .005$, η^2s $= .21$ and $.16$, correspondingly. Additionally, the contrast for the difference between the winning and losing condition reached significance for the fourth interval, $F(1, 41) = 3.58$, $p < .05$, $\eta^2 = .08$.

Insert Figure 4 about here

A comparison of the results on activity over the cheek region for the two types of appraisal shows that the effect of Stimulus Relevance, though not related to a priori hypotheses, appears earlier (starting at 800 to 1000 ms after picture onset) than the effect of Goal Conduciveness (starting at about 1 s after picture onset). This can be interpreted as evidence that goal or stimulus relevance is processed earlier than goal conduciveness.

Activity Over the Brow Region (M. Corrugator supercilii)

Intervals of 200 ms (during first 1-s interval of picture presentation). The four-factorial ANOVA showed a main effect of Stimulus Relevance, $F(2, 82) = 3.30$, $p < .05$, $\eta^2 = .07$. Planned contrasts revealed significant differences between cultural threat, on the one hand, and biological threat and neutral objects, on the other hand, $F\text{s}(1, 41) = 7.46$ and 3.30, $p\text{s} < .005$ and $.05$, $\eta^2\text{s} = .15$ and $.08$, for the comparisons cultural threat-biological threat, and cultural threat-neutral, respectively. As expected, cultural threat stimuli were accompanied by greater activity over the brow region than were neutral and biological threat stimuli ($M_{\text{biological}} = 0.054$; $M_{\text{cultural}} = 0.081$; $M_{\text{neutral}} = 0.059$).

The main effect of Stimulus Relevance was qualified by the marginally significant interaction effect Time × Stimulus Relevance, $F(8, 328) = 2.37$, $p = .05$, $\eta^2 = .06$ (see Figure 5). Planned contrasts revealed that biological threat differed from cultural threat from 400 ms on, $F\text{s}(1, 41) = 5.30, 7.99,$ and 6.59, $p\text{s} < .05, .005,$ and $.01$, $\eta^2\text{s} = .11, .16,$ and $.14$, for 400 to 600 ms, 600 to 800 ms, and 800 to 1,000 ms, accordingly. Likewise, neutral images could be distinguished from cultural threat in the same time intervals, $F\text{s}(1, 41) = 3.95, 4.05,$ and 4.59, all $p\text{s} < .05$, $\eta^2\text{s} = .09, .09,$ and $.10$.

Insert Figure 5 about here

As predicted, analysis of cultural threat seems to require more extensive cognitive processing than analysis of biological threat, reflected in longer processing time (as indexed by Corrugator activity) for cultural threat stimuli than for both biological threat stimuli and neutral stimuli. Interestingly, differential responding for the picture contents is reflected earlier in activity over the brow region than in activity over the cheek region (starting at about 800 to1,000 ms after picture onset). The four-factorial ANOVA did not yield a significant main effect for Goal Conduciveness, $F(2, 82) = 0.74$, *ns*, $\eta^2 = .02$, or a significant interaction effect of Time $\times$ Goal Conduciveness, $F(8, 328) = 1.15$, *ns*, $\eta^2 = .03$.

Intervals of 1 s (over entire picture presentation). The four-factorial ANOVA revealed a significant main effect of Stimulus Relevance, $F(2, 82) = 3.63$, $p < .05$, $\eta^2 = .08$, describing the same effect as reported in the preceding section. Paired comparisons revealed, as predicted, significant differences between cultural threat and both biological and neutral objects, Fs$(1, 41) = 5.82$ and 3.62, both ps $< .05$, η^2s $= .12$ and $.08$, for the contrasts cultural threat-biological threat and cultural threat-neutral, accordingly. Activity over the brow region was more elevated for cultural threat stimuli than for biological threat and neutral stimuli ($M_{biological} = 0.039$; $M_{cultural} = 0.081$; $M_{neutral} = 0.047$,).

Interestingly, there was a trend for the interaction Time $\times$ Stimulus Relevance $\times$ Goal Conduciveness, $F(16, 656) = 1.73$, $p = .08$, $\eta^2 = .04$. Visual inspection showed that differences in activity over the brow region between the goal conduciveness conditions could only be observed when the symbols were displayed on top of neutral picture contents (see Figure 6). In that case, activity over the brow region was stronger for losing trials than for neutral and winning trials.

This suggests that the effect of Goal Conduciveness is masked or diminished by the effect of both biological and cultural threat stimuli (manipulation of stimulus relevance).

In consequence, we performed a subanalysis for neutral picture content only. We found a significant interaction of Time $\times$ Goal Conduciveness, $F(8, 328) = 2.64$, $p < .05$, $\eta^2 = .06$. Planned contrasts revealed, in accordance with predictions, greater activity over the brow region for the losing as compared with the neutral conduciveness condition for 2 to 3 s and 3 to 4 s after picture onset, Fs$(1, 41) = 3.25$ and 5.52, both ps $< .05$, η^2s $= .07$ and $.12$, respectively. Additionally, for both time intervals, higher activity was observed for the losing than for the winning condition, Fs$(1, 41) = 3.11$ and 4.06, both ps $< .05$, η^2s $= .07$ and $.09$, for 2 to 3 s and 3 to 4s after picture onset, correspondingly. In conclusion, as in the case of activity over the cheek region, the effect of the goal conduciveness appraisal on Corrugator activity appears late in comparison with the effect of stimulus relevance appraisal.

Insert Figure 6 about here

Temperature Measures

Three-factorial ANOVAs on arm temperature and finger temperature data yielded no significant effects. The considered time interval (5 s) was probably too short to allow the appearance of differential responding toward the different stimulus relevance and goal conduciveness conditions. Figure 7 summarizes relevant results of the statistical analyses performed on the different physiological variables.

Insert Figure 7 about here

Discussion

Our main hypothesis was that the proposed sequential nature of the appraisal process (Scherer, 1984, 2001) should be manifest in physiological responding. Differences between the stimulus relevance conditions were thought to be reflected earlier in bodily responses than differences between the goal conduciveness conditions. First, we will discuss the efferent effects of the stimulus relevance appraisal. Second, we will do the same with the goal conduciveness appraisal. Finally, the sequential nature of these efferent effects will be outlined.

Stimulus Relevance Appraisal

We expected that biological threat should be processed more rapidly and lead to stronger response mobilization than cultural threat because of its earlier presence in the history of humankind (see Öhman, 1993, 1997). Our data provide evidence for differential processing of and resource mobilization for the two types of threat. Not surprisingly there was also a clear difference between images displaying both kinds of threat and images without threat content.

Specifically, we found that, as expected, heart rate acceleration was positively related to goal relevance, with strongest resource mobilization for biological threat and least for neutral stimuli, where there is no need for a particular response preparation.[8] Contrary to expectations, however, the difference between biological and cultural threat was negligible. Activity over the brow region was comparable for neutral objects and biological threat and could clearly be distinguished from cultural threat, which was accompanied by a strong increase in Corrugator activity. As predicted, processing of cultural threat seems to demand more cognitive effort than

processing of biological threat, suggesting particular sensitization to phylogenetically based threat.[9]

Somewhat unexpectedly, muscle activity measured over the cheek region was mostly elevated during the presentation of biological and least during the presentation of cultural threat stimuli. A common argument is that activity over the cheek region reflects positive affect. Consequently, one could claim that our manipulation of biological threat did not succeed and did not activate the fear or defense system. We do not agree. Instead, several observations suggest that high activity over the cheek region, depending on its nature, can even be considered a good indicator of defense system activation. First, EMG activity can be largely subject to cross-talk between adjacent muscles, which is particularly important in the lower part of the face (Lapatki, Stegeman, & Jonas, 2003). Human facial expressions of fear are often accompanied by muscle activity around the Zygomaticus major site (e.g., Elgee, 2003; Ekman, 2003). Comparably, the facial expression in monkeys corresponding to M. Risorius activation has been variously called *fear-grin*, *fear grimace*, *grin-face*, or *bared-teeth display* and is described as "possible primate homologue of laughter and smiling" (Van Hooff, 1972, p. 212). It is also thought to be characteristic of defensive or submissive behavior, followed by affiliative behavior (e.g., Waller & Dunbar, 2005). Second, the literature on picture viewing reports evidence of strong activation of the M. Zygomaticus major during the presentation of negative pictures, related to the emotions of fear and disgust (e.g., pictures displaying mutilations; see Bradley, 2000, p. 622; Larsen, Norris, & Cacioppo, 2003). Also, van Boxtel (personal communication, August 30, 2006) reports having frequently observed such "paradoxical laughter" (elevated activity over the cheek region for different types of negative stimuli) in his own studies.[10]

Importantly, the consideration that differential responses to biological and cultural threat reflect differences in valence or arousal can be ruled out because stimuli of both categories were

matched with respect to both valence and arousal ratings stemming from Lang et al. (1999).

Thus, we can preclude that different degrees of negative affect are responsible for the observed

effects.

Goal Conduciveness Appraisal

We postulated heart rate to be most elevated in the winning condition and lowest in the

neutral condition with the losing condition in between. Furthermore, we expected an increase in

activity over the cheek region in response to the goal conducive event and a pronounced increase

in activity over the brow region in response to the goal obstructive event.

There is some indication that goal conduciveness is reflected in facial EMG, but not in

heart rate data. As expected, we observed greatest activity over the cheek region in the winning

condition at particular time intervals. Further evidence of a goal conduciveness effect appeared in

activity over the brow region (frowning in the case of purportedly losing money). However, the

latter effect only appeared for pictures displaying neutral objects. This result suggests a priority

of strong stimulus relevance over goal conduciveness processing when confronted with threat.

Yet, results might have been different if we had manipulated more important goals for the

conduciveness check. As both threat categories are related to survival, this goal should have

precedence over losing or winning small amounts of money.

There are several alternative interpretations for the relatively sparse and weak effects of

the goal conduciveness manipulation on physiological responding. It is possible that some

participants did not believe that they would really win or lose money. In any case, "loss" in this

experiment only meant not to win any money. In addition, in the present design, the goal

conduciveness manipulation was not related to the participants' own behavior. As they were not

able to change the contingencies with respect to the outcome (having been told that the outcome

for each trial was determined randomly), there was no need for an action preparation or resource

mobilization. This probably explains the absence of significant goal conduciveness effects on heart rate data. Concerning heart rate, one can also speculate about whether the examined time interval was too short for goal conduciveness to pop out. Nonetheless, we do not think that it should take more than 5 s for it to do so.

Sequential Efferent Effects of the Included Appraisals

In essence, our data provide first evidence for the hypothesis that the appraisal process is organized in a sequential fashion and that different appraisals have efferent effects on physiological responses at different points in time, as postulated by Scherer's (2001) CPM (see Figure 7). An effect of stimulus relevance could be shown to start at about 500 ms after picture onset for activity over the brow region and at 800 to 1,000 ms for activity over the cheek region. In contrast, the effect of goal conduciveness on activity over the cheek region attained significance only after 1 s. Thus, effects of the goal or stimulus relevance check clearly preceded those of the goal conduciveness check. Together with the evidence for prioritization of stimulus relevance processing over goal conduciveness processing (the latter being visible at about 2 s after stimulus onset, but only for neutral picture content), as reflected in activity over the brow region, this result supports the notion that the appraisal process and its efferent peripheral effects occur in sequential order.[11] The reason that the effect of stimulus relevance was reflected earlier in activity over the brow region than in activity over the cheek region may be that activity over the brow region is implicated in the *processing* of the relevance check, whereas activity over the cheek region is related to the *outcome* of this appraisal.

Although, as always, more research is needed to replicate and extend the results to elucidate the underlying mechanisms, the current study underlines the utility of the general approach (i.e., manipulating appraisal outcomes experimentally and measuring their efferent effects over time). With respect to the research on basic or fundamental emotions, our results

strengthen the idea that there is no specific situation that is anger provoking or fear provoking per se. Instead, one should aim to manipulate specific individual appraisals in a given situation. The accumulation of efferent effects corresponding to these appraisals should then determine the final physiological response pattern.

However, an important issue to consider when studying sequential effects of the appraisal process concerns the dynamic properties (i.e., latency) of different physiological responses. Temperature changes, for example, are generally slower than heart rate changes, and those are slower than muscle activity changes. Physiological measures can provide information about the sequence of the appraisal, but not about the exact timing parameters (such as onset and duration). As a consequence, it is difficult to conclude that a certain appraisal check precedes another one, when the respective efferent effects are manifest in different physiological variables with different dynamic properties. However, a sequence interpretation seems justified if two different appraisals have an effect on the same variable at different moments in time (as was the case for the EMG measures in this study).

Our hypotheses required testing in terms of an interaction effect between type of stimulus and particular points in time in order to examine efferent effects on different physiological variables. The ANOVA techniques and contrasts used in this study are the most appropriate means of analysis because they allow directed tests. But, clearly, the dynamic nature of appraisal and the unfolding of emotional response patterns invites process-oriented analyses such as time-series approaches. The problem is that most of these methods require a large number of observations, with continuous fluctuations over time, to be applicable. In addition, it is difficult to test directed hypotheses between two points in time with such techniques. Nonetheless, in future work, it may pay off to develop designs that allow continuous measurement and dynamic modeling.

References

Bänninger-Huber, E., & Rauber-Kaiser, S. (1989). Die Differenzierung verschiedener

Lächeltypen: FACS-Codierung und Einschätzungen. Eine Untersuchung zur

Eindrucksbildung. *Schweizerische Zeitschrift für Psychologie, 48,* 21-34.

Berntson, G. G., Cacioppo, J. T., & Quigley, K. S. (1991). Autonomic determinism: The modes

of autonomic control, the doctrine of autonomic space, and the laws of autonomic constraint.

Psychological Review, 98, 459-487.

Berntson, G. G., Cacioppo, J. T., & Quigley, K. S. (1993). Respiratory sinus arrhythmia:

Autonomic origins, physiological mechanisms, and psychophysiological implications.

Psychophysiology, 30, 183-196.

Bradley, M. M. (2000). Emotion and motivation. In J. T. Cacioppo, L. G. Tassinary, & G. G.

Berntson (Eds.), *Handbook of psychophysiology* (pp. 602-642). New York: Cambridge

University Press.

Cacioppo, J. T., Berntson, G. G., & Crites, S. L., Jr. (1996). Social neuroscience : Principles of

psychophysiological arousal and response. In E. T. Higgins & A. W. Kruglanski (Eds.),

Social psychology: Handbook of basic principles (pp. 72-101). New York: Guilford Press.

Cacioppo, J. T., Berntson, G. G., Larsen, J. T., & Poehlmann, K. M. (2000). The

psychophysiology of emotion. In M. Lewis & J. M. Haviland-Jones (Eds.), *Handbook of

emotions* (2nd ed., pp. 173-191). New York: Guilford.

Cacioppo, J. T., Klein, D. J., Berntson, G. G., & Hatfield, E. (1993). The psychophysiology of

emotions. In M. Lewis & J. M. Haviland (Eds.), *Handbook of emotions* (pp. 119-142). New

York: Guilford.

Cacioppo, J. T., Petty, R. E., Losch, M. E., & Kim, H. S. (1986). Electromyographic activity over facial muscle regions can differentiate the valence and intensity of affective reactions. *Journal of Personality and Social Psychology, 50,* 260-268.

Darwin, C. (1965). *The expression of the emotions in man and animals.* Chicago: University of Chicago Press. (Original work published 1872)

Ekman, P. (1979). About brows: Emotional and conversational signals. In M. von Cranach, K. Foppa, W. Lepenies, & D. Ploog (Eds.), *Human ethology* (pp. 169-248). New York: Cambridge University Press.

Ekman, P. (2003). Darwin, deception and facial expression. *Annals of the New York Academy of Sciences, 1000*, 205-221.

Ekman, P., & Friesen, W. V. (1978). *Manual for the facial action coding system.* Palo Alto, CA: Consulting Psychologists Press.

Ekman, P., & Friesen, W. V. (1982). Felt, false, and miserable smiles. *Journal of Nonverbal Behavior, 6,* 238-252.

Elgee, N. J. (2003). Laughing at death. *Psychoanalytic Review, 90,* 475-497.

Flykt, A. (1998). A threat imminence approach to human fear responding. Direction of threat, aversive contexts, and electrodermal responses. In the *Acta Universitatis Upsaliensis* (Vol. 18), Studia Psychologica Upsaliensia Series, 1999. Stockholm: Almqvist & Wiksell International.

Frank, M., Ekman, P., & Friesen, W. V. (1993). Behavioral markers and recognizability of the smile of enjoyment. *Journal of Personality and Social Psychology, 64,* 83-93.

Fridlund, A. J., & Cacioppo, J. T. (1986). Guidelines for human electromyographic research. *Psychophysiology*, *23*, 567-589.

Gray, J. A., & McNaughton, N. (2000). *The neuropsychology of anxiety.* New York: Oxford

University Press.

Hamm, A. O., Schupp, H. T., & Weike, A. I. (2003). Motivational organisation of emotions:

Autonomic changes, cortical responses and reflex modulation. In R. J. Davidson, K. R.

Scherer, & H. H. Goldsmith (Eds.), *Handbook of affective sciences* (pp. 187-211). Oxford,

England: Oxford University Press.

Hugdahl, K., & Johnsen, B. H. (1989). Preparedness and electrodermal fear-conditioning:

Ontogenetic vs phylogenetic explanations. *Behaviour Research and Therapy*, *27*, 269-278.

Hugdahl, K., & Kärker, A. C. (1981). Biological vs. experiential factors in phobic conditioning.

Behaviour Research & Therapy, 19, 109-115.

Jänig, W. (2003). The autonomic nervous system and its coordination by the brain. In R. J.

Davidson, K. R. Scherer, & H. H. Goldsmith (Eds.), *Handbook of affective sciences* (pp. 135-

186). Oxford, England: Oxford University Press.

Kaiser, S., & Wehrle, T. (2001). Facial expressions as indicators of appraisal processes. In K. R.

Scherer, A. Schorr, & T. Johnstone (Eds.), *Appraisal processes in emotion: Theory, methods,*

research (pp. 285-300). New York: Oxford University Press.

Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (1990). Emotion, attention, and the startle reflex.

Psychological Review, 97, 377-395.

Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (1999). *International Affective Picture System*

(IAPS): Instruction manual and affective ratings (Technical Report A-4). Gainesville:

University of Florida, Center for Research in Psychophysiology.

Lapatki, B. G., Stegeman, D. F., & Jonas, I. E. (2003). A surface EMG electrode for the

simultaneous observation of multiple facial muscles. *Journal of Neuroscience Methods, 123,*

117-128.

Larsen, J. T., Norris, C. J., & Cacioppo, J. T. (2003). Effects of positive affect and negative affect on electromyographic activity over zygomaticus major and corrugator supercilii. *Psychophysiology, 40,* 776-785.

Lazarus, R. S. (1991). *Emotion and adaptation.* New York: Oxford University Press.

Levenson, R. W., Ekman, P., & Friesen, W. V. (1990). Voluntary facial action generates emotion-specific autonomic nervous system activity. *Psychophysiology, 27,* 363-384.

Leventhal, H., & Scherer, K. R. (1987). The relationship of emotion to cognition: A functional approach to a semantic controversy. *Cognition and Emotion, 1,* 3-28.

Obrist, P. A. (1976). The cardiovascular-behavioral interaction as it appears today. *Psychophysiology, 13,* 95-107.

Obrist, P. A. (1981). *Cardiovascular psychophysiology: A perspective.* New York: Plenum.

Öhman, A. (1988). Preattentive processes in the generation of emotions. In V. Hamilton, G. H. Bower, & N. H. Frijda (Eds.), *Cognitive perspectives on emotion and motivation* (pp. 127-144). Dordrecht, Netherlands: Kluwer Academic.

Öhman, A. (1993). Fear and anxiety as emotional phenomena: Clinical phenomenology, evolutionary perspectives and information processing mechanisms. In M. Lewis & J. M. Haviland (Eds.), *Handbook of emotions* (pp. 511-536). New York: Guilford Press.

Öhman, A. (1997). Unconscious pre-attentive mechanisms in the activation of phobic fear. In G. C. L. Davey (Ed.), *Phobias. A handbook of theory, research and treatment* (pp. 349-374). Chichester, England: John Wiley & Sons.

Pecchinenda, A., & Smith, C. A. (1996). The affective significance of skin conductance activity during a difficult problem-solving task. *Cognition and Emotion, 10,* 481-503.

Plutchik, R. (1980). *Emotion. A general psychoevolutionary synthesis.* New York: Harper & Row.

Pope, L. K., & Smith, C. A. (1994). On the distinct meanings of frowns and smiles. *Cognition and Emotion, 8,* 65-72.

Scherer, K. R. (1984). On the nature and function of emotion: A component process approach. In K. R. Scherer & P. Ekman (Eds.), *Approaches to emotion* (pp. 293-318). Hillsdale, NJ: Erlbaum.

Scherer, K. R. (1986). Vocal affect expression: A review and a model for future research. *Psychological Bulletin, 99,* 143-165.

Scherer, K. R. (1987). Toward a dynamic theory of emotion: The component process model of affective states. *Geneva Studies in Emotion and Communication, 1,* 1-98.

Scherer, K. R. (1992). What does facial expression express? In K. Strongman (Ed.), *International review of studies on emotion* (Vol. 2, pp.139-165). Chichester, England: Wiley.

Scherer, K. R. (2001). Appraisal considered as a process of multi-level sequential checking. In K. R. Scherer, A. Schorr, & T. Johnstone (Eds.), *Appraisal processes in emotion: Theory, methods, research* (pp. 92-120). New York: Oxford University Press.

Smith, C. A. (1989). Dimensions of appraisal and physiological response in emotion. *Journal of Personality and Social Psychology, 56,* 339-353.

Smith, C. A., & Scott, H. S. (1997). A componential approach to the meaning of facial expressions. In J. A. Russell & J. M. Fernández-Dols (Eds.), *The psychology of facial expression* (pp. 229-254). New York: Cambridge University Press.

Steiner, J. E. (1977). Facial expressions of the neonate infant indicating the hedonics of food-related chemical stimuli. In J. Weiffenbach (Ed.), *Taste and development: The genesis of sweet preference* (pp. 173-189). Washington, DC: US Dept. of Health, Education and Welfare.

Stemmler, G. (1989). The autonomic differentiation of emotions revisited: Convergent and discriminant validation. *Psychophysiology, 26,* 617-632.

Stemmler, G. (1992). The vagueness of specificity: Models of peripheral physiological emotion specificity in emotion theories and their experimental discriminability. *Journal of Psychophysiology, 6,* 17-28.

Stemmler, G. (1996). Psychophysiologie der Emotionen. *Zeitschrift für Psychosomatische Medizin und Psychoanalyse, 42,* 235-260.

Van Hooff, J. A. (1972). A comparative approach to the phylogeny of laughter and smiling. In R. Hinde (Ed.), *Non-verbal communication* (pp. 209-241). Cambridge, England: Cambridge University Press.

Van Reekum, C. M., Johnstone, T., Banse, R., Etter, A., Wehrle, T., & Scherer, K. R. (2004). Psychophysiological responses to appraisal dimensions in a computer game. *Cognition and Emotion, 18,* 663-688.

Waller, B. M., & Dunbar, R. I. M. (2005). Differential behavioural effects of silent bared teeth display and relaxed open mouth display in chimpanzees. *Ethology, 111,* 129-142.

Waterink, W., & van Boxtel, A. (1994). Facial and jaw-elevator EMG in relation to changes in performance level during a sustained information processing task. *Biological Psychology, 37*, 183-198.

Wright, R. A., Contrada, R. J., & Patane, M. J. (1986). Task difficulty, cardiovascular response, and the magnitude of goal valence. *Journal of Personality and Social Psychology, 51,* 837-843.

Wright, R. A., & Dill, J. C. (1993). Blood pressure responses and incentive appraisals as a function of perceived ability and objective task demand. *Psychophysiology, 30,* 152-160.

Author Note

Tatjana Aue, Anders Flykt, and Klaus R. Scherer, Geneva Emotion Research Group, FPSE, University of Geneva, Switzerland.

Tatjana Aue is now at the University of Chicago, IL, USA, Anders Flykt at the Karlstad University, Sweden.

Correspondence concerning this article should be addressed to Tatjana Aue, Geneva Emotion Research Group, FPSE, Université de Genève, Bd. du Pont d'Arve 40, 1205 Genève, Switzerland. E-mail: Tatjana.Aue@pse.unige.ch.

Footnotes

[1]It has to be considered that the pictures displaying threat may be goal obstructive in addition to goal relevant. One of the anonymous reviewers of this article argued further that, in addition to differences in stimulus relevance, biological threat and cultural threat could also differ in the degree of goal obstruction. Although we do not think that this applies to our experiment (because both stimulus categories did not differ in either valence and arousal ratings; see Appendix), we cannot completely rule out this possibility.

[2]Though not implicated in this study, one would also expect these mobilization differences to be reflected in skin conductance measures and systolic blood pressure (e.g., Flykt, 1998; Pecchinenda & Smith, 1996; Wright, Contrada, & Patane, 1986).

[3]Activity over the cheek region (measured over the M. Zygomaticus major, smiling) may be part of a positive affect expression (Frank, Ekman, & Friesen, 1993). However, this region can be activated by negative valence (e.g., Lang, Bradley, & Cuthbert, 1990) and associated emotions like fear and disgust (e.g., Van Hooff, 1972) as well. Also, activity over the cheek region, without concurrent activation of the M. Orbicularis oculi (AU 6), is often considered a communicative signal (e.g., Bänninger-Huber & Rauber-Kaiser, 1989; Ekman & Friesen, 1982).

[4]Activity over the brow region (M. Corrugator supercilii, frowning) can reflect ongoing cognitive processing (e.g., Darwin, 1872/1965; Scherer, 1992), negative affect (e.g., Cacioppo, Petty, Losch, & Kim, 1986), and communicative intent (e.g., Ekman, 1979; Kaiser & Wehrle, 2001). Activity over the brow region is mostly influenced by the M. Corrugator supercilii. Therefore, we use the terms activity over the brow region and Corrugator activity interchangeably. Activity over the cheek region, however, can be influenced by a large number of different muscles having different significance. For the winning goal conduciveness manipulation, we expected activity over the cheek region to be largely influenced by the M.

Zygomaticus major, thus reflecting positive affect. For the losing condition and biological or cultural threat, in contrast, we considered activity over the cheek region as an indicator of grimacing or a sign of negative affect (see Discussion for further details).

[5]During a time interval of 1 s there is usually only one peak in the electrocardiogram. PPP calculates heart rate, therefore, on the basis of a linear interpolation, including one peak preceding and another peak following the time interval concerned, which constitutes an optimal estimate of heart rate. Imagine that we were interested in the heart rate from 1 to 2 s following stimulus onset, but PPP detects only one peak at 1.7 s following stimulus onset. To resolve this problem, PPP gives a weight of 0.7 to the heart rate calculated on the basis of the interbeat interval between the peak in the preceding time interval (0-1 s) and the peak at 1.7 s, and it gives a weight of 0.3 to the heart rate calculated on the basis of the interbeat interval between the peak at 1.7 s and the peak in the following time interval (2-3 s).

[6]The original degrees of freedom are reported throughout the article for readability reasons.

[7]Note that all EMG values are based on differences between logarithmic scores (logarithmic task scores – logarithmic baseline scores).

[8]Heart rate acceleration can be a result of increasing sympathetic influences, or decreasing parasympathetic influences, or both. As both influences have an effect on heart rate (Berntson, Cacioppo, & Quigley, 1991), we cannot draw any conclusion about which determinant has been responsible for the observed changes. It is important to note, however, that there is substantial physiological evidence that short-latency heart rate responses are caused parasympathetically rather than sympathetically (see Berntson, Cacioppo, & Quigley, 1993, for further information).

[9]An alternative explanation is the possibility that complexity varied over the three picture categories. However, it is important to note that, when referring to the idea of an innate

sensitivity for biological threat, it seems only logical that these kinds of stimuli must be perceived as being less complex and easier to be processed than cultural threat stimuli, for which no such innate sensitivity exists. The significance of our results is therefore not necessarily affected by potential complexity differences. It can also be argued that greater activity over the brow region in response to cultural threat than in response to biological threat is functional. As the former results mostly from human actions, it is adaptive to display more frowning to signal our own intentions toward others in order to influence their behavior. Frowning, as an anger display could prevent another person from hurting us. In contrast, biological threat is often caused by dangerous animals. Direct fight or flight responses (as prepared by heart rate acceleration) should therefore be more important. This argument is, however, weakened by the fact that angry human faces were included as examples of biological threat in our study.

[10]An alternative explanation of our findings is that fear of interpersonal or cultural threat stimuli is widely accepted, whereas fear of spiders is often considered as being "girlish" or "childish" in urban Western European culture. Thus, the increase of activity over the cheek region starting about 1 s after picture onset might reflect an attempt at regulation in the form of a "masking smile" (Ekman & Friesen, 1982) of some participants, serving communicative objectives. This interpretation receives further support from the fact that stimulus relevance is reflected in activity over the cheek region at a later time than in activity over the brow region. This does not necessarily imply an implication of a high-level norm compatibility check, which should occur only later. As the effect occurs only at about 1 s and reaches its apex between 2 and 3 s, this alternative cannot be dismissed offhand. Importantly, the result cannot likely be attributed to the presence of spider or snake phobics among our participants, as none of them indicated that they had such phobias when specifically questioned in the postinterview. Furthermore, outliers were eliminated from all physiological data.

[11]Of course we cannot completely rule out that the goal conduciveness effect was simply too weak to become significant earlier, and therefore appeared only later in the time course.

Figure Captions

Figure 1. Heart rate. Means and standard errors for the interaction effect Time × Stimulus Relevance. b = biological threat; c = cultural threat; n = neutral objects. $^{\dagger}p < .10$, $*p < .05$, $**p < .001$, based on an *F* test with numerator *df* = 1 and denominator *df* = 40.

Figure 2. Activity over the cheek region (200-ms intervals). Means and standard errors for the interaction effect Time × Stimulus Relevance. Values are based on differences between logarithmic scores (logarithmic task scores − logarithmic baseline scores). b = biological threat; c = cultural threat; n = neutral objects. $*p < .05$, $**p < .01$, based on an *F* test with numerator *df* = 1 and denominator *df* = 41, Bonferroni corrected.

Figure 3. Activity over the cheek region (1-s intervals). Means and standard errors for the interaction effect Time × Stimulus Relevance. Values are based on differences between logarithmic scores (logarithmic task scores − logarithmic baseline scores). b = biological threat; c = cultural threat; n = neutral objects. $*p < .05$, $**p < .005$, $***p < .001$, based on an *F* test with numerator *df* = 1 and denominator *df* = 41, Bonferroni corrected.

*Figure 4*. Activity over the cheek region (1-s intervals). Means and standard errors for the interaction effect Time × Goal Conduciveness. Values are based on differences between logarithmic scores (logarithmic task scores − logarithmic baseline scores). l = lose money; n = neutral; w = win money. $^{\dagger}p < .10$, $*p < .05$, $**p < .005$, based on an *F* test with numerator *df* = 1 and denominator *df* = 41.

Figure 5. Activity over the brow region (200-ms intervals). Means and standard errors for the interaction effect Time × Stimulus Relevance. Values are based on differences between logarithmic scores (logarithmic task scores − logarithmic baseline scores). b = biological threat; c = cultural threat; n = neutral objects. *$p < .05$, **$p < .01$, ***$p < .005$ based on an *F* test with numerator *df* = 1 and denominator *df* = 41.

Figure 6. Activity over the brow region (1-s intervals). Means and standard errors for the interaction effect Time × Goal Conduciveness. Means and standard errors are shown for the neutral picture content only; values are based on differences between logarithmic scores (logarithmic task scores − logarithmic baseline scores). l = lose money; n = neutral; w = win money. *$p < .05$, based on an *F* test with numerator *df* = 1 and denominator *df* = 41.

Figure 7. Physiological variables displaying main effects of Stimulus Relevance and Goal Conduciveness at different times. Co = activity over the brow region (M. Corrugator supercilii); HR = heart rate; Zy = activity over the cheek region (M. Zygomaticus major). Significant effects are shown in black; trends are shown in gray. *Based on a subanalysis for pictures with neutral picture content only.
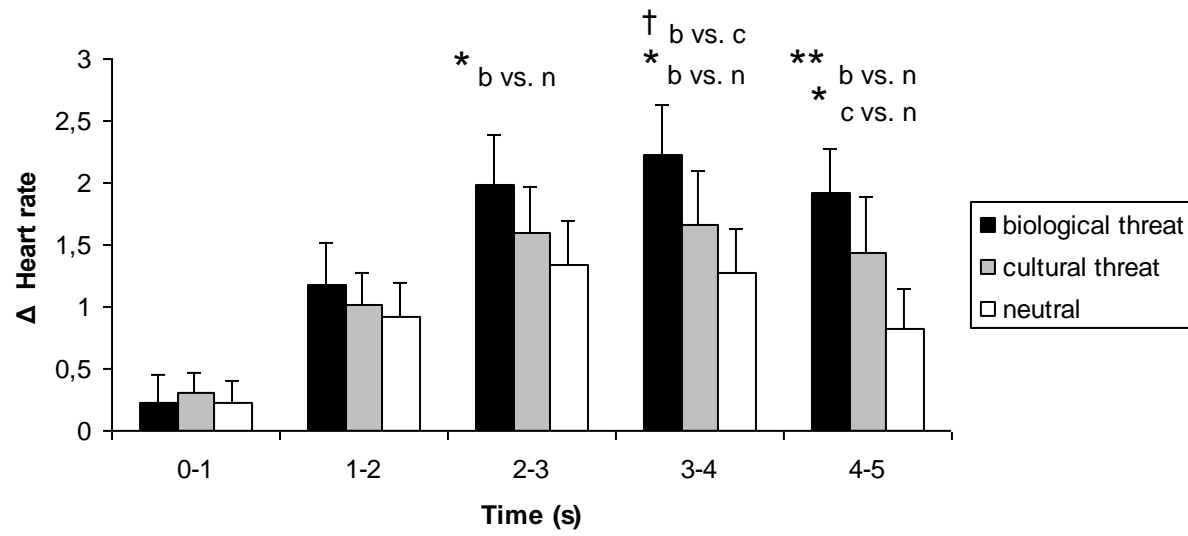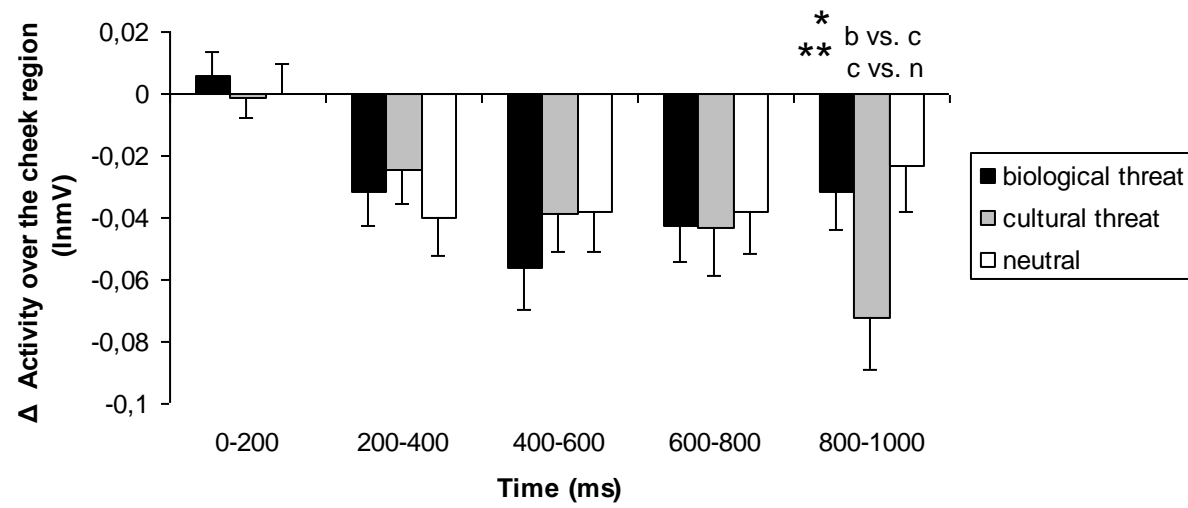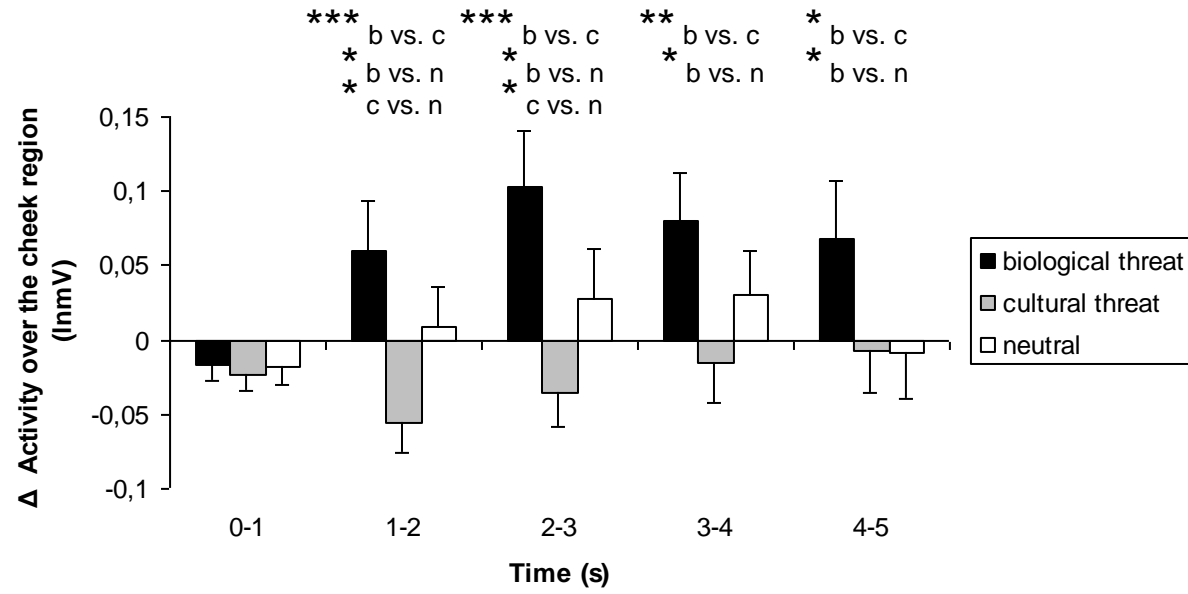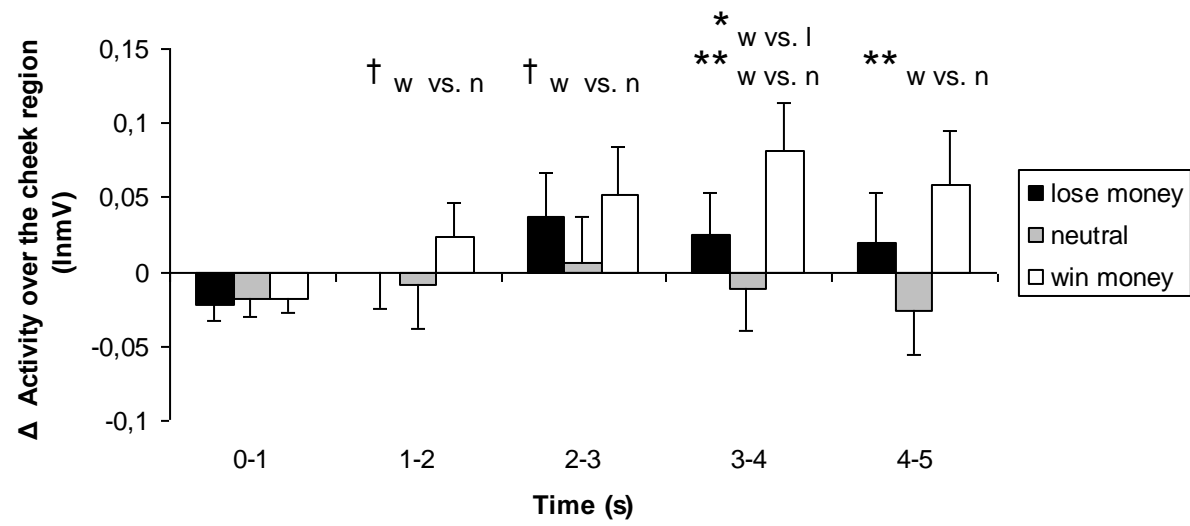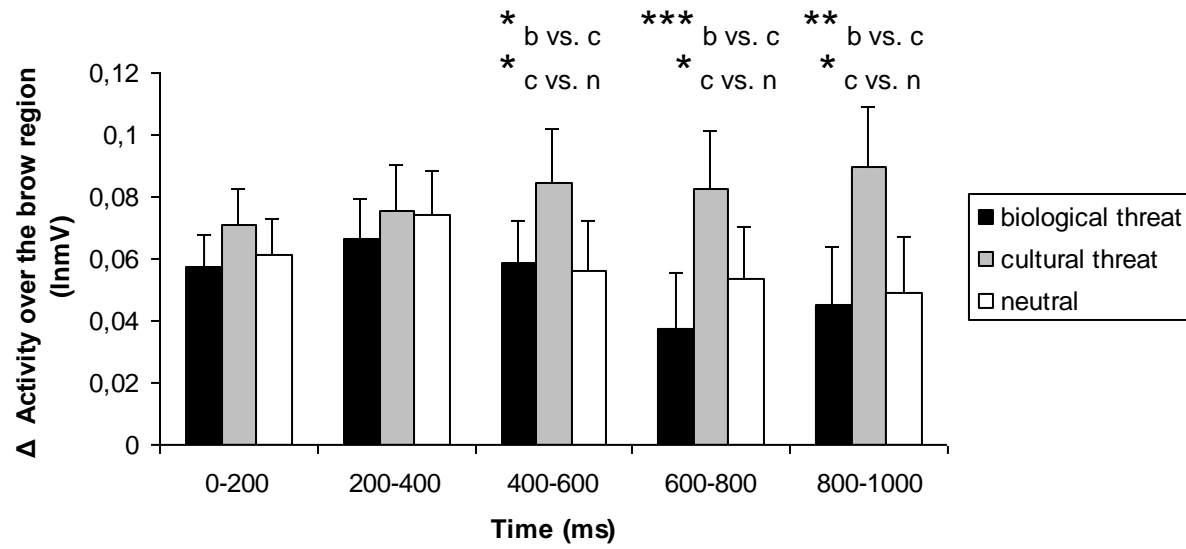
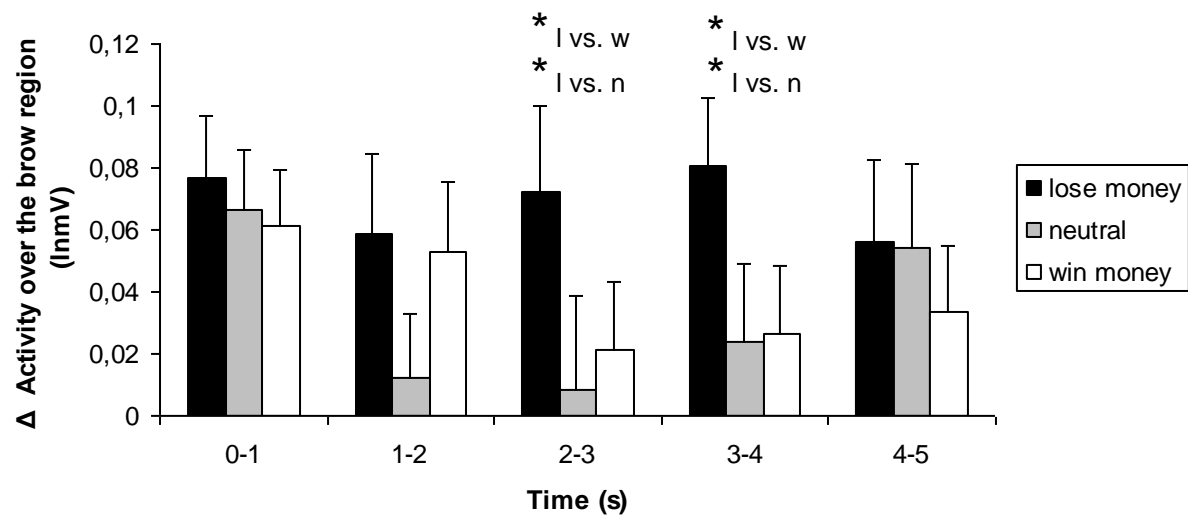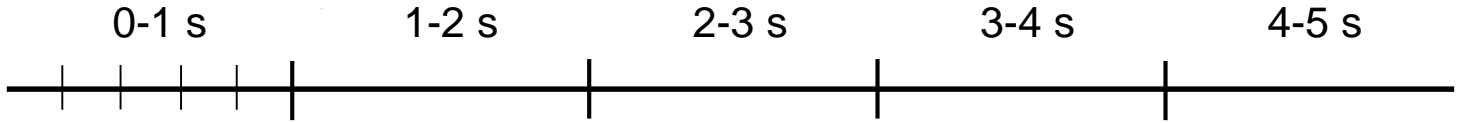Time after picture onset

| 0-1 s | 1-2 s | 2-3 s | 3-4 s | 4-5 s |

Stimulus
relevance

		HR	HR	HR
	Zy	Zy	Zy	Zy
Zy	Co	Co	Co	Co
Co Co Co				

Goal
conduciveness

| | Zy | Zy | Zy | Zy |
| | | Co* | Co* | |

Appendix

Means (Ms) and Standard Deviations (SDs) for Valence and Arousal Ratings for Pictures Selected From the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 1999).

Description	Slide no.	Valence		Arousal		Category
		M	*SD*	*M*	*SD*	
Snake	1040	3.99	2.24	6.25	2.13	biological threat
Snake	1050	3.46	2.15	6.87	1.68	biological threat
Snake	1120	3.79	1.93	6.93	1.68	biological threat
Spider	1200	3.95	2.22	6.03	2.38	biological threat
Pit Bull	1300	3.55	1.78	6.79	1.84	biological threat
Dog	1301	3.70	1.66	5.77	2.18	biological threat
Dog	1302	4.21	1.78	6.00	1.87	biological threat
Shark	1930	3.79	1.92	6.42	2.07	biological threat
Shark	1931	4.00	2.28	6.80	2.02	biological threat
Angry	2100	3.85	1.99	4.53	2.57	biological threat
Angry	2110	3.71	1.82	4.53	2.25	biological threat
Angry	2120	3.34	1.91	5.18	2.52	biological threat
Bomb	2692	3.36	1.61	5.35	2.19	cultural threat
Electric chair	6020	3.41	1.98	5.58	2.01	cultural threat
Aimed gun	6190	3.57	1.84	5.64	2.03	cultural threat
Aimed gun	6200	2.71	1.58	6.21	2.28	cultural threat
Aimed gun	6210	2.95	1.83	6.34	2.14	cultural threat
Aimed gun	6230	2.37	1.57	7.35	2.01	cultural threat
Aimed gun	6250	2.83	1.79	6.54	2.61	cultural threat
Aimed gun	6260	2.44	1.54	6.93	1.93	cultural threat
Knife	6300	2.59	1.66	6.61	1.97	cultural threat
Man with knife	6510	2.46	1.58	6.96	2.09	cultural threat
Knife	6550	2.73	2.38	7.09	1.98	cultural threat
Aircraft	6900	4.76	2.06	5.64	2.22	cultural threat
Bomber	6910	5.31	2.28	5.62	2.46	cultural threat
Missiles	6930	4.39	1.82	4.88	2.20	cultural threat
Tank	6940	3.53	2.07	5.35	2.02	cultural threat
Cemetery	9000	2.55	1.55	4.06	2.25	cultural threat
Exhaust	9090	3.69	1.92	4.80	2.23	cultural threat
Toxic waste	9270	3.72	1.51	5.24	2.15	cultural threat
Sunflower	5001	7.16	1.56	3.79	2.34	neutral
Flower	5010	7.14	1.50	3.00	2.25	neutral
Flower	5030	6.51	1.73	2.74	2.13	neutral
Mushroom	5500	5.42	1.58	3.00	2.42	neutral
Mushroom	5531	5.15	1.45	3.69	2.11	neutral
Mushrooms	5532	5.19	1.69	3.79	2.20	neutral
Spoon	7004	5.04	0.60	2.00	1.66	neutral
Mug	7009	4.93	1.00	3.01	1.97	neutral
Basket	7010	4.94	1.07	1.76	1.48	neutral
Fan	7020	4.97	1.04	2.17	1.71	neutral
Stool	7025	4.63	1.17	2.71	2.20	neutral
Fork	7080	5.27	1.09	2.32	1.84	neutral
House	7490	5.52	1.41	2.42	2.23	neutral
Lab building	7491	4.82	1.03	2.39	1.90	neutral
Building	7500	5.33	1.44	3.26	2.18	neutral

Note. Slide no. = slide number of the IAPS picture.