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Psychophysiological responses to appraisal dimensions in a computer game

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A computer game was used to study psychophysiological reactions to emotion-relevant events. Two dimensions proposed by Scherer (1984a, 1984b) in his appraisal theory, the intrinsic pleasantness and goal conduciveness of game events, were studied in a factorial design. The relative level at which a player performed at the moment of an event was also taken into account. A total of 33 participants played the game while cardiac activity, skin conductance, skin temperature, and muscle activity as well as emotion self-reports were assessed. The self-reports indicate that game events altered levels of pride, joy, anger, and surprise. Goal conduciveness had little effect on muscle activity but was associated with significant autonomic effects, including changes to interbeat interval, pulse transit time, skin conductance, and finger temperature. The manipulation of intrinsic pleasantness had little impact on physiological responses. The results show the utility of attempting to manipulate emotion-constituent appraisals and measure their peripheral physiological signatures.

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A number of appraisal theories of emotion have been developed in an attempt to predict the elicitation and differentiation of emotions on the basis of a detailed set of appraisal criteria (Frijda, 1986; Lazarus, 1991; Oatley & Johnson-Laird, 1987; Roseman, 1984, 1991; Scherer, 1984a, 1984b; Smith & Ellsworth, 1985; Weiner, 1986). Despite the divergent disciplinary and historical traditions of the authors involved, one finds a high degree of convergence with respect to the appraisal dimensions or criteria postulated by different theories (see Lazarus & Smith, 1988; Manstead & Tetlock, 1989; Reisenzein & Hofmann, 1990, 1993; Roseman, Spindel, & Jose, 1990; Scherer, 1988, 1999). These include the perception of a change in the environment that captures the subject's attention (novelty and expectancy), the importance of the stimulus or event to one's goals or concerns (relevance and goal conduciveness or motive consistency), the notion of who or what caused the event (agency or responsibility), and the estimated ability to deal with the event and its consequences (perceived control, power or coping potential).

Although appraisal theories in principle address the organisation of the response systems by such subjective evaluations, most empirical studies have been conducted using self-report instruments. Even though these studies indicate the success of appraisal theory in predicting and differentiating the experienced emotion (e.g., Scherer, 1993), such studies only concentrate on a single response system, namely, subjective, conscious feeling states. To make matters worse, most of these studies are plagued by a number of problems inherent to the reliance upon self-report and induction techniques used. Whereas the appraisal content assessed by self-report methods is informative with respect to the differentiation between emotions, the studies do not necessarily inform about the (appraisal) processes underlying elicitation of emotion. As in many other cognitive processes, only the outcome of the appraisal process may be conscious, not the process itself (Nisbett & Wilson, 1977).

Appraisal theory in general posits that these evaluations organise the response components, such as physiology and expressive behaviour (Frijda, 1986; Lazarus, 1991; Scherer, 1984a, 1984b; Smith, 1989). In particular, Scherer (1984a, 1984b, 1986, 2001) and Smith (1989, 1991) explicitly propose that each appraisal dimension influences each of the response components. In the framework of his Component Process Model, Scherer (1986, 2001) describes how a fixed sequence of appraisal checks triggers specific changes in facial, and vocal expressions, as well as in autonomic nervous system (ANS) activity. Smith proposes that with respect to facial activity, the expressive units might each convey information of specific appraisal components (see also Smith & Scott, 1997), whereas appraisals of coping directly affect the autonomic and postural changes required for the specific action serving to adapt to the situation.

Some research has been performed in which physiological changes served as markers of the appraisal process. Whilst Lazarus and colleagues (Lazarus & Alfert, 1964; Speisman, Lazarus, Mordkoff, & Davison, 1964) were the first to relate changes in skin conductance activity and heart rate to experimentally manipulated or habitually different interpretations of a stressful film, Smith (1989) found initial support for the idea that physiological changes can be related to a specific appraisal dimension. Smith provided participants with vignettes of potentially emotional scenarios, each of which aimed to manipulate the appraisals of low or high anticipated effort, and self- or other-agency. Smith's data provide evidence for the contribution of appraised anticipated effort to arousal as indexed by heart rate, with a higher heart rate for high anticipated effort than for low anticipated effort manipulations. However, no clear effects of the appraisal manipulations on skin conductance level measures were found.

Other work performed within the framework of appraisal processes has concentrated on the physiological concomitants of coping potential appraisals (e.g., Pecchinenda & Smith, 1996; Tomaka, Blascovich, Kelsey, & Leitten, 1993; Tomaka, Blascovich, Kibler, & Ernst, 1997; see Pecchinenda, 2001, and Smith & Kirby, 2001, for reviews), but little attention has been given to the physiological concomitants of valence-related appraisals. Indeed, in most of the preceding studies on coping-related appraisals, the possibility that the tasks used might be appraised either positively or negatively was not assessed. This is perhaps surprising, given the central role of valence in emotion theories in general, as well as valence-related appraisals in all appraisal theories. In contrast, emotion research outside the appraisal domain has extensively examined the role of valence in modulating physiology.

For example, a large body of research on affective responses to pictures by Lang and colleagues (e.g., Bradley, Codispoti, Cuthbert, & Lang, 2001; Lang, Bradley, & Cuthbert, 1990) has reported that skin conductance activity is not differentially affected by the positive-negative valence of information, but rather by the reported emotional arousal of information. Their data further indicate that valence does affect cardiovascular activity (see Bradley & Lang, 2000, for a review). A meta-analysis by Cacioppo, Berntson, Larsen, Poehlmann, and Ito (2000) confirmed these findings: Of 22 measures in the meta-analysis, only 5, all of which were related to cardiovascular function, differed between positive and negative emotions.

However, as underscored by Scherer (e.g., 1984a, 1984b, 1988), valence cannot always be used synonymously with valence-related appraisals, such as goal/need conduciveness or motive consistency. In his component process model of emotion, Scherer (1984a, 1986) insists on an analytical separation of intrinsic pleasantness and goal conduciveness as separate appraisal dimensions. Intrinsic pleasantness has to do with innate, or highly learned evaluations of pleasantness, regardless of the current goals and concerns of a person. According to Scherer's (1984a, 1984b, 1987, 2001) postulate of a sequential appraisal process, the outcome of a prior intrinsic valence appraisal determines the fundamental reaction in terms of sensitisation or desensitisation of the senses (including, possibly, basic approach or avoidance processes). Goal conduciveness involves an evaluation of whether a stimulus or event helps or hinders one to obtain a desired goal or need. Thus, the evaluation of intrinsic pleasantness can alter the emotional response to the situation, independent of the conduciveness appraisal.

So far there has been no attempt to test the possibly different effects of valence and goal conduciveness appraisals on emotional responding. This is quite understandable since there may be an ecological correlation between intrinsically pleasant/unpleasant events and conducive/obstructive goal implications. Thus, it is only via systematic experimental studies that one can attempt to independently manipulate the two theoretically postulated dimensions. The study reported here is a first attempt to investigate the well-foundedness of making a distinction between intrinsically pleasant and unpleasant stimuli and goal conducive or obstructive implications of an event. In particular, we aimed to examine differences in psychophysiological patterning corresponding to intrinsic pleasantness versus goal conduciveness appraisals.

In the present study, we used a computer game to study the effects of these two appraisal dimensions, *intrinsic pleasantness* and *goal conduciveness*. Compared to more classic and passive emotion induction techniques, such as the use of films (e.g., Gross & Levenson, 1995), or showing emotionally laden images (e.g., Lang, Greenwald, Bradley, & Hamm, 1993; Ito, Cacioppo, & Lang, 1998), computer games have the advantage that the subject is actively engaged (e.g., MacDowell & Mandler, 1989). Furthermore, parameters, which are in theory relevant for emotion elicitation, can be carefully manipulated in a relatively controlled setting (see also Kappas & Pecchinenda, 1999).

The game that we selected is a typical arcade-type game, where the main task of the player is to manoeuvre their spaceship around a galaxy to collect crystals and avoid enemies and mines. From the possible events in the game that may elicit particular patterns of appraisal, two types of events were selected a priori on the basis of their closest match to Scherer's definition of conduciveness to the goal of winning. These events are losing a ship (by hitting an obstacle or being shot by an enemy) and passing to the next game level after having successfully completed the previous one. In the context of the game, the first type of event is obstructive and the latter conducive in the pursuit of gaining points and progressing to as high a game level as possible. The intrinsic pleasantness dimension was manipulated by playing valenced (i.e., pleasant and unpleasant) sounds. The appraisal dimensions were studied in a fully crossed 2 (intrinsic pleasantness) $\times$ 2 (goal conduciveness) within-subjects design. That is, as part of the event of the player reaching the next level or losing a life, either a pleasant or unpleasant sound (randomly selected) was presented at event onset. Thus the two sounds used for the intrinsic pleasantness manipulation only occurred with ship destroyed and new level events. Similarly, ship destroyed and new level events were always accompanied by one of the two sounds. In this manner, the sounds were an intrinsic property of the two game events.

The Component Process Model's (Scherer, 1984a, 1984b, 1987) principal idea of a functional connection between appraisal and physiological reactions draws on Gellhorn's (1970) ergotropic-trophotropic tuning model. Gellhorn's model describes how the ANS and the somatic nervous system are ''tuned'' to states ranging from conservation or replenishment of organismic resources to mobilising organismic resources to provide energy for action. In the light of recent and more sophisticated models of autonomic space (e.g., Berntson, Cacioppo, Quigley, & Fabro, 1994), Gellhorn's account of the functioning of the sympathetic and parasympathetic branches of the ANS seems too simplistic, and therefore the specific theoretical predictions derived from Gellhorn's theory need to be revised. Even though Scherer has since made modifications to the theoretical predictions on the physiological concomitants of different outcomes of single appraisal dimensions (see e.g., Scherer, 2001), these predictions were not detailed and conceptualised enough at the time of the current study to be submitted to hypothesis testing.

However, based upon the general functional framework which laid the ground for Scherer's predictions, we can formulate some general hypotheses with respect to main effects of the appraisal dimensions under study. First, we expected that the appraisal of high goal conduciveness would cause a shift towards energy conservation and resource replenishment indicated by a deceleration of heart rate, and a decrease in electrodermal and muscle activity. Conversely, the appraisal of stimuli as obstructive to goals was predicted to lead to an acceleration of heart rate, an increase in electrodermal activity, muscle tension, and peripheral vasoconstriction. Predictions for the intrinsic pleasantness check with respect to the measures taken in this study are congruent with those of obstructive and conducive appraisals. However, Scherer did not make detailed and testable predictions concerning the effects of combinations of such appraisals on physiology. Hence, the aim of the current study is rather more exploratory—given that little, if anything, is known about the relationship between the efferent effects of intrinsic pleasantness and goal conduciveness appraisals, if indeed they can be reliably distinguished. Thus, we were particularly interested in seeing whether game situations that are contingent with specific appraisal conditions would also show specific physiological response patterns.

In addition to examining the physiological responses related to goal conduciveness and intrinsic pleasantness, we also explored how such physiological responses depended on the player's progress in the game relative to the player's previous best performance. We expected that the players' progress in the game, relative to their best performance, would influence the relevance or importance they attached to events occurring. The closer players got to attaining their best performance, the more importance they were expected to attach to events in the game. Consequently, we expected that conduciveness effects would be larger for high relative performance levels.

METHOD

Participants

A total of 33 adolescents (age 13–15, 27 boys and 6 girls)[1] were recruited from several high schools and were paid CHF15 (approx. US$10) for their participation in the experiment. The choice of adolescent participants in this experiment was motivated by the assumption that adolescents are in general more interested and involved in playing computer games than adults (including undergraduate students). We thus expected adolescents' strong motivation to play the game would result in stronger emotions.

Description of the game

The game XQUEST (Mackey, 1994) situates the player in a fictional galaxy, filled with crystals, mines, and enemies. The general assignment is to gather the crystals which are present in each galaxy. Mouse movement does not directly cause a corresponding movement of the player's spaceship (as with a mouse cursor in a text editor), but rather causes the ship to accelerate. The resulting ballistic movement makes the game particularly interesting to play. Pressing the left button of the mouse launches bullets in the direction in which the ship is going, which destroy any enemies that are hit. Pressing the right button launches a bomb, if available, which destroys every enemy and mine in the galaxy. Once the player has picked up all the crystals in the ''galaxy'', a gate opens through which the player can proceed to the next ''galaxy'' (i.e., the next game level).

The difficulty increases in successive game levels since there are more crystals to pick up, the number of mines increases, the enemies become more numerous and vicious, and the exit to the next game level becomes smaller. Points are awarded for every crystal gathered, completion of a game level within a certain time limit (''time bonus'') and every enemy destroyed. Depending on the amount of points gained, extra ships are given. A game is over when the player has lost all the ships, after which the player starts a new game at the first game level.

[1] Due to an unbalanced number of boys and girls, we were not able to appropriately test for effects of gender. To verify that qualitative differences in the data of the girls were not changing results, we performed the analyses excluding the data of the girls. Effects were identical to those found on the entire population, albeit with reduced significance in some cases (for frontalis and forearm extensor of the playing arm, and relative performance level for pulse transit time). Given the stability of the pattern of results we maintained the complete sample for the main report of the results.

Procedure

Upon their arrival in the laboratory, participants were informed about the general aim of the study. They also received information on how to play the computer game and how long they would be asked to play. Following this, participants played the game for a 20 minute practice session. In order to ensure that all players were sufficiently involved in the game, and to establish a minimal performance level for all players, a selection criterion was employed. To continue, participants needed to reach at least the fourth game level during the practice period. All players met this criterion. Following the practice session, the sensors for the physiological measures were attached. In addition, players were fitted with a microphone that was used to record vocal reports. A full and detailed acoustic analysis of these vocal reports is the subject of a separate paper (Johnstone, van Reekum, Scherer, Hird, & Kirsner, 2003). The players were seated in a comfortable armchair, and were given a plank of wood upon which the mouse was placed. This plank rested on both armrests, ''locking'' the player in the chair, which helped restrict gross body movements. The experiment started with a 2.5 minute relaxation phase. Participants played for 45 minutes, after which the game halted automatically.

Design

The appraisal of *goal conduciveness* was operationalised by selecting situations in which the player's ship was lost (goal obstructive) or a game level was successfully completed (goal conducive). *Intrinsic pleasantness* was manipulated by a random presentation of a pleasant or an unpleasant sound with either one of the two conduciveness events. Both sounds were digitally synthesised sounds taken off a shareware sound-effects CD. The pleasantness of these sounds, which were equal in duration and average intensity, had been established in an independent pretest of 15 judges who were asked to rate the sounds on a 7-point scale from −3 (*very unpleasant*) to +3 (*very pleasant*). The mean ratings (with standard deviations in parentheses) for the sounds were −2.3 (1.1) for the unpleasant and 2.2 (0.8) for the pleasant sound, thus the sounds were rated as very unpleasant and very pleasant, respectively, with the intensity of the ratings of the sounds being highly similar.

In order to differentiate between responses to the lead up of the target events and responses to the event itself, physiological measures were taken during the seconds immediately before and after target events. This time factor can be thought of as a moving baseline-treatment contrast that allows one to distinguish appraisal effects with an onset at the critical event from effects of possible anticipation of the events.

The relative performance level factor was determined after the data were collected. Observations were categorised into three relative performance levels so that a sufficient number of each type of game event could be allocated to each level. The levels were defined as performing at 33% (level 1), between 33% and 66% (level 2), and 66% and better (level 3) of the player's prior best performance. For example, if the prior best performance of a player was galaxy 6, in the next game, events of either type occurring at the 1st and 2nd galaxy were assigned to level 1, from the 3rd and 4th to level 2, and events at level 5 or higher to level 3. If the player reached galaxy 8, this new high score was used to calculate the levels for the following game. Given that all players needed to reach galaxy 4 in order to be able to participate (see above), the initial relative level calculations used galaxy 4 as prior best performance. During the course of the experiment, each player played a number of games and in each game, the player started from scratch. Thus, each player passed through all *relative* performance levels a number of times during the experimental session. The average number of observations for each of the relative performance levels was 27.3 (total 903) for level 1, 26.1 (total 861) for level 2 and 25.2 (total 831) for level 3. To verify that the relative performance level was not confounded with time, we analysed the average onset times (in seconds) per relative level. The differences in onset time significantly differed across the three levels, $F(2, 64) = 8.69$, $p = .001$, with the mean onset time (in seconds) being relatively earlier for level 3 ($M = 1459.8$, $SD = 45.56$) than for level 2 ($M = 1632.2$, $SD = 30.11$) and 1 ($M = 1653.6$, $SD = 28.01$). Hence, to test whether this time confound bore any effect on the measures, we performed regression analyses for each of the measures, with the onset time as the predictor. These analyses showed that less than 1% of the variance was explained by onset time in all of the measures, except for finger temperature slope, where onset time explained 2% of the variance. Yet, to eliminate all possible confounds of onset time with relative performance level on finger temperature slope, event onset time was regressed out of the data and the influences of the factors of interest were analysed on the residuals.

Emotion self-report

An emotion self-report was obtained using a pop-up screen which displayed a cartoon character (Gaston Lagaffe), expressing eight different emotions (interest, joy, surprise, anger, shame, pride, tenseness, and helplessness). These images were used to make the rating clearer and easier for the adolescents, and were accompanied by the corresponding emotion labels. Below each emotion image and label was a continuous graphic scale on which the felt intensity of each emotion could be indicated by means of clicking and dragging an indicator with the mouse. The ratings were converted to values ranging from 0 to 1. The pop-up screen was presented immediately after a subset of target game events and disappeared as soon as the participant clicked the OK button at the bottom of the screen (provided that the participant rated their feelings on at least one of the scales). The events were chosen randomly with the restriction that the emotion self-report was not presented more often than once every 4 minutes so that the continuity of the game was not unduly interrupted.

Physiological measures

All physiological recordings were taken continuously throughout the game using equipment and software from Contact Precision Instruments Inc.

Electrodermal activity. Skin conductance level (SCL) was measured using Med Associates 4 mm Ag/AgCl electrodes placed on the middle phalanx of the index and third finger of the nondominant hand. The electrodes were filled with NaCl paste. A SCL coupler with automatic back-off (offset adjustment) applied a constant 0.6 volts across the electrodes and amplified the signal.

Cardiovascular activity. Interbeat interval was measured using pregelled, disposable ECG electrodes secured to the rib cage. The cardiac interbeat interval (IBI) was calculated online at milliseconds precision using the Contact Precision Instruments interval timer with a sampling rate of 1 kHz. Finger pulse was measured using a reflection photoplethysmograph transducer placed on the middle finger of the nondominant hand. The pulse transit time (PTT) was detected online computing the interval between R-wave of the electrocardiogram (ECG) and the maximum amplitude of the finger pulse. Respiration was assessed with a single respiration strain gauge placed around the chest, coupled to a bridge amplifier and was used as a covariate in the interbeat interval data analysis (see below) to control for respiratory influences on interbeat interval.

Finger temperature. Finger temperature was assessed using a temperature probe placed on the little finger of the nondominant hand.

Muscle activity. Three pairs of Med Associates 4 mm Ag/AgCl electrodes were placed above the sites of the left *frontalis medialis*, the *forearm extensor* of the inactive arm, and the *forearm extensor* of the arm holding the mouse. The skin at these muscle sites was cleaned using PDI electrode prep pads (70% alcohol and pumice). Med Associates electrode electrolyte (TD41) was used as conducting medium. All electrode pairs were referenced to a forehead electrode placed near the midline. The raw EMG signals were amplified (with a factor of 50,000 for frontalis and with a factor of 10,000 for the forearm extensor activity recordings, which were adjusted downward only when extensive clipping of the signal occurred during experimentation), band pass filtered (100 Hz–1 kHz), rectified, and integrated with a time constant of 200 milliseconds.

Synchronisation. All target events were marked by a digital code transmitted through the parallel port of the game computer to a digital input channel of the physiological measuring apparatus. All measurements were sampled continuously at 20 Hz and stored.

Artefact control and data reduction

All recordings were visually inspected, and obvious movement artefacts, characterised by out-of-range values and discontinuities across channels, were deleted. The skin conductance recording contained occasional high frequency spikes introduced by the automatic back-off. These spikes were deleted and the missing data replaced by interpolating the signal. Routines created in LabView by the authors were used for post-processing of the signals.

Events were excluded from analysis if: (a) a target event followed a previous target event by less than 6 seconds (in this case, physiological responses might have been influenced by the previous event); (b) if the event was followed by a pop-up screen for the assessment of emotion report data or voice samples (to prevent interference of verbal responses with physiological measurements), the latter of which are not part of the current report (but see Johnstone et al., 2003). The number of pop-up screens for the emotion reports that appeared per condition was 9 on average (min 8 and max 11). Either the pop-up screen for assessment of emotion report data or the pop-up screen for the collection of voice samples appeared on average once every 171 seconds (M = 171.84, SD = 65.15 s). The interruptions due to these pop-up screens were on average 21.2 seconds long (SD = 7.67). The total number of events was 3305; out of which 2595 were retained for further analysis.

An automated routine enabled the scoring of the skin conductance response amplitudes. A skin conductance response was scored when the increase in skin conductance level exceeded 0.05 microSiemens, and the onset of the response occurred within a window of 3 s, starting 2 s before event onset and ending at 1 s after event onset for the pre-event time window, or starting 1 s until 4 s after event onset for the event-related time window (event-related skin conductance responses typically occur within 1–3 s after stimulus onset, see also Dawson, Schell, & Filion, 1990). The amplitudes of the response were scored as the difference between the point of onset and the point of maximum deflection. If no response occurred in the 3 s window, a zero was scored.

The time windows used in this analysis are very short for a slow-changing signal such as finger temperature. This causes a problem since if finger temperature is changing in a particular direction before an event, it is likely to continue doing so until well after the event. The effects of experimental manipulations are thus likely to affect the rate at which finger temperature is changing, rather than the direction of change *per se*. In addition, differences in the rate of finger temperature change, rather than in finger temperature itself, are a more sensitive short-term indicator of event-related vasoconstriction. For this reason, we measured finger temperature slope rather than mean finger temperature, by calculating the mean slope in the 3 s windows preceding and following event onset (using the gradient of a least-squares linear estimate of finger temperature in each window).

Second-by-second estimates of interbeat interval were calculated using a weighted average of measured interbeat intervals that fell at least partially within each given 1 s window, with weights for each measured interval based upon the proportion of that interval which fell within the 1 s window (cf. Hugdahl, 1995). Ten 1 s epochs were thus created, covering a window of 5 s prior to event onset until 5 s after event onset. Those windows containing missing data due to artefact removal were excluded. Pulse transit times were calculated using a similar procedure.

Because the accurate assessment of respiration patterns requires volume calibrations, ideally two strain gauges, and sequences of at least 1 minute duration (Boiten, 1993), respiration was merely assessed to control for the influence of phase-locked inspiration or expiration on interbeat interval. To obtain an index of inspiration and expiration, the first derivative of the respiratory signal within a window of 10 s (5 s prior and 5 s following event onset) was taken, smoothed using a 1 s median filter, and down-sampled to give a second-by-second value to serve as a covariate in the analysis of the interbeat interval data.

The electromyograph (EMG) measures were analysed in a second-by-second fashion covering a window from 3 s preceding to 3 s following event onset. For each second, the rectified and integrated EMG signal was averaged.

Data analysis

For each participant, the physiological parameters were averaged across trials within each condition and allocated to each of the cells of the fully crossed 3 (Performance Level) $\times$ 2 (Conduciveness) $\times$ 2 (Pleasantness) $\times$ Time factorial within-subjects design. The number of levels of the time factor was either 2 (before-after event onset) for skin conductance and finger temperature data, 10 (5 s before until 5 s after event onset) for interbeat interval and pulse transit time, or 6 (3 s before until 3 s after) for the EMG measures. These differences in the length of time over which measures were analysed reflect the different time constants of the different measures; changes to muscle activity happen very quickly whereas heart rate varies more slowly, and skin conductance and finger temperature vary even more slowly.

Even though the inclusion of the relative performance level was constructed in a *post-hoc* fashion, we entered this factor in the design to reduce the number of tests performed (i.e., rather than performing a separate set of *post-hoc* tests with the relative performance level). All the physiological data were analysed in a MANOVA with repeated measures, entering Time and Performance Level as main effect and interaction effects of Time with all other factors in the model. The physiological variables of two of the participants contained missing data. These two cases (both male) were therefore deleted. As outlined above, we predicted specific effects for goal conduciveness and pleasantness for skin conductance, finger temperature slope, EMG, and heart rate (as quantified by interbeat interval). These effects were predicted to be observable after event onset. Hence, effects of conduciveness and pleasantness were tested by means of Time × Conduciveness and Time × Pleasantness interactions. Interactions between time, conduciveness, and pleasantness, as well as main and interaction effects with relative performance level were explored. A significance level of .05 was used for all analyses.

RESULTS

Emotion ratings. Due to the relatively low frequency of the emotion ratings, not enough observations were accumulated to check for effects of the relative performance level on self-reported emotions. Shame and helplessness were dropped from further analysis, because of the strong deviation of the emotion ratings from normal distributions and a relative lack of nonzero responses (i.e., frequency of 10 or less) for all conditions. Univariate repeated measures ANOVAs were carried out separately for each of the remaining six emotions on the four cells of the Conduciveness × Pleasantness design.

The analyses showed significant main effects of Conduciveness for pride, $F(1, 31) = 18.73$, $p < .001$, joy, $F(1, 31) = 10.59$, $p = .003$, anger, $F(1, 31) = 19.55$, $p < .001$, and surprise, $F(1, 31) = 5.94$, $p = .021$, and a trend for feelings of tenseness, $F(1, 31) = 3.93$, $p = .056$. As shown in Table 1, joy and pride were both higher in conducive conditions than in obstructive conditions. Anger, surprise, and tenseness were both higher in obstructive conditions than in conducive conditions. For Intrinsic Pleasantness, the analysis revealed a trend for anger, $F(1, 31) = 3.87$, $p = .058$, where the reported intensities were higher for events accompanied with the unpleasant sound compared to those accompanied with the pleasant sound. No other main or interaction effects were significant.

Skin conductance responses. The analysis revealed, as predicted, a significant Time × Conduciveness interaction, $F(1, 30) = 16.3$, $p < .001$. Follow-up analyses for each of the time windows separately indicated that the effect of conduciveness was not significant before event onset, $F < 1$, but after event onset, skin conductance response magnitudes were higher for obstructive compared to conducive events, $F(1, 30) = 14.27$, $p < .001$. Contrary to predictions, there was no Time × Pleasantness interaction, $F < 1$. However, the undirected tests showed a three-way Time × Conduciveness × Pleasantness interaction, $F(1, 30) = 5.02$, $p = .033$. Follow-up tests indicated that

TABLE 1
Means (and SDs) of the intensity per emotion scale as a function of event type

	Event type							
	Obstructive/ Unpleasant		*Obstructive/ Pleasant*		*Conducive/ Unpleasant*		*Conducive/ Pleasant*	
Emotion label	*M*	*(SD)*	*M*	*(SD)*	*M*	*(SD)*	*M*	*(SD)*
Interest	0.26	(0.33)	0.25	(0.34)	0.25	(0.27)	0.27	(0.29)
Surprise[a]	0.08	(0.13)	0.10	(0.12)	0.04	(0.07)	0.05	(0.10)
Joy[a]	0.14	(0.27)	0.13	(0.24)	0.21	(0.27)	0.19	(0.24)
Pride[a]	0.10	(0.17)	0.08	(0.15)	0.23	(0.25)	0.26	(0.26)
Helplessness	0.07	(0.16)	0.05	(0.11)	0.03	(0.08)	0.02	(0.06)
Tenseness	0.20	(0.26)	0.20	(0.25)	0.15	(0.22)	0.17	(0.25)
Anger[a]	0.18	(0.23)	0.12	(0.15)	0.06	(0.13)	0.03	(0.06)
Shame	0.02	(0.07)	0.01	(0.03)	0.01	(0.04)	0.01	(0.03)

Note: Values range from 0 to 1. [a] Significant differences between conducive and obstructive events.

conduciveness interacted significantly with pleasantness before event onset, $F(1,30) = 7.82$, $p = .01$, but not after event onset, $F < 1$. However, pleasantness showed a main effect after event onset, $F(1,30) = 4.14$, $p = .051$, and not before onset, $F < 1$, with higher response magnitude for unpleasant compared to pleasant sounds (see also Figure 1). The significant Conduciveness × Pleasantness interaction before event onset must thus be attributed to chance, given that the sound was played at event onset, hence there was no way for players to predict the pleasantness before event onset. The relative performance level did not yield a main effect nor interaction effects with either conduciveness or pleasantness.

Interbeat interval. To control for the possible phase-locked effects of respiration on IBI, we first performed a regression analysis with second-by-second respiration derivative (as described above) as the predictor of IBI. Respiration was found to explain less than 1% of the variance in IBI, indicating that the effects of respiration on IBI in this experiment were negligible.

The second by second analysis of IBI differed across the levels of the time factor, $F(9,22) = 12.71$, $p < .001$. Time interacted significantly with conduciveness as predicted, $F(9,22) = 13.31$, $p < .001$, but not with pleasantness, $F(9,22) = 1.75$, $p = .137$. As Figure 2 indicates, IBI increased just prior to passing to the next level compared to losing the ship [simple contrast at time -1 versus time -5 with conducive versus obstructive, $F(1,30) = 9.44$, $p = .004$]. Interestingly, whereas the IBI started to decrease immediately after event onset for both types of events, the decrease was stronger for conducive than for

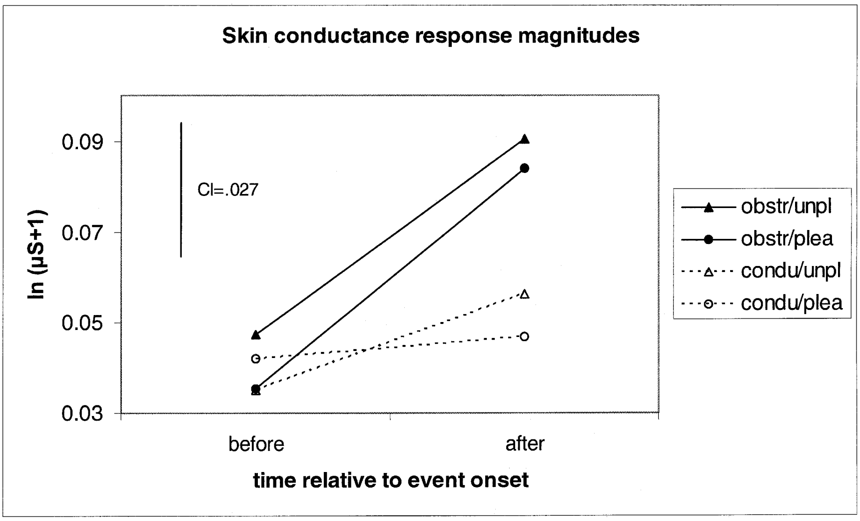

Figure 1. Mean log-transformed skin conductance response (SCR) magnitudes before and after each type of game situation. The 95% within-subjects confidence interval (CI) for all comparisons is 0.027 and marked in the graph. obstr = obstructive; condu = conducive; unpl = unpleasant; plea = pleasant.

obstructive situations [time 2, 3, 4, and 5 vs. time -5 and conducive vs. obstructive, $F(1,30) = 8.44$, $p = .007$; $F(1,30) = 31.14$, $p < .001$; $F(1,30) = 25.04$, $p < .001$; $F(1,30) = 14.81$, $p = .001$, respectively]. The interaction between time, conduciveness, and pleasantness was not significant.

The relative performance level showed a main effect, $F(2,29) = 10.51$, $p < .001$, but no interaction with conduciveness or pleasantness (all interactions show $F < 1$). The IBIs linearly decreased across the performance levels [level 1 vs. level 2: $F(1,30) = 16.79$, $p < .001$; level 1 vs. level 3: $F(1,30) = 20.37$, $p < .001$]. No other effects were found.

Pulse transit time. Due to recording error (2 cases) and unreliable peak-to-peak detection (5 cases), the data of 7 players (all male) were deleted listwise. For the remaining subjects, the PTT varied over time, $F(9,15) = 7.47$, $p < .001$, and showed a significant effect for Time $\times$ Conduciveness, $F(9,15) = 2.98$, $p = .03$, but not for Time $\times$ Pleasantness, $F < 1$. Follow-up analyses (simple contrasts using the first level of the time factor as a reference) indicate differences of conduciveness after event onset, specifically at 1 s, $F(1,23) = 4.08$, $p = .055$, 3 s, $F(1,23) = 5.82$, $p = .024$, and 4 s after event onset, $F(1,23) = 8.07$, $p = .009$, and no effect before event onset, all Fs < 1. As Figure 3 also indicates, conducive events were related to shorter PTTs than obstructive events at 1 s and 4 s after event onset, whereas at 3 s after onset, the PTT was longer for

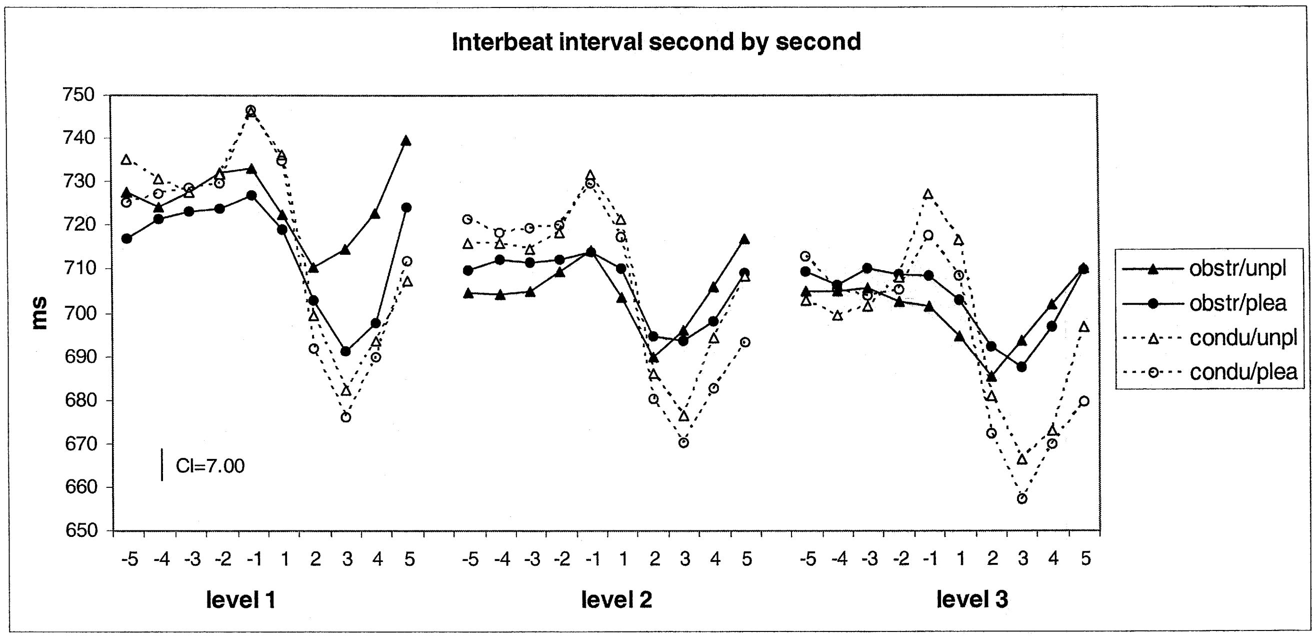

Figure 2. Mean second-by-second interbeat intervals 5 s before and after event onset of each of the game situations, which are plotted separately for each of the three relative performance levels (levels 1, 2, and 3). The 95% within-subjects confidence interval (CI) for all comparisons is 7.00 and is marked in the graph. obstr = obstructive; condu = conducive; unpl = unpleasant; plea = pleasant.

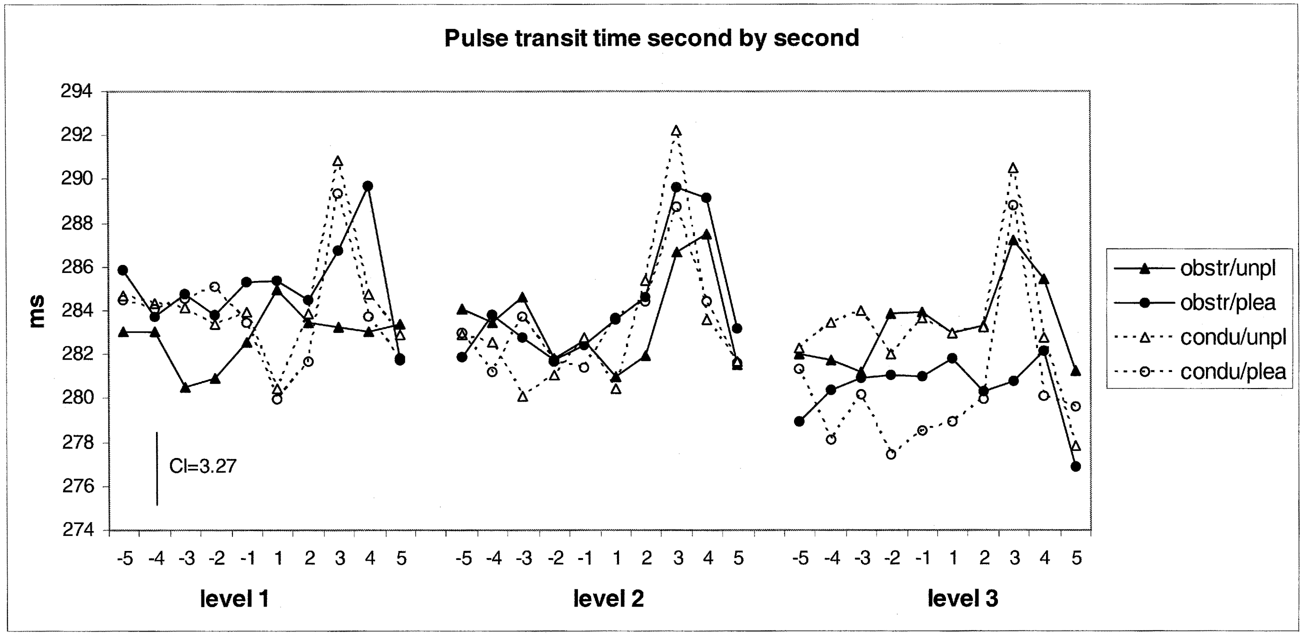

Figure 3. Mean second-by-second pulse transit times 5 s before and after event onset of each of the game situations, which are plotted separately for each of the three relative performance levels (levels 1, 2, and 3). The 95% within-subjects confidence interval (CI) for all comparisons is 3.27 and is marked in the graph. obstr = obstructive; condu = conducive; unpl = unpleasant; plea = pleasant.

conducive compared to obstructive events. Furthermore, the relative performance level altered the PTT, $F(2, 22) = 3.49$, $p = .048$, with decreasing times across the levels, which was significant only for level 3 compared to level 1, $p = .013$.

Finger temperature slope. The analysis of the finger tempereature slope data (with possible effects of event onset time regressed out of the data, see above) did not yield the predicted interaction between time and conduciveness, $F < 1$. Finger temperature slope did vary with time, $F(1, 29) = 4.52$, $p = .042$, with stronger decreasing slopes after event onset compared to before event onset. The relative performance level showed a significant effect, $F(2, 28) = 26.26$, $p < .001$, which was indicative of a significant difference between level 1 and level 3, $F(1, 29) = 28.86$, $p < .001$. As illustrated in Figure 4, the slopes were positive at level 1, approached zero at level 2, and were negative at level 3. Furthermore, relative performance interacted with conduciveness and time, $F(2, 28) = 6.12$, $p = .006$. Follow-up analyses showed that this was due to a significant Time × Conduciveness effect at level 1, $F(1, 30) = 7.99$, $p = .008$, but not at level 2, $F < 1$, nor at level 3, $F(1, 30) = 2.28$, $p = .142$. The conduciveness manipulation showed an increase in finger temperature slope (i.e., faster rise in finger temperature) for conducive events after event onset

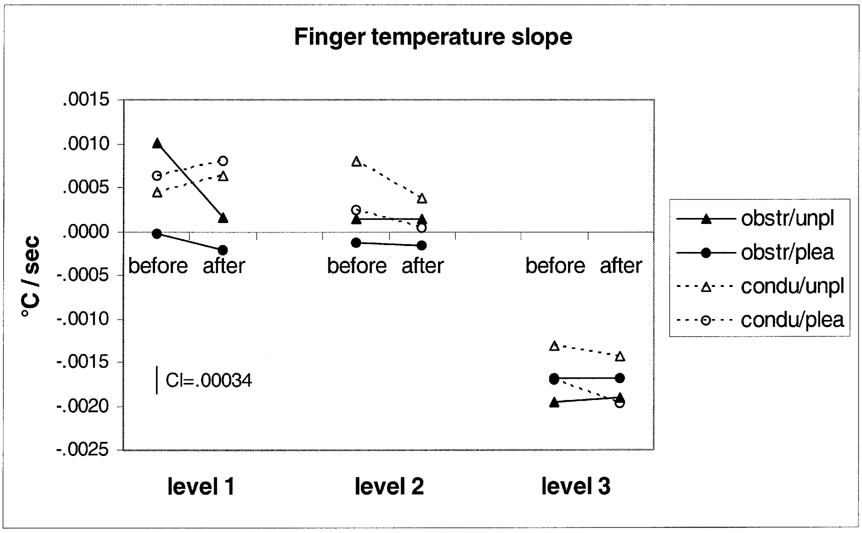

Figure 4. First derivative of the finger temperature slope (residualised) before and after each type of game situation and plotted separately for each of the three relative performance levels (levels 1, 2, and 3). The 95% within-subjects confidence interval (CI) for all comparisons is 0.00034 and marked in the graph. obstr = obstructive; condu = conducive; unpl = unpleasant; plea = pleasant.

compared to before event onset at relative performance level 1, whereas the slopes decreased (but were still positive; i.e., indicating a more slowly rising finger temperature) for obstructive events after event onset compared to before the event. At level 3, the interaction of time and conduciveness was characterised by a stronger decrease in finger temperature slope after event onset compared to before event onset for conducive events, while obstructive events did not show such an effect (see Figure 4). There was no significant Time × Pleasantness interaction.

EMG. The second-by-second analysis of the activity measured over the frontalis yielded no interaction effect of time and conduciveness, $F < 1$. A significant effect was found before event onset, $F(2, 29) = 4.26$, $p = .024$, which has to be ascribed to chance, given that the sound was played *after* event onset.

The forearm extensor measured from the resting arm showed only a main effect for Time, $F(5, 26) = 2.65$, $p = .046$, no interaction with conduciveness nor pleasantness or any effect of relative performance level, all Fs < 1.6, n.s.. The effect of time for resting forearm extensor activity was characterised by an increase after event onset compared to before event onset in particular [comparisons with time −3 are significant for time 1, $F(1, 30) = 4.35$, $p = .046$; time 2, $F(1, 30) = 7.52$, $p = .01$; and time 3, $F(1, 30) = 7.49$, $p = .01$]. Forearm extensor activity from the playing arm showed the predicted Time × Conduciveness interaction, $F(5, 26) = 8.29$, $p = .022$, characterised by higher muscle activity for obstructive than for conducive situations at time −1 in particular, in the time window immediately before event onset, $F(1, 30) = 15.23$, $p < .001$ (see also Figure 5, bottom panel). The forearm extensor activity of the playing arm did not vary as a function of the pleasantness of the sound, all Fs < 1.9, n.s.. Relative performance level also bore no effect on either EMG measure, all Fs < 1.

DISCUSSION

Before discussing the specific results of this study, it is worth noting that since this study was not based on well established paradigms, it had some shortcomings. Most notable is the instantiation of dimensions in the computer game and the related issue of appraisal effects versus context effects. The relevance of these shortcomings to an interpretation of the results and to the design of future studies is addressed following a discussion of the results obtained in this experiment.

The operationalisation of goal conduciveness was characterised by different physiological patterns. Higher phasic skin conductance activity was observed in response to the obstructive events than in response to the conducive events. Furthermore, finger temperature slopes were more positive for conducive events than for obstructive events, which indicates relatively stronger peripheral

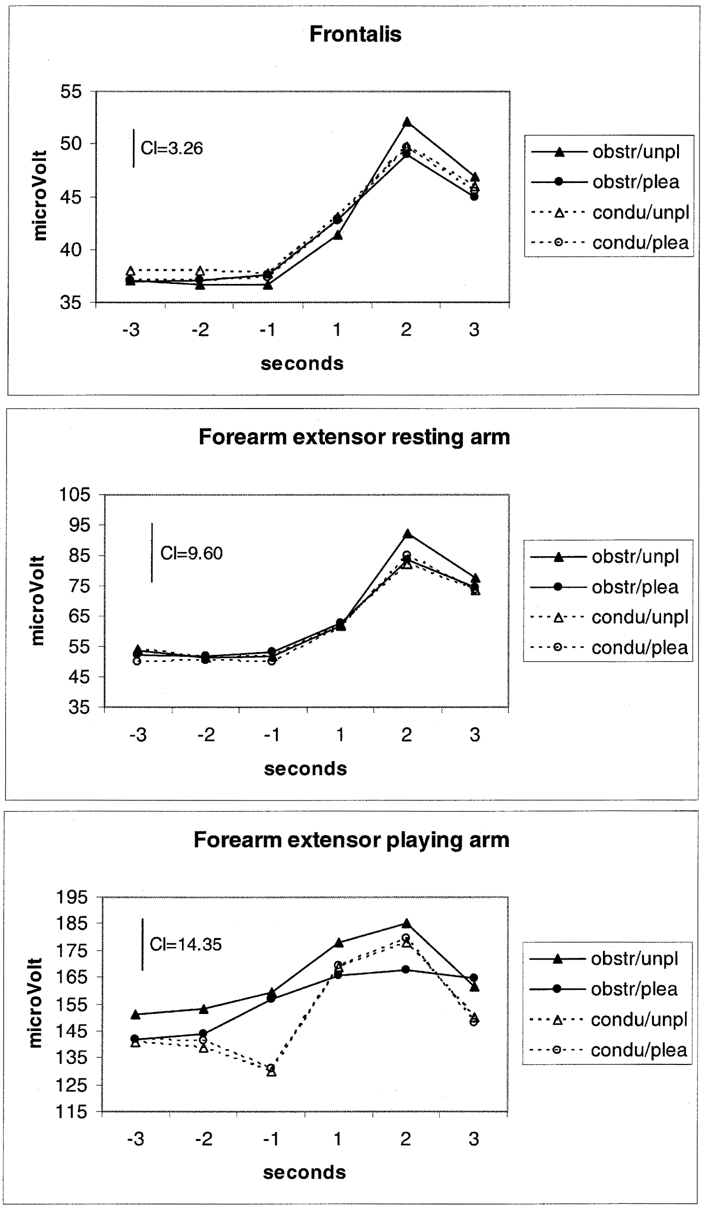

Figure 5. EMG activity in micro volts measured over the frontalis (top plot), the forearm extensor of the resting arm (middle plot), and the forearm extensor of the playing arm (bottom plot) averaged per game event type and per second before and after event onset. The 95% confidence interval (CI) for frontalis is 3.26, for the forearm extensor of the resting arm is 9.60, and for the forearm extensor of the playing arm is 14.35, obstr = obstructive; condu = conducive; unpl = unpleasant; plea = pleasant.

vasodilation in response to the conducive events. The results of these two measures are consistent with a lower level of sympathetic arousal related to conducive compared to obstructive events. The results are also in line with the emotion intensity ratings, with higher ratings for positive, relative low-arousal emotions (i.e., pride and joy) associated with conducive events, and higher ratings for relative high-arousal, negative emotions (i.e., anger, a trend for tenseness) associated with obstructive events—surprise being the exception to the latter. However, even though self-reported tenseness showed a trend, there was no discernible difference in measured muscle tension in response to conducive compared to obstructive events.

Surprisingly, the interbeat interval data showed that the conducive events were related to longer intervals (i.e., lower heart rate) prior to event onset, and a stronger decrease in interbeat intervals (i.e., faster heart rate) after event onset than were obstructive events. This stronger decrease in interbeat interval following conducive situations could be due to an accelerative recovery of heart rate, or rebound effect (e.g., Stern & Sison, 1990) of sympathetic dominance after predominantly parasympathetic nervous system activity, or of increased anticipated effort required for the new game level, or of a combination of these factors. The results for pulse transit time, which showed a clear increase after event onset, are at odds with the interbeat interval shortening. However, Fernandez and Vila (1989) have shown that cardiac period and pulse transit time can show opposite effects in the first few seconds after the presentation of a high intensity auditory stimulus. This they explain in terms of separate effects of sympathetic and vagal influences on heart function, a topic discussed in detail by Berntson et al. (1994).

Scherer's appraisal theory holds that appraisals lead to adaptive physiological changes that should be measurable using psychophysiological techniques. The principal hypothesis of this study was that the systematic manipulation of game events that can be assumed to produce specific appraisals along the intrinsic pleasantness and conduciveness dimensions would have measurable effects on the physiological response systems measured. Indeed, there were a number of significant effects for several response modalities. Skin conductance activity, finger temperature slope, pulse transit time, and interbeat interval all showed significant effects of conduciveness, while manipulations of intrinsic pleasantness produced significant changes in skin conductance activity only. The fact that distinct effects were found for intrinsic pleasantness and goal conduciveness supports the suggestion by Scherer (1984a, 1984b; 2001) to theoretically and empirically separate these appraisals.

It might be suggested that the relative lack of effects of intrinsic pleasantness (i.e., other than skin conductance activity) in the present study casts doubt on the relevance of this dimension to emotion-related physiology. One explanation for the lack of effects of intrinsic pleasantness manipulations on physiology is that the intrinsic pleasantness of a situation affects systems other than the autonomic nervous system (e.g., see Johnstone et al., 2003, for the relevance of this dimension to vocal expression of emotion that could not be explained in terms of autonomic arousal). It might be possible that the sounds were simply ineffective in eliciting physiological changes, despite the fact that in the pretest the sounds were rated as highly pleasant and unpleasant.

The most likely explanation is that, in the scheme of the game, the conduciveness or obstructiveness of a situation is of more relevance and hence results in stronger emotional responses than does the situation's pleasantness. In accordance with Scherer's formulation of intrinsic pleasantness (which is unique among appraisal theories in being conceptually distinct from goal-relevant appraisals of valence), the manipulation of intrinsic pleasantness in this experiment had no bearing or consequences in the game, and therefore have diminished impact on players' physiology.

The relative performance level was related to changes in a number of physiological measures. Interbeat interval, pulse transit time, and finger temperature slope all showed a linear decrease with increasing performance level. These decreases can be explained in terms of a greater challenge and task engagement at higher performance levels. At higher performance levels in XQUEST, players encounter new objects and enemies, and the game difficulty increases. Assuming that the game does not become too difficult for a player (which could lead to task disengagement), an increase in active engagement in the game could reasonably be expected at high task levels, as has been found in other studies of task engagement (see Pecchinenda, 2001). Such an increase in active engagement is reflected in a sympathetically mediated increase in cardiovascular activity. The player's relative performance did not influence the responses to the different types of events, with the exception of finger temperature. Finger temperature slope was more positive after conducive events than after obstructive events at the lowest relative performance level, with no significant effect of conduciveness at levels 2 and 3. It is likely in this case that increased general task engagement at higher relative performance levels masked any effects of conduciveness at these levels.

As mentioned at the start of the discussion, the present experiment, being one of the first of its kind in this field, does have some shortcomings. Perhaps the most important concerns the instantiations of conduciveness and obstructiveness, which were limited to two specific game events. Given the difficulty in convincingly manipulating goal conduciveness in a computer game, we decided to start with natural events within an existing and compelling game that have clear appraisal function and that occur repeatedly. Nevertheless, it is possible that the events differed in ways other than just their conduciveness, possibly giving rise to nonconduciveness related effects on physiology. For example, EMG measured at the playing arm and interbeat interval showed effects prior to event onset, which suggests that the events were differently anticipated: The anticipation of passing to the next level was associated with less tension (as indexed by lower EMG activity) and possibly less arousal (as indexed by longer interbeat intervals) than the anticipation of losing a ship. Future studies will need to use game events that are more precisely matched and controlled.

More generally, the question can be posed as to whether the observed effects were specific to the particular game events examined in this study, or whether the effects could be generalised to other conducive or obstructive situations. The question of whether observed physiological responses can be attributed to emotional processes or whether they reflect or are influenced by context or situation specific response systems has been thoroughly discussed by Stemmler (1992; Stemmler, Heldmann, Pauls, & Scherer, 2001). In the present study, the observed effects could certainly be context-specific. Future studies, in which conduciveness and pleasantness are manipulated differently will be required to establish the extent to which physiological responses generalise. The problem of confounding context effects with emotion- or appraisal-related physiological responding is by no means unique to this study, however. The same problem exists for studies that rely solely on single induction procedures, such as picture viewing or imagination techniques. Indeed, the primary motivation for investigating the utility of computer games as an experimental tool for examining emotion-related psychophysiology is that they are very different from more widely used induction methods. Comparing results from computer game studies with studies using more established techniques should help to identify those physiological responses that are truly emotion-related rather than context-specific.

One assumption made by this study was that the manipulated events were indeed appraised as intended. Clearly, it would be preferable to directly measure the players' subjective appraisals. However, in such an experimental context, appraisal is difficult if not impossible to assess in a direct fashion. It would have been possible, of course, to ask participants directly about how they evaluated the event (Was it pleasant or unpleasant? Did it help or hinder reaching your goals?) as is generally done in much of appraisal research. However, it is exactly that kind of verbal report of appraisal which is generally attacked by critics, arguing that individuals do not have direct conscious access to these appraisal processes, especially when they occur in an automatic fashion. We therefore refrained from asking such appraisal questions (in part also since it would have interrupted the game and focused the attention of the players on these evaluations, probably resulting in changing processing from automatic to controlled).

It should also be noted that the game events had been devised on the basis of their high face validity. Losing a ship in a game is, by definition, obstructive to the goal of winning points, and reaching the next level is by definition conducive to such a goal. It is likely that subjective reports to the events would merely have reflected the players' acknowledgement of the obvious link between each event type and winning more points. With respect to the pleasantness manipulation, it is worth reiterating that Scherer's proposed intrinsic pleasantness appraisal is an evaluation of the pleasantness of a stimulus in general, *regardless of the context*. Asking for evaluations of the pleasantness of the sounds outside of the context of the game would therefore seem to be the best way to measure intrinsic pleasantness.

Importantly, and in accordance with Kappas and Pecchinenda (1999), the present study demonstrates that the computer game paradigm is a promising new tool for experimental research in emotion psychology in general, and appraisal theory in particular. This study is a first step in using a computer game to single out appraisal dimensions and to directly measure their influence on physiological variables. Given that appraisal theories emphasise that emotion is a process with fast-changing evaluations and responses, and that a large amount of the evaluative processes occur outside of awareness, studies should move away from the use of questionnaires as a sole dependent measure of evaluation processes. The results of this study indicate that a more time-sensitive analysis of physiological changes as opposed to averaging across a larger time window is particularly informative with respect to fast-changing processes, the kind of processes that appraisal theories propose but have not studied with the appropriate measures or experimental design. In particular, it was found that second-by-second analysis of interbeat interval, EMG and pulse transit time, and event-locked analysis of phasic skin conductance activity provide useful information on the time course of physiological responses to events that vary in terms of two important appraisal dimensions, conduciveness, and pleasantness.

Other appraisal dimensions, in particular appraisals of coping potential, would seem ideal candidates for study using the computer game paradigm (see also Johnstone & Scherer, 2000; Kappas & Pecchinenda, 2000; van Reekum, Johnstone, & Scherer, 2000, for preliminary reports of such efforts). Indeed, other research programmes in the domain of appraisal theories of emotion are focusing on coping appraisals, task engagement, and physiology (e.g., Pecchinenda & Smith, 1996; Smith & Kirby, 2001; Tomaka et al., 1997). This study and others like it highlight the importance of considering appraisal as a process, examining appraisal using experimental appraisal manipulations coupled with time-sensitive analysis of response modalities other than subjective feeling, such as physiology.

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