Alexithymia and Empathy Predict Changes in Autonomic Arousal During Affective Stimulation

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Background: Alexithymia, the inability to describe one's own emotions, is linked to deficits in empathy, manifesting as a diminished capacity to recognize or understand the emotions and mental states of others. Several brain centers of autonomic control and interoception that are activated in empathy are thought to misfunction in alexithymia. We hypothesized that individual differences in autonomic changes under affective stimulation might be associated with differences in alexithymia and empathy.

Methods: We studied 21 healthy volunteers, comparing their alexithymia and empathy scores with changes in their sympathetic autonomic arousal, indexed by the palmar skin potential level, during 3 tasks: playing a computer game, performing mental arithmetic, and watching a negative emotional valence video.

Results: Both autonomic and subjective sense of arousal increased at the beginning of each task and then gradually subsided over the course of the task. Higher autonomic arousal at the onset of the computer game was associated with higher empathy scores, and at the onset of the negative video with higher scores for both empathy and alexithymia. Alexithymia delayed the habituation of autonomic arousal during the computer game, while the empathy score was related to a faster decline in arousal during the negative video task.

Conclusions: High alexithymia and high empathy scores were linked to increased autonomic arousal at the onset of emotional stimulation, but were distinguishable in the rates of habituation of the evoked arousal. Our data provide insight into the relationships among interacting psychological traits, physiologic regulation, and the arousal dimension of emotional experience.

Key Words: alexithymia, empathy, autonomic arousal, skin potential level

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Reader Benefit: Alexithymia and empathy share strong autonomic reactivity to onset of emotional arousal, but alexithymia is related to slower habituation.

df = degrees of freedom; **G-G epsilon** = Greenhouse-Geisser epsilon parameter; **SAM** = Self-Assessment Manikin; **SPL** = skin potential level.

Alexithymia is a limited ability to recognize and communicate one's own emotions (Lumley et al, 2007). It remains unclear whether the primary deficit in alexithymia is a failure to distinguish emotions from bodily sensations or an inability to verbalize one's emotions (Lesser, 1981). Alexithymia is associated with poor quality of life (Mattila et al, 2009) and with somatization, the conversion of psychological distress into physical symptoms (Mattila et al, 2008). Alexithymia is found in a disproportionately high percentage of people with disorders that may have psychological complications, such as fibromyalgia, functional gastrointestinal disorders, cardiac disease, essential hypertension, anxiety, depression, compulsive behavior, and a higher-than-average risk of death from injury, accident, and violence (Lumley et al, 2007).

There is evidence that stress-sensitive disorders like these are mediated in part by abnormalities in autonomic state and reactivity, but the data about autonomic changes in people with alexithymia are weak or contradictory. Indeed, affected people's physiologic reactions to emotional stimuli have been reported to be nil, increased, or inhibited.

Intense arousal may be a causal factor in the development of alexithymia (Rabavilas, 1987). People with alexithymia may have unusually high baseline electrodermal reactivity (Stone and Nielson, 2001). Electrodermal responses to erotic images are higher than normal in people with difficulty in identifying, verbalizing, and

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analyzing emotions—considered high cognitive facets of alexithymia. Frightening images induce unusually strong responses in people with reduced emotionalizing and fantasizing—pronounced affective facets of alexithymia (Bermond et al, 2010). Patients with anxiety and alexithymia respond with higher levels of electrodermal arousal and slower recovery time when confronting novel situations (Rabavilas, 1987).

Alexithymia also predicts greater heart rate and blood pressure reactivity to stressors (Luminet et al, 2004; Waldstein et al, 2002). Significant correlation between alexithymia and the norepinephrine:cortisol ratio has been reported in men (Spitzer et al, 2005). Outpatients with alexithymia and psychiatric disorders have high stable levels of autonomic reactivity at baseline and during cognitive tasks and visual stimulation (Infrasca, 1997). Patients with fibromyalgia and alexithymia show dissociation between their affective and autonomic responses (Brosschot and Aarsse, 2001).

However, these findings are contradicted by other studies suggesting either that alexithymia has no effect on stressor reactivity (Friedlander et al, 1997; Fukunishi et al, 1999; Martínez-Sánchez et al, 2001) or that alexithymia predicts reduced stressor reactivity (Hyer et al, 1990; Linden et al, 1996; Neumann et al, 2004; Roedema and Simons, 1999; Wehmer et al, 1995). One study (Connelly and Denney, 2007) found no relationship between alexithymia and heart rate or skin conductance throughout a baseline period, stressor exposure (Stroop task and a conversation task), and a recovery period, despite participants reporting consistently worse mood across all conditions.

Other studies found that people with alexithymia had blunted cardiac (Pollatos et al, 2008) and electrodermal (Wehmer et al, 1995) responses to emotion-evoking pictures. People with severe alexithymia had smaller skin conductance responses during speech preparation and speech (Pollatos et al, 2011). This variability in the reported autonomic associations of alexithymia may reflect differences in criteria for group selection (healthy volunteers vs patients, age, sex, physical health, comorbidity), axis of autonomic investigation, and type of experimental task.

Electrodermal activity is a sensitive psychophysiologic index of changes in autonomic sympathetic arousal, mediated by sympathetic regulation of sweat glands (Christie, 1981) and integrated with emotional and cognitive states. One measure of electrodermal activity is the skin potential level (SPL), a negativity in direct current potential at the surface of palmar skin (Figure 1). SPL is an index of tonic sympathetic arousal (Leiderman and Shapiro, 1964; Nishimura and Nagumo, 1985).

Autonomic sympathetic arousal, reflected in changes of electrodermal activity, is integrated with emotional and cognitive control via several brain areas (Critchley, 2002; Nagai et al, 2004). Altered function of those brain areas has been described in alexithymia, eg, in the prefrontal cortex (Berthoz et al, 2002; Moriguchi et al, 2006), cingulate cortex (Berthoz et al, 2002; Heinzel et al, 2010; Moriguchi et al, 2007), insula (Moriguchi et al, 2007), and amygdala (Kugel et al, 2008). These reports led us to theorize that individual predisposition to alexithymia is associated with differences in SPL. Therefore, our aim in this study was to explore, in a normative group, the relationship between individual alexithymia score and autonomic arousal (indexed by SPL negativity) in response to affective stimulation.

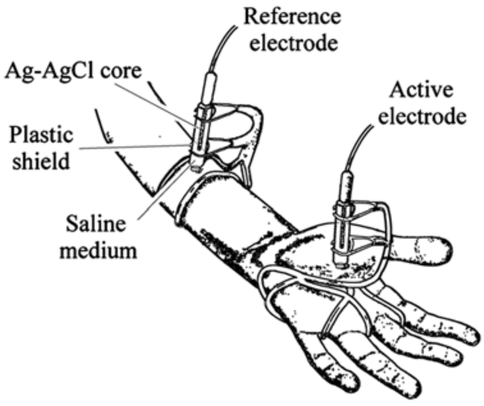

FIGURE 1. Locations of electrodes on left hand and arm for skin potential level (SPL) recording. The reference electrode has a silver chloride (Ag-AgCl) core.

Many people with alexithymia also have deficits in emotional empathy (Bernhardt and Singer, 2012; Moriguchi et al, 2007), which is the capacity to understand another's emotional state of mind and a "naturally occurring subjective experience of similarity between the feelings expressed by oneself and others" (Decety and Jackson, 2004). Deficits in insight into one's own emotional state may constrain the capacity for understanding emotions in others. Responses to stimulation, including autonomic reactions, have been proposed to be important for empathic awareness (Preston and de Waal, 2002). Activity within the anterior cingulate and the insular cortices increases during empathic responses (Bernhardt and Singer, 2012; Guo et al, 2012; Han et al, 2009; Lamm et al, 2011; Singer et al, 2004), and both regions contribute to the control of autonomic arousal (Critchley, 2009).

Individual differences in emotional empathy are related to differences in the reactivity of the anterior cingulate and insular cortices (Krach et al, 2011; Masten et al, 2011; Pfeifer et al, 2008) in a manner similar to alterations in the reactivity reported in some studies of alexithymia (Berthoz et al, 2002; Heinzel et al, 2010). Activation of the medial prefrontal cortex, a part of the "default-mode network" that is hyporesponsive in both high empathy (Kramer et al, 2010) and high alexithymia (Berthoz et al, 2002; Moriguchi et al, 2006), correlates in healthy individuals with lower tonic electrodermal activity (Nagai et al, 2004). Together, these observations motivated us to define the relationship between individual empathy scores and changes in tonic autonomic arousal evoked by different types of emotional challenge.

We hypothesized close, yet distinct, relationships between autonomic arousal induced by affective stimulation and scores for both alexithymia and empathy. We used 3 types of affective stimulation to engender high levels of emotional arousal: a video clip including scenes of violence from several feature films, a computerized "arcade" game, and a mental arithmetic task. These 3 tasks allowed us to test whether autonomic response had associations with alexithymia and empathy that were generalizable across types of emotional challenge.

Ultimately, we aimed to gain insight into the causal relationship between alexithymia and the pathogenesis of certain somatic illnesses (Taylor, 2000). For example, based on the observed link between pathologic gambling and alexithymia (Ferguson et al, 2009; Lumley and Roby, 1995; Mitrovic and Brown, 2009; Parker et al, 2005; Toneatto et al, 2009), we predicted a greater and more sustained autonomic arousal during the computer game task to correlate with higher alexithymia scores. Similarly, the known "empathic" autonomic arousal in a person witnessing the distress of others (Campbell-Yeo et al, 2008) led us to predict that increases in autonomic arousal during the negative emotional video task would relate to higher empathy scores. Last, we anticipated that autonomic arousal during the mental arithmetic task, representing neutral valence stimulation, would not relate to either alexithymia or empathy scores.

METHODS

Participants

Our 21 healthy volunteers, all students at Taras Shevchenko National University of Kiev, were 10 men and 11 women aged 19 to 23 years, all right-handed.

The participants came to our laboratory for 3 sessions spaced about a week apart. During the first session, all participants underwent psychological assessment and then they played the computer game. During the second session, all did the mental arithmetic task. During the final session, all watched the negative video.

Participants gave written informed consent after reading a full description of the experimental procedures. The study protocol was approved by the local ethics committee of the Taras Shevchenko National University of Kiev.

Psychological Tests

Before beginning the 3 experimental tasks, we gave an established Russian translation of the Toronto Alexithymia Scale to quantify individual differences in alexithymia (Bagby et al, 1994; Eresko et al, 2005; Haviland and Reise, 1996). We translated the Multi-Dimensional Emotional Empathy Scale devised by Caruso and Mayer (Caruso and Mayer, 1998; Mayer et al, 1999) into Russian and used it to evaluate the participants' empathy.

To assess the participants' changes in mood and psychological arousal during the 3 tasks, we gave them a paper-and-pencil version of the Self-Assessment Manikin (SAM) (Bradley and Lang, 1994). For this test, the participants were given 2 graphical scales, each depicting 9 continuously varying values along the dimensions of mood (valence) or arousal. The mood scale ranged from a schematic human figure with smiling, happy face to a frowning, unhappy face. The arousal scale ranged from a schematic human figure with excited, wide-eyed face to a relaxed, sleepy face. Four times during every testing session, the participants were asked to rate their own mood and arousal at that moment.

Affective Stimulation Procedures

For each of the 3 tasks, a participant sat facing a computer screen in a quiet room. Each experimental session lasted 28 minutes: a 9-minute pre-stimulus rest period, the 9-minute affective stimulation task, and a 9-minute post-stimulus rest period. We recorded the SPL throughout the 28 minutes (Figure 2). During the pre- and post-stimulus rest periods, we instructed participants to sit quietly and try to relax. During those periods, the screen showed them a neutral picture of a snowy winter forest.

Participants assessed their mood and arousal changes with the SAM. They filled out a SAM form 4 times per session: SAM1 just before the SPL recording was started, SAM2 just before the emotional stimulation task began, SAM3 just after the task ended, and SAM4 just after the recording was stopped. We gave them 30 seconds to fill out each form (Figure 2).

Tasks

Computer Game

We gave the computer game to raise participants' arousal level through positive subjective engagement (Barrett, 2004). They played 9 minutes of the game "3D Pinball for Windows: Space Cadet," included in Windows 2000 software (Microsoft 3D Pinball for Windows Space Cadet Version 5.0 Copyright 1981 to 1999; Microsoft Corp, Redmond, WA; 3D Pinball Table created for Microsoft by Maxis, Copyright 1995; Maxis, Emeryville, CA [now a subsidiary of Electronic Arts, Redwood City, CA]). Participants used only their right hand to operate the game controls.

Mental Arithmetic Task

Mental arithmetic represents a mental stress challenge (Bolshakov et al, 2003; Dedovic et al, 2005), and evokes effort-related autonomic arousal coupled to cognitive load (Yamada and Miyake, 2007); it is stressful but mostly neutral emotionally. For our mental arithmetic task, we asked participants to multiply a 2-digit number by a 1-digit number, and we presented new number combinations at a fast tempo over the 9 minutes. Each trial (eg, $36 \times 7 = \ldots$) appeared at the top of the screen; beneath it were 8 response options and a "no correct answer" option.

We heightened the stress and arousal in our mental arithmetic task by adding 2 types of distraction. One was white noise with sinusoid frequency modulation of 10 to 15 Hz over a period of 1 minute, 70 to 80 db, played

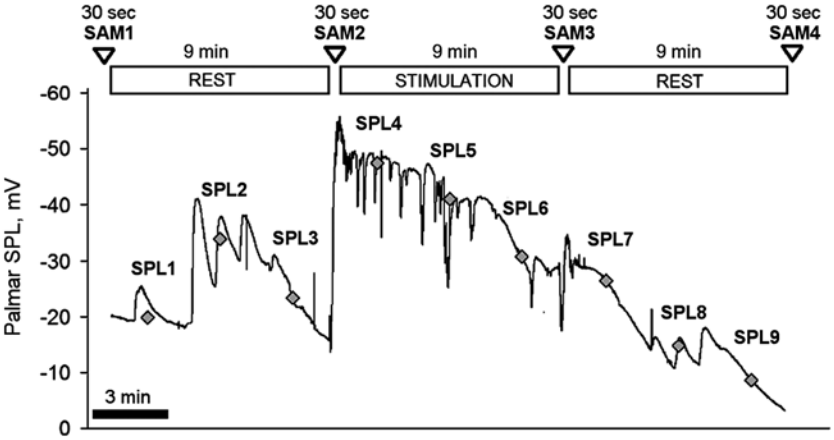

FIGURE 2. Scheme of the experimental procedure. Each of the three 28-minute sessions began and ended with a 9-minute rest period. During the 9-minute middle "stimulation" period, we gave the experimental task: during the first session, a computer game; second session, a mental arithmetic task; and third session, a negative video clip. We measured the participant's skin potential level (SPL) in millivolts (mV) throughout each session. This example shows SPL filtered data and median SPL values per 3-minute window (shown in the graph by diamonds). At 4 points during the session, we asked participants to fill out a Self-Assessment Manikin (SAM) form describing their level of psychological arousal and their mood: SAM1 (before start of recording), SAM2 (before task onset), SAM3 (after task offset), and SAM4 (after end of recording). The SPL calculations excluded the 30-second breaks when participants were filling out their SAM forms.

through the participant's headphones. The other distractor was false feedback, in the form of randomized messages saying "too long a delay" or "wrong answer," displayed onscreen every 3 to 5 trials irrespective of the participant's performance.

We developed the task using TestShield software, written by Maxim Zhigadlo, freely distributed on http://www.lonely-dragon.com/testshield.

Negative Video Task

We showed participants an almost-9-minute video clip containing violent scenes from feature movies. After the video, we showed images of high negative valence: International Affective Picture System 1111, 1120, 1275, 1300, 2095, 2352.2, 2375.1, 2661, 2981, 3005.1, 3010, 3015, 9490, 3053, 3060, 3061, 3062, 3064, 3068, 3069, 3071, 3080, and 3100 (Lang et al, 2008). Our goal was to induce mixed negative emotions, including anger, disgust, and fear (Schaefer et al, 2010).

We purposely made the first task the emotionally positive computer game, the second task the neutral to negative mental arithmetic, and the last task the negative video. We did not counterbalance the order of the tasks because we wanted to avoid the confound that responses to the less aversive tasks—the computer game and mental arithmetic—would be overshadowed by the powerful negative emotions raised by the video.

Electrodermal Activity Recordings

As shown in Figure 1, we recorded palmar SPL continuously from each participant's left hand (Fowles et al, 1981) using silver chloride (Ag-AgCl) electrodes with saline medium. Bias potential was <1 mV/hour; contact area to the skin was 1 cm^2. We placed the active electrode at the middle of the left palm, between the thenar and hypothenar eminences. We placed a reference electrode on the upper third of the left medial forearm.

Galvanically isolated signal was voltage-amplified at high-input impedance of 40 MΩ with band-pass filtering of direct current at 0.1 Hz. Skin potential was amplified 50 times. Analog data were digitized by analog-to-digital conversion (Lab-PC+ Low-Cost Multifunction Input/Output Board for Industry Standard Architecture; National Instruments, Austin, TX) with a sampling frequency of 1 kHz. The digital data series were saved for further analysis (recording, filtering, resampling, and calculation of medians) in Matlab 6 (Mathworks Inc, Natick, MA).

Data Reduction and Statistical Analysis

We low-pass filtered the SPL data using fast Fourier transformation and inverse fast Fourier transformation (0.15 Hz cutoff). Then we resampled the SPL data from 1000 Hz to 10 Hz. We calculated median SPL values within 3-minute windows over the course of the recording (Figure 2; median values are labeled SPL1 to SPL9).

We assessed the changes in median SPL values before, during, and after the task. Increases in SPL negativity correspond to higher sympathetic electrodermal tone (ie, autonomic arousal). Conversely, positive shifts (decreased negativity) in SPL indicate lower sympathetic autonomic tone (relaxation). Until the basal SPL is reached, a decrease in SPL negativity can be considered clear evidence of relaxation, ie, a decrease in arousal level (Christie and Venables, 1971, 1974). The idea that reduction of SPL negativity can be an autonomic sign of reduced arousal and relaxation in participants is endorsed by studies using longitudinal monitoring of SPL (Knott, 1980; Nishimura and Nagumo, 1985; Shiihara et al, 2000).

Statistical Tests for the Effects of Sequential Measurements and the Tasks

We tested the effect across sequential measurements of SPL and SAM using repeated measures analysis of variance that included the task factor (computer game, mental arithmetic, and negative video). We also tested for the interaction between sequential measurements and the tasks. If we found a significant *F* score, we reported the *F* score, degrees of freedom (*df*), and Greenhouse-Geisser epsilon (G-G epsilon) parameter used to correct for violation of sphericity. In post-hoc analysis (least significant difference), we tested for significant sequential differences in the dependent parameters (SPL1-SPL2, SPL2-SPL3, and so on). Group values were expressed as mean ± standard error of the mean.

Statistical Tests for the Effects of Psychological Variables

We estimated the effects of the psychological test variables (scores for alexithymia and empathy) on the SPL values under the general linear model within a full factorial design. The Levene test for homogeneity of variances was estimated only for effects of the task, alexithymia, and empathy. We selected as dependent variables only the most significant SPL values and the SPL and SAM values showing the greatest across-tasks change (eg, changes toward positive affect in 1 task vs negative affect in another task). The categorical factor was the task, and the continuous predictors were rank scores of alexithymia and empathy. We used rank scores in place of the raw parameters to constrain the biasing of our statistics by possible outliers. For the post-hoc tests, we calculated correlations between individual differences in psychological parameters and SPL dynamics using the Spearman rank correlation coefficient (ρ).

We performed the statistical analysis using STATISTICA 6.0 (StatSoft, Tulsa, OH). We set the criterion threshold for significance at $P = 0.05$.

RESULTS

Effects of Emotional Stimulation on Psychological Arousal and Mood

The participants rated their subjective psychological arousal and mood on SAM forms before and after each task. Thus, their subjective psychological arousal was different across the sequential ratings ($F = 15.01$, $P < 0.001$, $df = 3$, G-G epsilon = 0.88), but not between the tasks (Figure 3 and Table 1). Level of arousal was low pre-task (SAM2), higher immediately after task offset (SAM3), and lower again after post-task rest (SAM4).

As for participants' mood, we found significant effects across the sequential measures ($F = 15.13$, $P < 0.001$, $df = 3$, G-G epsilon = 0.69), the task ($F = 4.88$, $P < 0.05$, $df = 2$, Levene test for homogeneity of variances $P > 0.05$), and the interaction between the sequential measures and the tasks ($F = 7.15$, $P < 0.001$, $df = 6$, G-G epsilon = 0.69) (Figure 4 and Table 1).

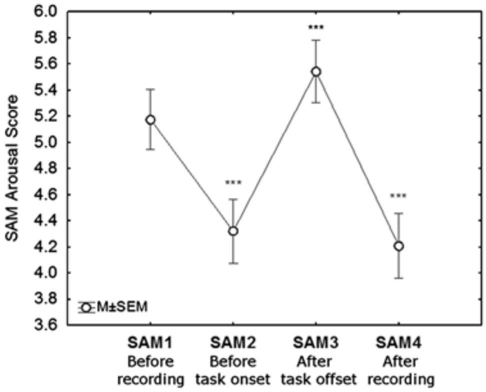

FIGURE 3. Subjective arousal ratings averaged for all 3 experimental tasks (computer game, mental arithmetic, and negative video) in the 21 participants. The ratings were obtained through the Self-Assessment Manikin (SAM), mean ± standard error of the mean (M ± SEM). ***$P < 0.0001$ value compared to previous measurement.

The computer game induced a stable increase in mood. The mental arithmetic task did not change mood. The negative video induced a strong darkening of mood, even during the pre-stimulation rest period when participants were anticipating the task, because they had been told that they would be seeing videos and pictures that could induce strong emotions. Mood ratings immediately after the computer game were significantly higher than after the other tasks. Over the post-task rest period, mood improved after the negative video and mental arithmetic task, but not after the computer game.

Effects of Emotional Stimulation on SPL

SPL changed significantly across the sequential measurements ($F = 13.75$, $P < 0.001$, $df = 8$, G-G epsilon = 0.44), but we did not find a significant effect of the task or the interaction between task and sequential measurements.

Participants relaxed, ie, had a decrease in sympathetic tone, expressed as a decrease in SPL negativity, before the onset of each task (Figure 5, SPL3 vs SPL2, $P \leq 0.001$; Table 1). The most significant among the serial differences was that between SPL3 and SPL4 ($P \leq 0.001$), corresponding to the autonomic response at task onset. At the end of the task period, we found secondary relaxation or habituation (SPL6 vs SPL5, $P = 0.025$). SPL continued to decline until the end of the experimental session (SPL9 vs SPL8, $P = 0.004$).

Alexithymia and Empathy Scores

The average score on the Toronto Alexithymia Scale was about 44 points out of a possible 100, but individual scores ranged from 31 to 61. The average score on the Multi-Dimensional Emotional Empathy Scale was about 3.3 points out of a possible 9, with individual scores varying from 1.9 to 4.5. Across the whole sample, there was no significant relationship between empathy and alexithymia.

TABLE 1. Self-Assessment Manikin (SAM) Ratings for Subjective Arousal, Mood, and Skin Potential Level (SPL)

Period During the Experimental Session	Measurement	Task (n = 21) Computer Game	 Mental Arithmetic	 Negative Video
Subjective arousal*				
Pre-task rest	SAM1	4.7 ± 0.4	4.8 ± 0.3	6.0 ± 0.4
	SAM2	4.3 ± 0.4	3.8 ± 0.4	4.8 ± 0.5
Post-task rest	SAM3	5.6 ± 0.4	4.9 ± 0.4	6.1 ± 0.4
	SAM4	4.2 ± 0.4	3.8 ± 0.4	4.6 ± 0.5
Mood*				
Pre-task rest	SAM1	6.8 ± 0.3	6.2 ± 0.4	7.1 ± 0.3
	SAM2	6.1 ± 0.3	5.5 ± 0.2	6.1 ± 0.2
Post-task rest	SAM3	6.9 ± 0.3	5.0 ± 0.4	4.2 ± 0.5
	SAM4	6.0 ± 0.3	5.8 ± 0.3	4.9 ± 0.3
SPL (mV)				
Pre-task rest	SPL1	−18.1 ± 2.6	−17.1 ± 2.2	−17.6 ± 2.4
	SPL2	−19.1 ± 2.1	−18.4 ± 2.4	−18.5 ± 2.2
	SPL3	−14.9 ± 2.0	−13.4 ± 2.1	−13.0 ± 2.5
Stimulation	SPL4	−20.0 ± 2.4	−20.2 ± 2.3	−20.5 ± 2.7
	SPL5	−18.3 ± 2.2	−18.6 ± 2.3	−19.5 ± 2.7
	SPL6	−16.8 ± 2.2	−16.6 ± 2.4	−16.3 ± 2.5
Post-task rest	SPL7	−15.5 ± 2.3	−18.3 ± 2.3	−15.3 ± 2.5
	SPL8	−12.8 ± 2.3	−16.9 ± 2.4	−15.5 ± 2.2
	SPL9	−10.7 ± 2.2	−14.6 ± 2.4	−11.5 ± 2.5

The data are shown as mean ± standard error of the mean.
See Figure 2 for explanations of the measurements.
*Scores: 1 = minimum, 9 = maximum, 5 = neutral.

Relationships of Alexithymia and Empathy with SPL Results

The SPL values that we used as sequential measurements within general linear models were pre-task SPL (SPL3), post-task-onset SPL (SPL4), and SPL at the end of the task (SPL6). We selected these variables because the difference between SPL3 and SPL4 was the most significant SPL change across conditions, while SPL4 and SPL6 showed changes specific to the different tasks. We treated sequential measurements as within-effects with 3 levels. We included the tasks in the model as categorical predictors, and the rank scores for alexithymia and empathy as continuous predictors. We found an overall effect of both alexithymia and empathy on SPL ($F = 4.118$,

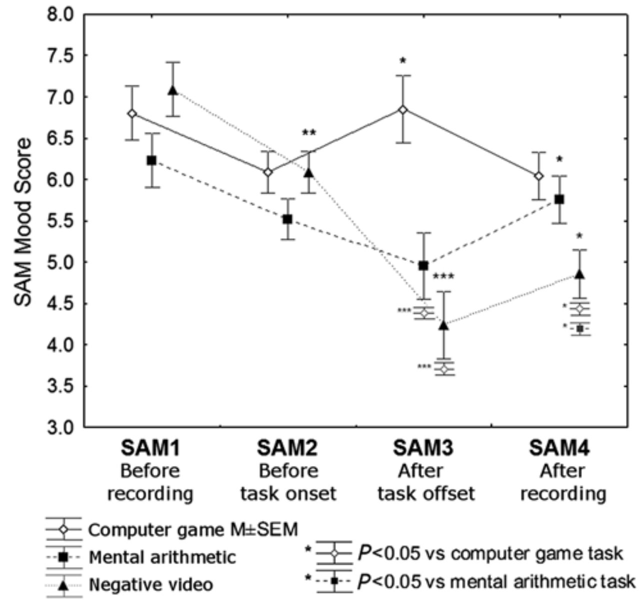

FIGURE 4. Mood ratings for each of the tasks in the 21 participants. The ratings were obtained through the Self-Assessment Manikin (SAM), mean ± standard error of the mean (M ± SEM). *$P < 0.05$, **$P < 0.01$, ***$P < 0.0001$ compared to value in the same task on previous measurement.

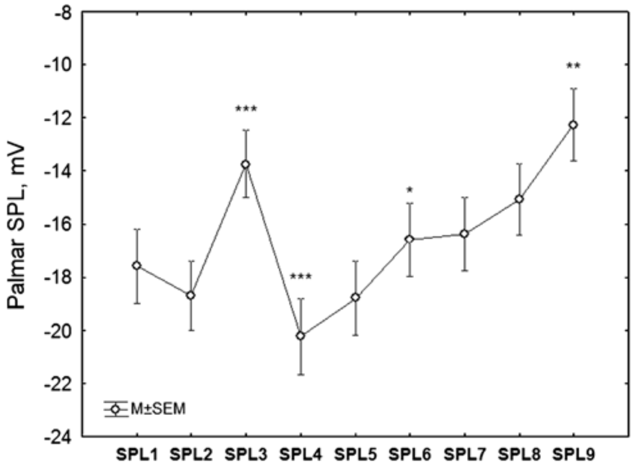

FIGURE 5. Changes in skin potential level (SPL) in millivolts (mV), mean ± standard error of the mean (M ± SEM), averaged for all 3 experimental sessions (computer game, mental arithmetic, and negative video) in the 21 participants. *$P < 0.05$, **$P < 0.01$, ***$P < 0.0001$ value compared to previous measurement.

$P < 0.05$ and $F = 8.915$, $P < 0.005$, respectively; for both, Levene test for homogeneity of variances $P = 1$). The interaction between effect of sequential measures and psychological effect was significant for empathy ($F = 5.238$, $P < 0.01$, $df = 2$, G-G epsilon = 0.87).

We also analyzed the specific effects of alexithymia, empathy, and task on SPL changes at the onset of the tasks (SPL4 vs SPL3, corresponding to task-evoked autonomic arousal) and during the tasks (SPL6 vs SPL4, corresponding to habituation during the task). Full factorial design of the effects of the tasks, and rank scores of 2 psychological predictors, showed that SPL changes at task onset were affected by both alexithymia ($F = 4.083$, $P = 0.049$) and empathy ($F = 6.906$, $P = 0.011$), regardless of the task. SPL changes during the tasks were also affected by both alexithymia ($F = 4.16$, $P = 0.047$) and empathy ($F = 10.24$, $P = 0.002$). We found a significant effect of interaction between alexithymia and empathy scores on SPL habituation rate during the tasks ($F = 7.60$, $P = 0.008$).

Figure 6 illustrates differences between participants with low and high alexithymia and empathy scores. These differences are described below.

Absolute Values of SPL

We did not see deviations of absolute SPL values associated with alexithymia. Empathy scores trended ($P < 0.10$) toward correlating with increased sympathetic arousal at the beginning of each of the 3 tasks (SPL4, Spearman rank correlation coefficients, $\rho = -0.40$ for the computer game, $\rho = -0.38$ for the mental arithmetic, and $\rho = -0.40$ for the negative video, $P < 0.10$; Figure 6) and at the end of the mental arithmetic task (SPL6, $\rho = -0.45$, $P < 0.05$; Figure 6).

Response to Task Onset

Both alexithymia and empathy scores were related to a greater increase in sympathetic arousal (SPL negative amplitude) at the onset of the negative video than the other tasks (SPL3 vs SPL4; Figure 6; $\rho = -0.51$ and $\rho = -0.47$, respectively, $P < 0.05$). Empathy scores were also related to greater sympathetic arousal at the onset of the computer game (SPL3 vs SPL4; Figure 6; $\rho = -0.52$, $P < 0.05$).

Recovery-Habituation During the Task

Alexithymia scores correlated with no habituation during the computer game (SPL4 vs SPL6; Figure 6; $\rho = -0.49$, $P < 0.05$). Empathy scores predicted faster habituation of sympathetic arousal during the negative video (SPL4 vs SPL6; Figure 6; $\rho = +0.48$, $P < 0.05$).

DISCUSSION

Our findings confirm the stimulatory effects of 3 tasks of different valence on autonomic arousal, as indexed by SPL values. Our findings are consistent with the notion that SPL is an index of mental arousal level and is independent of changes in valence and mood (Cacioppo and Sandman, 1978; Leiderman and Shapiro, 1964).

Although alexithymia is often reported to be comorbid with deficits in empathy (Bird et al, 2010; Decety and Jackson, 2004; Guttman and Laporte, 2002; Williams and Wood, 2010), we found no simple relationship between these traits in our healthy volunteers. Nevertheless, we found significant correlations among alexithymia, empathy, and changes in sympathetic arousal during the different tasks. Those relationships allowed us to distinguish between the response tendencies of participants with low and high alexithymia and empathy scores.

We did not see any association between deviations in absolute values of sympathetic arousal and alexithymia. Our finding is consistent with previous findings in healthy student populations (Bausch et al, 2011; Connelly and Denney, 2007) and in patients suffering from anxiety states (Rabavilas, 1987).

Conversely, our participants with greater alexithymia had a greater increase in autonomic arousal at the start of the negative video. This finding suggests that rather than being tonically overaroused, people with alexithymia have a hyperresponsive sympathetic nervous system. An increase in electrodermal reactivity—another index of raised sympathetic tone (Grimnes et al, 2011)—was reported in healthy people with high alexithymia scores after they listened to music that provoked negative emotions (Grynberg et al, 2012) and in depressed patients with high alexithymia scores during an emotion processing task (eg, recognition of emotions while watching short video clips of actors expressing basic emotions with their face, voice prosody, and sentence content) (Schneider et al, 2012). This autonomic hyperreactivity suggests that exposure to negative emotional stimuli affects individuals with alexithymic traits more than those without alexithymia, and that the hyperreactivity putatively originates in impaired cognitive control of negative emotions.

Our results contrast with some earlier studies that reported no effect of alexithymia on autonomic reactions to negative emotional stimulation. This divergence of findings may be explained by differences in experimental protocols. Tasks of long duration (Grynberg et al, 2012; Infrasca, 1997; Luminet et al, 2004; Rabavilas, 1987; Schneider et al, 2012; Waldstein et al, 2002), like ours, induce greater and more sustained autonomic changes. Event-related protocols, focused only on rapid, transient autonomic alterations (Pollatos et al, 2008, 2011; Roedema and Simons, 1999; Wehmer et al, 1995), would not be sensitive to sustained emotional arousal. Moreover, autonomic skin measurements have a wide dynamic range (Nishimura et al, 1995) and thus potentially greater sensitivity to stressful stimulation than do the cardiovascular measures used in some studies (Friedlander et al, 1997; Fukunishi et al, 1999; Linden et al, 1996; Neumann et al, 2004). Finally, studying groups with extremely high and low alexithymia (Connelly and Denney, 2007; Pollatos et al, 2008, 2011) may lead to conclusions different from our comparison of groups along a continuous spectrum of alexithymia and autonomic reactivity.

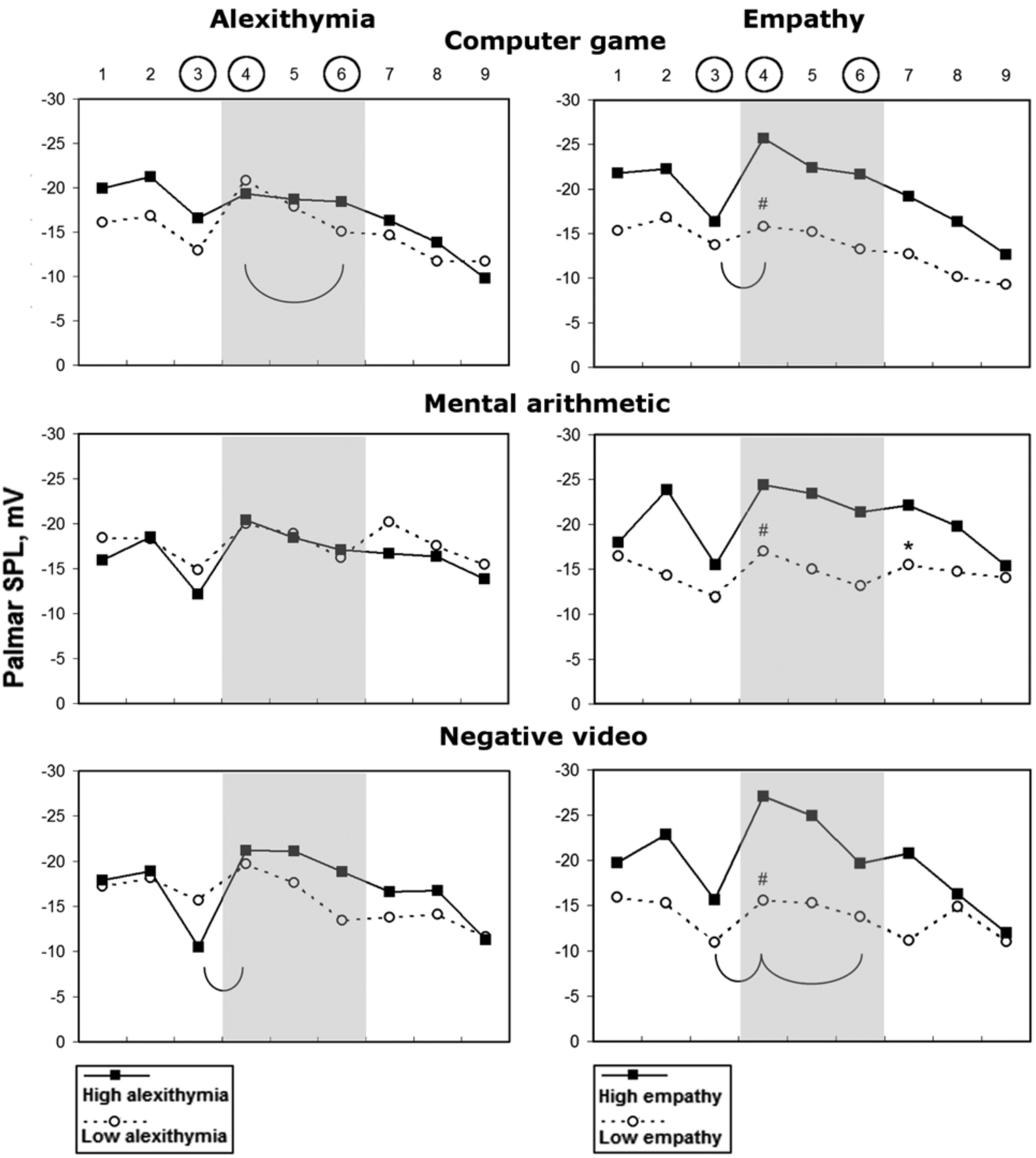

FIGURE 6. Sympathetic arousal changes expressed in average skin potential level (SPL) before (SPL1, 2, 3), during (SPL4, 5, 6), and after (SPL7, 8, 9) each task. Left graphs: Participants with low ($n=11$; open circles) and high ($n=10$; black boxes) alexithymia scores, defined by Toronto Alexithymia Scale below and above the group average score of 43.8. Right graphs: Participants with low ($n=9$; open circles) and high ($n=12$; black boxes) empathy scores, defined by Multi-Dimensional Emotional Empathy Scale, based on a mean of 3.28. We estimated the correlations between psychological and electrodermal measurements for the following parameters: SPL3 (values before onset of the task), SPL4 (after onset of the task), SPL6 (at the end of the task), all circled in the graphs; changes in SPL during onset of the task (difference between SPL4 and SPL3); and changes in SPL during the task (difference between SPL6 and SPL4). Significance of correlations of psychological measurements with SPL3, 4, or 6 is labeled with # ($P<0.10$) or * ($P<0.05$). Significance of correlations of psychological measurements with changes in SPL (SPL4 vs SPL3 and SPL6 vs SPL4) is indicated with semicircles beneath curves ($P<0.05$).

We found that empathy was generally associated with greater autonomic arousal across all tasks and with greater emotional autonomic reactivity at the onset of the tasks. Surprisingly, these effects were independent of affective valence. In other studies, patients with traumatic brain injury and low empathic ability had lower skin conductance than controls (de Sousa et al, 2012), while more empathic individuals had greater skin conductance when viewing a person in a painful situation (Hein et al, 2011), an effect that increases with social identification (Forgiarini et al, 2011). Clinical studies have shown that empathy scores drop in patients with autonomic failure disorder whose capacity to produce autonomic arousal is impaired (Chauhan et al, 2008). Agreeableness, a feature associated with empathy, is also linked to autonomic reactivity (Ryan et al, 2011).

It is noteworthy that decreases in skin conductance are associated with ventromedial prefrontal cortex activation, part of the default-mode network (Nagai et al, 2004) involved in both autonomic control and emotion regulation (Critchley, 2002). The medial prefrontal cortex shows less activation during the viewing of emotionally negative scenes in participants who are more predisposed to feeling distressed according to the Interpersonal Reactivity Index's Personal Distress subscale (Kramer et al, 2010). These findings can explain the mechanism of an elevated SPL reaction to a negative video in participants with high empathy. Our findings are consistent with the idea that empathy and anticipatory states of arousal have a shared basis and that, ultimately, a high empathy score is a marker for predisposition to greater arousability.

Our participants had marked variability in their individual responses and changes in sympathetic arousal. For example, some had a post-onset decrease in arousal. That decrease might reflect relaxation after the beginning of the task or relief of tension related to their expectations about the task. Interestingly, we saw this decrease most often in our participants with lower alexithymia and lower empathy (Figure 7).

Psychological traits related differently to the observed rate of habituation of autonomic arousal over the course of tasks. Alexithymia was linked to a low rate of autonomic habituation during the computer game, while empathy scores were linked to a high rate of habituation during the video task. Sustained autonomic arousal correlated with alexithymia scores only under pleasant emotional stimulation. This finding provides insight into mechanisms that may underlie alexithymic people's high risk for pathological gambling (Parker et al, 2005). Our finding also aligns with a steady increase in skin conductance level found in antisocial children during imaging of pleasant situations (Garralda et al, 1990) and slow recovery of electrodermal activity in patients with high alexithymia scores (Rabavilas, 1987).

Our participants with higher empathy scores showed faster habituation of arousal during the negative video task. Our results complement findings from patients who had suffered a loss of emotional empathy after traumatic brain injury and who, unlike controls, showed no habituation of sympathetic arousal when watching an unpleasant video (de Sousa et al, 2012). This observation links the empathy score not only to emotional reactivity but also to emotional lability, a common consequence of

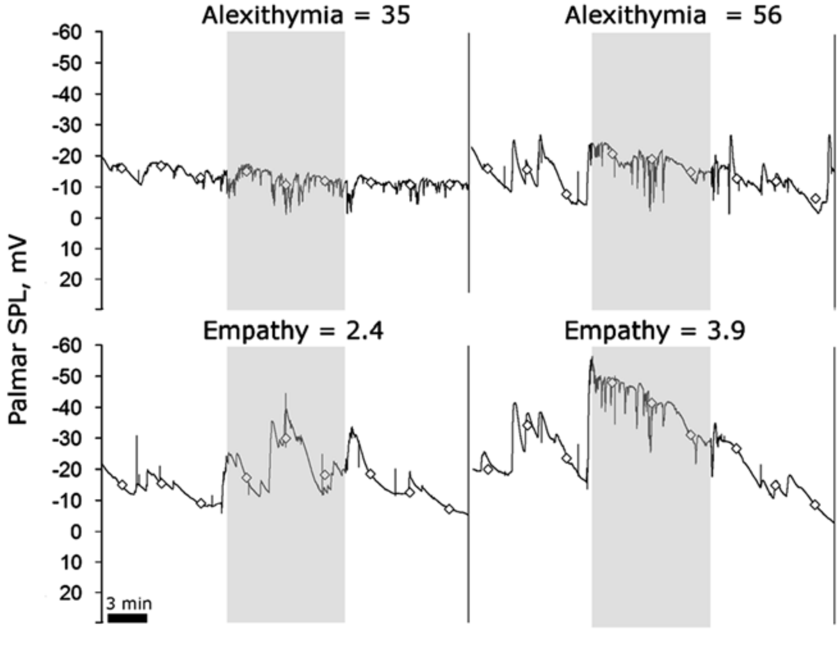

FIGURE 7. Negative video task: comparison of the skin potential level (SPL) recordings in millivolts (mV) in 4 individual participants. Upper graphs: sample low (left) and high (right) alexithymia scores (our whole group had a mean score of 44 and a range of 31 to 61). Lower graph: sample low (left) and high (right) empathy scores (our whole group had a mean score of 3.3 and a range of 1.9 to 4.5). Each diamond shows median SPL values per 3-minute window over the 28-minute session.

closed head injury and frontal lobe damage, and also found in conditions such as attention deficit hyperactivity disorder and Tourette syndrome.

Interestingly, the empathogen oxytocin has corresponding effects on brain excitability (Barraza and Zak, 2009; Kirsch et al, 2005), suggesting that oxytocin may mediate faster habituation to negative emotional stimulation in high-empathy participants. The fronto-insular cortex shows significant activation in empathy for pain (Gu et al, 2010) and is engaged in switching between central-executive and default-mode networks across task paradigms and stimulus modalities (Sridharan et al, 2008). We can speculate that the slower habituation of autonomic arousal in participants with high alexithymia scores and the faster habituation (decrease) in participants with high empathy scores may reflect functional impairment of the fronto-insular cortex in alexithymia and enhanced functioning of this network hub in empathy.

Our study had 2 potential limitations. One possible confound was that participants made nonessential hand movements during the computer game and mental arithmetic task. Changes in electrodermal sympathetic activity are nonspecific; they can reflect both exercise and anxiety (Wilhelm et al, 2006). Thus, hand motion during our computer game and mental arithmetic tasks might have contributed to apparently emotion-evoked SPL changes. However, we found the strongest relationships between psychological variables and SPL with the video task, which did not involve any hand movements. Moreover, we did not find significant differences in magnitude of SPL across the 3 tasks, while hand motion was obviously greatest during the computer game.

The other potential limitation of our study was the relatively small number of participants, perhaps too small a group to allow identification of weak effects. Nevertheless, our cohort was large enough to let us find statistically significant differences in autonomic arousal in people predisposed to alexithymia or empathy within the normal range of the psychological variables.

In conclusion, we linked SPL measures of sympathetic arousal to psychological differences in emotionality within a healthy population. While we found arousal at the onset of emotional stimuli to be greater in both people with high alexithymia and people with high empathy, the sustained autonomic arousal in those with high alexithymia may underlie vulnerability to cardiovascular and psychosomatic disorders. In contrast, the rapid habituation that we saw in those with high empathy linked their emotional attribution skills to self-regulation ability. Further investigation is needed to establish more clearly the neurologic mechanisms underlying common and divergent electrodermal activity changes in alexithymia and empathy, and their contribution to psychological processes.

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