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Computer-mediated communication and time pressure induce higher cardiovascular responses in the preparatory and execution phases of cooperative tasks

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The cardiovascular (CV) response to social challenge and stress is associated with the etiology of cardiovascular diseases. New ways of communication, time pressure and different types of information are common in our society. In this study, the cardiovascular response to two different tasks (open vs. closed information) was examined employing different communication channels (computer-mediated vs. face-to-face) and with different pace control (self vs. external). Our results indicate that there was a higher CV response in the computer-mediated condition, on the closed information task and in the externally paced condition. These role of these factors should be considered when studying the consequences of social stress and their underlying mechanisms.

La comunicación mediada por ordenador y la presión temporal inducen mayores respuestas cardiovasculares durante la preparación y la ejecución de tareas cooperativas. Las respuestas cardiovasculares (CV) en situaciones de estrés y reto han sido asociadas a diversos trastornos cardiovasculares, de alta prevalencia en las sociedades actuales. El empleo de nuevos canales de comunicación, el ritmo acelerado y el tipo de información manejada son potenciales factores moduladores de la respuesta psicofisiológica a situaciones comunes en nuestra sociedad, como la cooperación en grupos de trabajo En este estudio se ha analizado la respuesta cardiovascular ante dos tareas (con información abierta vs cerrada), realizadas mediante distintos canales de comunicación (mediado por ordenador vs cara a cara) y con o sin presión temporal. Los datos muestran mayor frecuencia cardíaca y presión arterial sistólica en la condición mediada por ordenador, con información cerrada y con presión temporal. Estos factores deberán tenerse en cuenta en el estudio de las consecuencias del estrés social y de los mecanismos subyacentes.

Blood pressure (BP) and heart rate (HR) responses to psychosocial stressors have been associated with the etiology of disorders related to stress (Chida & Hamer, 2008; Fredikson, Tuomisto, Lundberg, & Melin, 1990; Steptoe & Brydon 2009). These responses reproduced repeatedly by the subjects in their daily lives have been related to the development of cardiovascular diseases (Fernández-Abascal, Martín, & Domínguez, 2003; Manuck, 1994; Matthews, Owens, Allen, & Stoney, 1992). Most daily-life stress comes from social interactions. To replicate these situations different laboratory stressors have been employed, such as simulated public speaking (Keltikangas-Järvinen & Heponiemi, 2004; Kudielka, Schommer, Hellhammer, & Kirschbaum, 2004), structured interviews (Dimsdale, Stern, & Dillon 1988), assertive role playing (Morrison, Bellack, & Manuck, 1985), efforts to exert social influence or control (Smith, Limon, Gallo, & Ngu, 1996), re-living a stressful situation speech (Chatkoff, Maier, Javaid, Hammoud, & Munkrishna, 2009), family problem-solving interactions (Lassner, Matthews, & Stoney, 1994) or playing computer games (Ricarte, Salvador, Costa, Torres, & Subirats, 2001). These stressors include challenging components (Smith et al., 1996) that resemble the stress of daily life more closely than more purely cognitive or psychomotor stressors do (Al'Absi et al., 1997). Nowadays, social interactions are increasingly conducted by means of electronic devices such as computer mediated communication (CMC) (Mejías, 2007). The use of this information technology (IT) is spreading rapidly in today's working world, as well as in life in general. Along with these trends, there is an increasing concern about the possible health effects of employing IT (Arnetz, 1997). In fact, the term «techno-stress» has been introduced to describe the psychophysiological consequences of a poor man-IT machine fit (Martínez, Cifre, Llorens, & Salanova, 2002; Salanova & Schaufeli, 2000). However, the physiological reactions to the use of IT in social communications have still not been sufficiently studied (Arnetz & Wiholm, 1997; Gracia, Caballer, & Peiró, 2002; Seppala, 1995).

Moreover, temporal pressure is currently an important worldwide stressor, especially in work contexts. This variable has been studied in relation to different communication channels with cohesion and performance (Gracia, Arcos, & Caballer, 2000; Gracia et al., 2002). High job demands (including time urgency) with low control have been associated with hypertension and

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increases the long-term risk of myocardial infarction (Karasek & Theorell, 1990; Steptoe & Brydon 2009). The pace of task performance has been recognized as a particularly important stressor for cardiovascular risk (Alterman, Schekelle, Vernon, & Burau, 1994; Karasek & Theorell, 1990; North, Syme, Feeney, Shipley, & Marmot, 1996). When the pace was experimentally manipulated, lower levels of stress and diastolic (DBP), but not systolic, blood pressure (SBP) and HR were reported by Bohlin, Eliasson, Hjemdahl, Klein and Frankenhaeuser (1986) in students performing mental arithmetic under externally imposed compared to self-paced conditions, although in a second study differences appeared in SBP but not in DBP (Bohlin, Eliasson, Hjemdahl, Klein, Fredrikson, & Frankenhaeurser, 1986). Larger increases in SBP, DBP and HR during tasks in the externally paced situation were found in men aged 55-65 years (Steptoe, Fieldman, Evans, & Perry, 1993), although these results were confirmed only for SBP in a larger sample of adult men and women (Steptoe, Evans, & Fieldman, 1997).

The primary aim of this study was to assess the impact of the communication technology employed (computer-mediated communication or face-to-face interaction), and the control over the task pace (externally controlled or self-paced) on cardiovascular response (HR and BP) in young women coping with two problem-solving tasks that had to be carried out in a group. Our hypothesis was that the technology of the communication would affect cardiovascular response, with the computer-mediated communication (CMC interaction) being more stressful. We also predicted that an externally-paced task would elicit greater HR and BP responses than a self-paced task. A secondary purpose was to test whether these effects were different depending on whether the social task employed had an open or closed resolution. Although there is no empirical evidence on this topic, we assumed that subjects would feel more in control when performing a closed information task than when engaging in open information tasks. Finally, we expected lower performance in the most stressful condition, that is, a computer-mediated, externally paced and open-information task.

Methods

Participants

The final sample was composed of 60 healthy female undergraduate students with an average age of 21.35±2.17 years. They were normotensive (lower than 90/140 mm Hg at rest), were not taking medication and had no history of a major illness or psychiatric disorder. They practiced sports an average of 1.5 hours per week and had slept 7-8 hours the night before the experimental sessions.

Instruments

HR (beats/min) was recorded continuously at 15-sec intervals 5 min before the tasks (baseline), during the tasks and 5 min after the tasks, using a Polar Vantage NVTM Cardiac Monitor (Polar Electro Oy, Finland), which allows continuous free-hands heart rate measuring with ECG accuracy and has previously been used in other studies in real contexts (Moya-Albiol, Serrano, González-Bono, Rodríguez-Alarcón, & Salvador, 2005; Serrano, Moya-Albiol, & Salvador, 2008). This instrument is composed of a codified transmitter, an elastic belt and a wrist receiver. The transmitter was in contact with the skin of the thorax, under the pectorals, and was adjusted by means of the elastic belt. The data were recorded in the receiver and, immediately after each session, stored in a computer by means of the Polar Precision Performance SoftwareTM for Windows® (Copyright by Electro Oy, Finland), which allowed the edition and reduction of the data. The data transmission from the receiver to the computer was executed with the Polar Advantage InterfaceTM. Data transfer between the computer and the wrist receiver took place via an RS232C serial line.

Two measures of BP were obtained in each experimental session: when subjects arrived at the experimental room (baseline) and after five minutes of recovery from the task. BP (mm Hg) was recorded by means of an auto-inflation digital blood pressure monitor (DS-143D) while subjects were seated, after five rest minutes. The accuracy of cuff pressure was ±3mm Hg. A programmable exhaust system for deflation (3 mm Hg/sec) was used. This standard deflation rate should be adequate to provide accurate estimates of BP for most adult subjects in psychophysiological studies (Shapiro et al., 1996). The BP monitor used the oscillometric method to determine BP inferred from changes in the intensity of pulse oscillations in the occluding cuff. The validity of this method has been previously established (Fowler et al., 1991; Light, Obrist, & Cubeddu, 1988).

Procedure

Subjects were recruited in their classrooms and asked to participate in a study about group communication. Sixty-four women were randomly assigned to groups of four persons (16 groups). Each group performed two different tasks in each of four experimental sessions (1 week between sessions). In this paper we will focus on the results obtained from the first task in each of the two last sessions. In the first session, subjects were informed about the general aims of the study, and they signed an informed consent. A monetary reward (approximately 120 €) was established for the group with the best performance, in order to promote the subjects' involvement. In each session, confirmation of whether instructions had been followed (hours of sleep and intake of alcohol, food, medication, tobacco or caffeine) was obtained, and at the end, subjects were debriefed and asked not to discuss details of the study with others.

Experimental conditions: Half the groups were assigned to the CMC condition and the other half to the face-to-face (FTF) communication condition. In the CMC condition, subjects were placed in four different experimental rooms, so they could not see or hear their peers. In the FTF condition, subjects were placed together in a larger room with work-tables opposite each other. The subjects had computers on their tables to help in their task resolution and record the partial or final results.

In each communication channel, half of the subjects performed the tasks with external control over the pace, while the other half controlled the pace themselves. The groups in the self-paced condition finished their tasks when they felt they had arrived at a good group resolution, and theywere not exposed to any temporal clue. The task duration in the self-paced condition was around one hour (55-70 minutes). To implement the second condition, 25% was subtracted from the average time that the first groups had spent in the resolution of the tasks to be performed. This time was given as a maximum to the groups in the externally paced conditions, who were informed of the time available for the task resolution at the beginning of each task and after the baseline period.

Tasks: Groups participated in two tasks which differed in the availability of information to solve them as well as alternatives in their resolution (open/closed). In the first task (open-resolution task), each group had to generate a maximum of 10 ideas about specific acts and activities to be implemented during a cultural week at the Faculty they were members of. An external professional expert on creativity, blind to the composition of the groups, assessed the performance, taking into account the degree of originality and how viable the ideas were.

In the second task (closed-resolution), each group had to find the name and surname of the persons that best fit a number of requirements for various pre-determined positions. The necessary information available for resolving the task was different for each member of the group, so they had to share information in order to reach a satisfactory resolution. Evaluation of performance was practically automatic: the response sheet had 8 boxes (4 names and 4 surnames). The group got 1 point for every correct name and 2 points for every surname guessed.

Data analysis

Some practical problems led to the loss of one group in the CMC condition. Thus, the final number of subjects for the experimental conditions was: CMC/self-paced: 12; CMC/externally paced: 16; FTF/self-paced: 16; FTF/externally paced: 16.

HR data from the baseline, task and recovery periods were averaged to obtain mean values for the analyses. Reactivity was assessed via simple change scores (task value minus baseline), according to Llabre, Spitzer, Saab, Ironson and Schneiderman (1991).

A mixed MANOVA was carried out with Channel (CMC/FTF) and Control (self-paced/externally paced) as between-subjects factors, and Task (open/closed) and Period (Baseline/Task/Post-task for HR, and Pre- and Post-task for BP) as repeated-measures factors. The effects of Channel and Control on performance were analyzed separately for each task by a two-factor ANOVA. Post-hoc tests were performed using simple contrasts. To reduce the likelihood of Type I error, the Greenhouse-Geisser adjustment of degrees of freedom was performed (Greenhouse & Geisser, 1959). Only the Greenhouse-Geisser (G-G) corrected probability levels are reported.

All analyses were carried out by SPSS for Macintosh. The alpha level was fixed at 0.05.

Results

Subjects did not present significant differences in baseline HR, BP or habits (sleep pattern, sports practice, food intake) in each experimental session.

Heart rate

The main effect of the factor Period was significant ($F_{2,96}$= 4.12, $p<0.01$). Post-hoc analyses showed an HR rise when the task started ($F_{1,51}$= 10.07, $p<0.002$), a significant post-task drop ($F_{1,48}$=75.88, $p<0.001$), and lower values during the post-task in comparison to baseline ($F_{1,50}$= 55.49, $p<0.001$).

The Channel × Period interaction was significant ($F_{2,96}$= 7.61, $p<0.001$), showing that, although HR evolution was significant in both channels ($F_{2,40}$= 18.02, $p<0.001$, $F_{2,54}$= 37.36, $p<0.001$, for CMC and FTF, respectively), it presented some differences depending on the channel (Figure 1). For the FTF condition, the task produced a significant HR increment ($F_{1,28}$= 8.42, $p<0.007$), while for the computer mediated condition the task did not elicit significant HR increases. The rest of the HR evolution was similar in both channels, with significant post-task HR decreases and lower post-task values than for baseline (all p values <0.001).

The Task × Period interaction was significant ($F_{2,96}$= 36.77, $p<0.001$), showing that HR evolution was significant in both tasks ($F_{2,106}$= 21.46, $p<0.001$, $F_{2,112}$= 25.83, $p<0.001$, for the open and closed resolution tasks, respectively). There was no difference in baseline levels between the open and closed information tasks, but in the task and recovery periods, the differences were significant ($F_{1,51}$= 5.28, $p<0.02$; $F_{1,56}$= 10.08, $p<0.002$, for task and recovery periods, respectively), with higher levels in the closed information task (Figure 1). Although the factor Control was not found to be significant for HR evolution, HR reactivity was significantly higher in the externally paced conditions ($F_{1,48}$= 10.03, $p<0.003$).

Blood pressure

For DBP and SBP, the factor Period (baseline/post-task) was significant ($F_{1,56}$= 6.86, $p<0.01$; $F_{1,56}$= 51.74, $p<0.001$, respectively), with lower post-task values compared to baseline (Table 1). The SBP was also affected by Channel ($F_{1,56}$= 5.3; $p<0.02$), showing that subjects performing by means of CMC displayed higher SBP (Table 1).

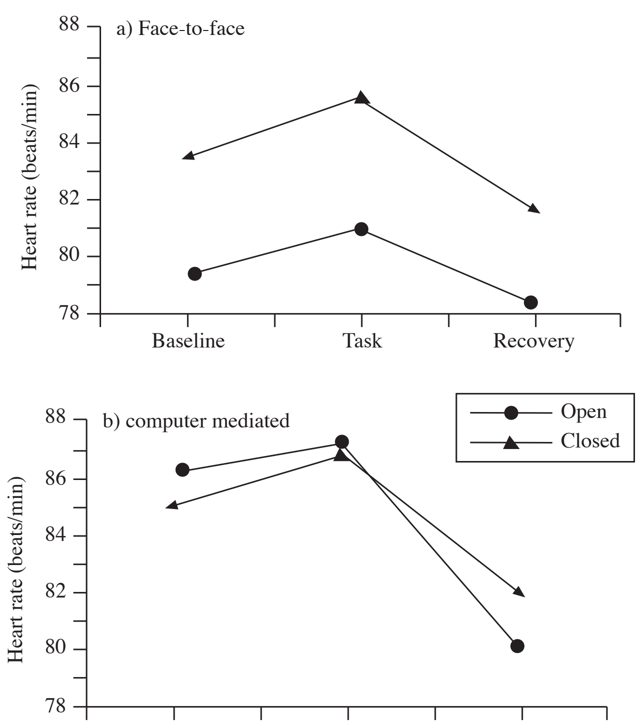

Figure 1. *Means of HR for each period (baseline-task-recovery) in FTF (a) and CMC (b) groups, for open and closed information tasks*

Table 1
Means of SBP/DBP (mmHg) according to Channel of communication (CMC, FTF) for open- and closed-information tasks, in self- and externally paced conditions

	PRE-TASK		POST-TASK	
Channel	**CMC**	**FTF**	**CMC**	**FTF**
Open information	SBP / DBP	SBP / DBP	SBP / DBP	SBP / DBP
Self-Paced	119.66/73.16	108.43/67.68	104.25/66.33	105.62/69.56
Externally Paced	119.68/70.25	112.12/65.62	109.62/69.50	102.62/63.75
Closed information				
Self-Paced	112.33/65.83	107.12/67.37	107.00/65.33	100.31/61.62
Externally Paced	112.87/67.50	113.68/69.93	107.25/64.56	105.12/67.12

Performance

In the open-resolution task, the Channel and Channel × Control interaction were significant ($F_{1,56}$= 5.17, p<0.027; $F_{1,56}$= 9.22, p<0.004, respectively). The best performance was under the CMC condition. Post-hoc interaction analyses showed that in the computer mediated condition, the performance was higher in the externally paced condition ($F_{1,30}$= 9.17; p<0.005), while under FTF communication, the best performance was in the self-paced condition ($F_{1,30}$= 14.44, p<0.001). No significant effects were found in the closed resolution task (Figure 2).

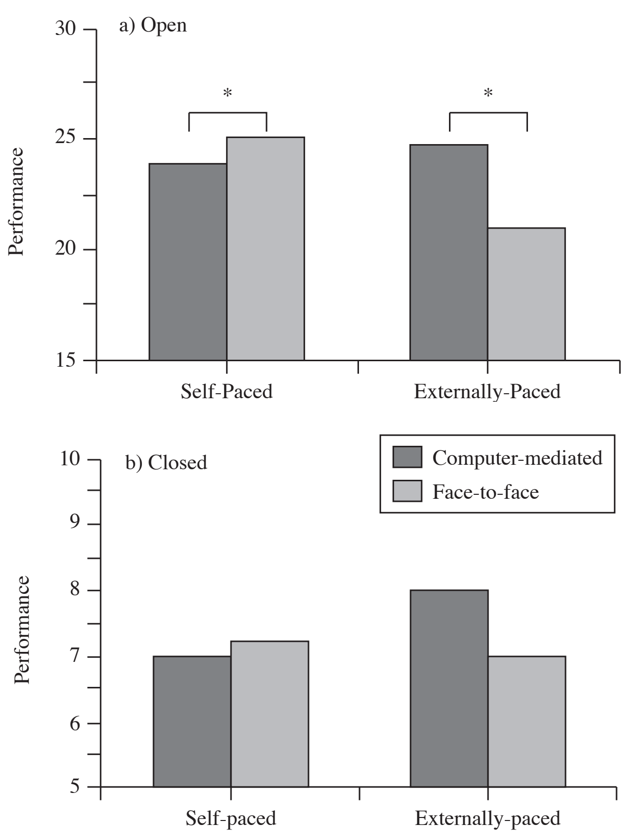

Figure 2. *Performance scores in CMC and FTF conditions, with and without temporal pressure, for open (a) and closed (b) information tasks*

Discussion

Our findings showed that although the women displayed higher systolic blood pressure (SBP) when performing the tasks by computer (CMC), they presented greater heart rate (HR) increases during face-to-face (FTF) interactions. This discrepancy would seem to indicate that cardiovascular measures are going in different directions, when in reality the lack of HR increase in the CMC condition was due to the higher basal values, which suggests an anticipatory HR response (although the differences did not reach statistical significance, p <0.08), supporting the stressful role of the use of IT in group interactions. No significant effects were found for DBP, as could be expected, since SBP seems more sensitive to different stressors (Bongard, Hodapp, Frisch, & Lennartz, 1995) and more representative of subjects' responses in real situations than DBP (Obrist, 1981). Taken together, these findings support the idea that subjects displayed greater cardiovascular response (HR and SBP) when performing the task over CMC compared to the FTF condition. This result complements previous research (Gracia et al., 2000, 2002) suggesting different psychobiological responses when resolving tasks in different communication channels.

As expected, the lack of control over task pace was associated with greater HR reactivity, showing a stressful effect on physiological response to tasks, which supports previous findings (Maule, Hockey, & Bdzola, 2000; Peters et al., 1998; Ritcher & Gendolla, 2007; Steptoe, Fieldman, & Evans, 1993). The modeling of job control or decision latitude in the laboratory is an important step towards understanding the processes through which job stress may increase cardiovascular disease risk (Steptoe et al., 1997). In this sense, our results provide indirect evidence for the hypothesis that heightened physiological reactivity is a mechanism through which job strain influences disease risk (Chida & Hamer, 2008). During effortful coping stressors, the sympatho-adreno-medullary system is activated, which implies increases in HR and BP and the release of epinephrine and norepinephrine (Peters et al., 1998), as part of actively coping with a challenging task (Obrist, 1981).

It is worth noting that depending on the type of task, different HR responses were found. Closed information tasks had more stressful effects than open ones, in contrast to our hypothesis. We assumed that selecting a correct solution on a closed information task would be less stressful than generating several solutions on an open information task. Subjects probably employed different problem-solving strategies for each task. The importance of the task structure in the solution strategies that people choose to solve them has been pointed out (Maule et al., 2000). The impact of different tasks on cardiovascular responses has been extensively reported in the literature; however, tasks of different natures have usually been employed (Smith et al., 1996; Al'Absi et al., 1997). To our knowledge, there is no information about the effects of group tasks with open or closed information, although in everyday life people are exposed to problems which require urgent, group solutions with very different types of information available.

Time pressure with lack of control over the task pace acting as a stressor could affect performance efficiency, which is low when the activation level of the subject is either too high or too low (Ritcher & Gendolla, 2007), but effective performance under stress is typically accompanied by high levels of physiological activation (Ricarte et al., 2001; Ritcher & Gendolla, 2007). Although in the present study subjects showed a higher stress response under externally paced and CMC conditions, this activation was not related to a lower performance, at least on the open resolution task. This result disagrees with previous studies (Bohlin et al., 1986; Steptoe et al., 1997) which employed other kinds of stressors and ways to produce time pressure. It has been argued that imposing a deadline (the usual way to generate time pressure) may induce the use of different strategies in solving the task, such as acceleration, filtration, decision rules and information processing priorities (Maule & Edland, 1997). Moreover, deadlines induce feelings of time-pressure and may reflect greater task involvement and the need to work harder (Maule et al., 2000). To our knowledge, no results about open-resolution task performance under time manipulation are available, so our results should be further contrasted. On the other hand, subjects using face-to-face communication under self-paced conditions showed a better performance, suggesting that the effects of control over the work on the performance would be mediated by the means of communication.

In sum, our results show that the CV response to social interactions in performing diverse tasks is moderated by the communication channel and the temporal pressure. In the CMC condition, the SBP levels and basal HR are higher for both tasks, preparing the subjects for their performance, whereas in the FTF condition, HR is higher in the closed solution task. In general, externally paced tasks produce higher HR responses. These factors also have an influence on the performance. However, the effect of new-technology-mediated communication and time pressure on physiological variables should be further considered in future research), especially if we take into account the extension and applicability of these conditions. Further work is needed to verify and amplify our results in laboratory and field research, in order to advance knowledge of the psychophysiological effects and their potential consequences for health. Furthermore, the employment of social group tasks that closely resemble real-life tasks improves the external validity of the results. Finally, in order to delve into the physiological consequences of the different types of social interactions, it would be interesting to more carefully analyze the strategies employed to solve tasks of different natures.

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