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Physiological stress response to video-game playing: the contribution of built-in music

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Abstract

Recent studies on video game playing have uncovered a wide range of measurable physiological effects on the organism, such as increases in cardiovascular activity and breathing responses. However, the exact source of these effects remains unclear. Given the well-known effects of sound on physiological activity, especially those of noise and of music, and on the secretion of the stress hormone cortisol in particular, we hypothesized that music may be a major source of stress during video game playing. We thus examined the effect of built-in music on cortisol secretion as a consequence of video game playing. Players were assigned quasi-randomly to either a Music or a Silence condition. Four saliva samples were taken, that is, after practice (T1), immediately after having played for 10 minutes (T2), 15 minutes after the end of the experiment (T3), and 30 minutes after the end of the experiment (T4). The results show that the Music group had significantly higher cortisol levels at T3, that is, when cortisol levels are assumed to reflect the stress induced by the game. These findings suggest

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for the first time that the auditory input contributes significantly to the stress response found during video game playing.
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Introduction

The market for video games has increased steadily in the last decade, and seems to be one of the few recession-proof sectors. According to data from NPD FunWorld that measures consumer purchasing and product movement, sales of console video game hardware, software, and accessories, brought in $10.3 billion in 2002 in the United States only, a record for the second consecutive year (John Gaudiosi, The Hollywood Reporter, Mon Feb 3, 2003). Given the scope of these numbers and the prediction that video games sales will continue to expand in the future, it is no surprise that a new research interest has grown into investigating what kind of effects video games exert on the players.

The most dramatic effects reported were certainly those related to the neurological system, that is, seizures induced by the flashing components of arcade and Nintendo games in photosensitive individuals, mainly children and adolescents (e.g., Rushton, 1981; Kasteleijn-Nolst Trenite et al., 1999, 2002). Besides effects on the neurological system, many other studies have reported arousal and physiological reactions in video game playing, Reported effects include increases in breath duration in children (Denot-Ledunois et al., 1998) and increases in cardiovascular reactivity, blood pressure (most often systolic blood pressure), and oxygen consumption in children or adolescents (Modesti et al., 1994), as well as in adults of all ages (Segal and Dietz, 1991; Mounier-Vehier et al., 1995), especially in those with a family history of hypertension (Ditto and Miller, 1989; Cook et al., 2001) and in those with *Type A* personality (i.e., competitive individuals; Griffiths and Dancaster, 1995). Cardiovascular reactivity to video games in young men has also been taken as a reliable predictor of the future occurrence of hypertension (Markovitz et al., 1998). Additionally, the finding of dopamine release during video game playing (which involved learning to navigate a tank for a monetary incentive) suggests that, as in the case of animals, this neurotransmitter may play a role in the anticipatory or appetitive phase of motivated behavior in humans (Koepp et al., 1998). Based on these findings, video games have often been used in studies as a stressor to measure cardiovascular reactivity (e.g., Modesti et al., 1994; Cook et al., 2001). Yet, secretion of the stress-related hormone per se, namely cortisol, has rarely been measured. The few studies that have done so have mostly found either no changes (e.g., Skosnik et al., 2000) or found declines in cortisol secretion during video game playing (Hubert and de Jong-Meyer, 1992; Denot-Ledunois et al., 1998, in children). Comparing testosterone and cortisol changes in winners versus losers after a video ping-pong game, Mazur et al. (1997) found an overall decline of cortisol over time for both groups.

Apparent conflicting results may arise from a lack of comparability between the types of video games used. For example, one explanation for the effects reported on cortisol is that those latter studies have used unsophisticated, unexciting video games (e.g., ping pong games or Tetris). From this perspective, studies that have examined cortisol secretion can hardly be compared with the ones that have examined other measures, which have used other types of games (e.g., Ms Packman, Atari breakout, or other, unspecified games). In addition, on the whole, in all of the studies reviewed but one that specified that "sound" during video game was present and "rather loud" (Modesti et al., 1994), the presence or absence of music and sound has been completely overlooked. Yet there are bases to postulate that music in action video games might be an important stressor. Anecdotal evidence suggests that video game designers have long acknowledged the importance of music in video games as a crucial part of gaming to enhance excitement and to draw the players into the game, as much as does music in films (e.g., Olivia Crosby, www.gignews.com/crosby2.htm). More empirically, one stream of research focuses on examining the psychological and physiological effects of music (by itself). Although such studies have mainly examined the relaxing role of music both in laboratory settings (e.g., Knight and Rickard, 2001; Khalfa et al., 2003; Salamon et al., 2003), or in clinical populations (e.g., Field et al., 1998; Schneider et al., 2001), some have (often incidentally) uncovered the stressful effects of techno and rock music, i.e., the type of music found in violent video games. At the psychological level, studies have consistently reported increases in self-ratings of aggressiveness, hostility, tension, anxiety, discomfort, and reduced caring, relaxation, and the like, after listening to rock or grunge music, with respect to silence or classical music (McCraty et al., 1998; Umemura and Honda, 1998; Burns et al., 1999, 2002).

At the physiological level, studies have found, on the whole, differential effects depending on the type of music involved. When considering the effects of classical music over silence, in general studies have found that classical music shows more relaxing effects (e.g., Knight and Rickard, 2001; Schneider et al., 2001; Khalfa et al., 2003; but see Burns et al., 2002, for the opposite results). When considering the effects of different types of music, findings also converge towards a lack of a soothing effect for rock/ techno music with respect to other types of music. For instance, Umemura and Honda (1998) have reported similar types of changes in respiratory-related parameters when comparing rock music and noise, and which are different than those elicited by classical music. Other studies have reported an absence of changes in physiological parameters such as blood pressure, heart rate, skin temperature, and EMG, following rock music listening with respect to other types of music (Burns et al., 1999, 2002; Salamon et al., 2003).

The purpose of this study was to specifically examine the effects of built-in techno music on cortisol levels in video game playing. Two groups of participants (one playing with music, the other one playing in silence) played a video game for ten minutes and gave four saliva samples for analysis of cortisol levels at regular intervals. We hypothesized that the group exposed to music would show higher cortisol levels than their unexposed counterpart at 15-minute post-game, i.e., the moment around which cortisol reaches its maximum value after the beginning of a stressor. Since the experimental conditions were identical for both groups with respect to visual stimulation, any difference between cortisol values would be directly attributable to the presence/absence of music during playing. In addition, in order to determine whether or not the presence of music had any influence on performance, the total score and final rank of the player were also examined.

Materials and methods

Participants

Fifty-two men (mean = 24.3, range = 19-30 years) in good health served as participants. Exclusion criteria were: 1) the presence of any medical condition that could interfere with the functioning of the hypothalamic-pituitary adrenal (HPA) axis (e.g., diabetes, hyper- or hypo- tension, lupus, adrenal insufficiency, etc.), 2) any psychiatric or 3) neurological disorders, and 4) any dependence to alcohol, drug, steroids, or tobacco. Most participants had had some experience with video games in the past, but it was not extensive (median = 1 hour/week). In all cases, they had to be unfamiliar with the Quake III Arena game (ID Software, 1999) to be included in this study. They all had normal hearing levels according to their age, as assessed by a tonal standard audiometry at the end of the experiment. The experiment was approved by the Ethics committee of the Institut universitaire de gériatrie de Montréal, in accordance with the Declaration of Helsinki, and was carried out with the adequate understanding and written consent of the participants.

Materials and apparatus

The Quake III Arena software was installed on a Macintosh G3, and could be controlled by the keyboard and a two-button mouse. The Q3DM3 arena was selected among the 16 possible ones, because it enabled the players to move freely and to avoid dead ends, thus ensuring equivalent actual playing time for all players. For the Silence condition, the (built-in) music was set to a value of 0. For the Music condition, the music was set to a maximal value, which corresponded to a sound level between 70 and 85dBA at peaks (as measured by a Bruel-Kjaer Model 2225 sound level meter) when transmitted by the Koss headphones connected directly into the computer. For both the Music and the Silence condition, the Sound effects (signals or noise that serve to help or orient the players) were set to 0: These effects are dependent upon the action happening during the game, and hence, may influence (either positively or negatively) players' performance and also vary among players. Therefore, not presenting them ensured that the presence or absence of Music was the only factor that varied across the two conditions.

The composer of the music was Bill Brown, well known as a composer for film, (e.g., Any given Sunday) television (e.g., C.S.I.: NY), and multimedia (e.g., Xena: Warrior princess, Shadow watch, etc). A professional composer analyzed the style and spectral content. The music was written in a "pop-techno style", basically repetitive, without chord changes. This is achieved by the use of synthesized bass sounds repeating a single note (or in few cases, a simple two- or three- notes pattern) on a steady and relatively fast rhythmic pattern. Many synthesized percussive sounds are added over for blend and resonance. The overall energy in the low frequency range (below 200Hz) is due to the heavy bass and rhythm.

Procedure

Participants were asked to avoid eating for at least a half hour prior to the experiment, and to avoid intense physical exercise for at least one hour before the experiment took place. They were tested individually, and distributed in a quasi-random manner into two groups, which corresponded to two different experimental conditions (Silence or Music): The average number of hours of video game playing per week, presence/absence of hypertension in the family (only first-order parents were considered), and time of experimentation (before 3 pm and after 4pm) were counter-balanced across the two groups.

Upon arrival, the participants were asked to fill a questionnaire of general information and to sign the consent form. They were then asked to sit in front of the computer (about 40cm from the screen) in a quiet room lit with soft light, where instructions were given. Their task was to use the Klesk character (representing themselves, as in any other similar "first-person shooter" games) to fight three robots Orbb, Mynx, and Angel (all four generated by the computer) and to accumulate the greatest amount of points. The participants were then instructed to put on headphones, and were allowed to practice for 5 minutes, with the possibility to ask questions to the experimenter, who remained in the room. All participants were familiarized with the game in the same condition as the experimental condition (that is, practice in Silence condition for the Silence group, and practice with Music for the Music group). Participants in the Silence group were *not* told beforehand that there would be no sound present. After the practice session, participants rested for 10 minutes. A first saliva sample was taken at the end of this period. Participants were then left alone in the room and played for 10 minutes. A saliva sample was taken immediately after the experiment. Two additional samples were subsequently taken at regular intervals of 15 minutes, in between which the participant was told to relax and allowed to read neutral-content magazines. At the end, participants were then asked to rate on a 7-point scale (going from 1 = important decrease to 7 = important increase, with 4 = no change) if the presence/absence of music during the game entailed a subjective stress response.

Results

Preliminary analyses on controlled factors

The two groups did not differ with respect to age or mean number of hours per week of video game playing (see Table 1). The number of participants with a parent suffering from Hypertension did not differ either between the two groups (all *p*s > .05).

Cortisol analyses

Before the 208 samples were sent to the Biochemiches Labor of TRIER Universität (Germany), they were all recoded for blind analyses. Cortisol in saliva was extracted with ethanol and quantified by the TR-FIA method (Time-resolved fluorescence immunoassay) with the use of a conjunct tracer (Cortisol-biotin) and a fluorescent conjunct marker (Streptavidin-Europium). Inferior limit for detection was 0.43 nmol/50µl of saliva. Two measures per sample were taken.

Table 1
Factors counter-balanced across the two groups (Silence and Music)

Factor	Silence Group	Music Group	*p*
Mean age (SD)	24.3 (3.1)	24.1 (2.8)	n.s.
Mean nbr of hours of video game playing per week (SD)	3.24 (5.1) range: 0 to 20	3.56 (5.9) range: 0 to 21	n.s.
Number of participants with one parent suffering from hypertension	5	4	n.s.
Number of participants tested between 1 and 3 pm	14	13	n.s.
Number of participants tested between 4 and 8 pm*	12	13	n.s.

* No one was tested between 3 and 4 pm.

Table 2
Mean raw cortisol levels in nmol/liter (SD) for the two groups (Silence and Music) over time

	Pre-expt	0-min Post-expt	15-min Post-expt	30-min Post-expt
Silence	11.511 (7.06)	9.128 (5.85)	7.488 (3.47)	6.645 (2.77)
Music	12.515 (7.10)	10.718 (7.14)	11.101 (6.10)	8.410 (4.78)

Data analyses

Analyses performed on raw cortisol levels (averaged across the two measures) did not meet the criterion of homogeneity of variance. Consequently, the raw data are reported in Table 2 but analyses were performed on normalized levels. These latter values are taken to minimize between-subject variation and were calculated by dividing each subject's raw hormone value by his highest measured level (as described in Mazur et al., 1997). This value could range from above zero to 1.0. There were four values per subject for each type of dependent variable. These values served in a multivariate analysis of variance (MANOVA), with Group as the between-subjects factor (Silence vs. Music), and Time of measurement (T1 to T4) as the within-subject factor.

Fig. 1 displays the Normalized cortisol levels with respect to Group and Time. The expected interaction between these two factors was significant, F (3, 150) = 3.68, p<.02. Planned comparisons (with adjusted p levels for multiple tests) revealed only one significant difference at T3, that is, when cortisol is expected to reach the maximum value (after about 15 minutes), t (50) = −3.07, p < .003, with the Music group having a higher proportion than the Silence group (means = .79 and .66 for the Music and the Silence groups, respectively). All other comparisons were non significant (all ps > .05).

Performance data

Each player's total score and final rank (which could range from 1 to 4, since there were four characters) served also as dependent variables in two t-tests (the total score was unavailable for one

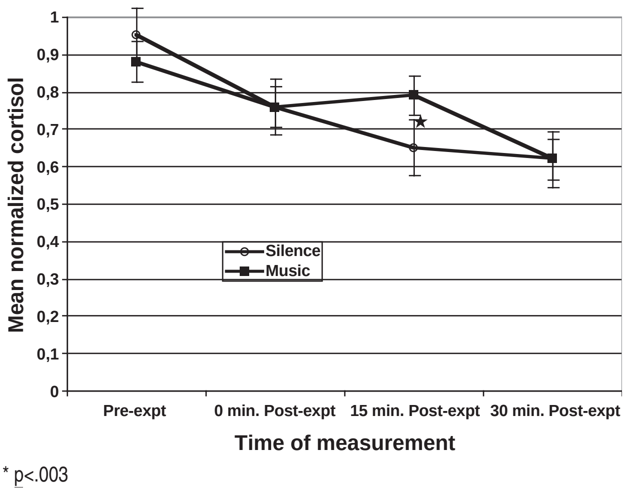

Fig. 1. Mean normalized cortisol levels (with standard errors) for the two groups over time.

participant in the Silence group). The two groups did not differ with respect to either Total score (mean scores were 14.5 and 12.4 for the Silence and Music groups, respectively, $p > .05$) or their Final rank (mean ranks were 2.6 and 2.8 for the Silence and Music groups, respectively, $p > .05$). Total scores and final rank (across groups) were negatively correlated, $r\ (50) = -.82$, $p < .001$, logically reflecting that high scores resulted in being higher in rank and vice versa (e.g., a high score meant finishing the game as amongst the first positions).

Correlations between performance and cortisol data

Correlations were run between performance (total score and rank) and normalized values at T3 (i.e., 15 min post-expt), for each group and for the whole sample. None of these correlations was significant or approached significance. A correlation between subjective stress scale and normalized cortisol levels at T3 was also found not significant, $r\ (51) = .23$, $p = .11$. That is, there was no correlation between how participants felt and their actual physiological stress level.

Discussion

Our study provides the very first empirical support to the informal idea that music is an integral part of the stress generated by video game playing. Our findings show that the built-in sound environment of video games, here pop/techno music, entails a measurable physiological response in the organism, which is different from the one produced under silence. In addition, the fact that the group exposed to music did not perform any better than the unexposed group rules out the possibility that the stress response was linked to performance rather than to the presence of music. Conversely, it also shows that the presence of music does not affect performance at a behavioral level, or at least not in this case.

These findings are in line with the ones of a previous study that examined the physiological effects of this type of music alone. Gerra and colleagues (Gerra et al., 1998) compared the effects of listening to 30 minutes of techno vs. classical music, and found significant increases in heart rate, systolic blood pressure, and cortisol, among other measures, following techno music listening. Other studies have reported similar findings regarding rock and heavy metal music (e.g., Burns et al., 1999; 2002; Salamon et al., 2003). Since techno and rock music are typical in "first-person shooter" games, which was used here and is representative of violent video games available on the market, it is more than likely that the effects found here are representative of those that would be obtained with other games.

Violent video game playing has been connected to violent behavior. An updated meta-analysis from Anderson (2004), looking at 32 independent samples and involving 5,240 participants, most of which were under 21 years of age, has revealed that exposure to violent video games similar to the one used here is significantly and causally linked to increases in aggressive behavior, cognition and affect, to cardiovascular arousal, and decreases in helping behaviour.

Informal reports on video games soundtracks suggest that they serve to heighten tension, to manipulate the mood, and to draw the player into the gameworld faintly (http://www.gamespot.com/features/6092391/: Collin Oguro). Our study points to the importance of taking into account the sound environment involved in violent video games. Roberts and colleagues (Roberts et al., 1998) surveyed a group of adolescents and found that teens who responded to music with strong emotions, especially negative emotions such as being distressed, upset, guilty, scared, hostile, irritable, ashamed, nervous, jittery, and afraid while listening to music, were more prone to engage in risky behavior.

Cortisol increases have been shown to be related to gambling situations in both problem and non-problematic gambling. Although this is still a very speculative matter, we would suggest that music in video games, as a cortisol secretion trigger, could well be the biochemical basis for an addiction process. Only longitudinal studies can provide an answer to this question. It is to note that it remains unknown whether or not these effects of cortisol secretion have long-term consequences on the players' health. Although recovery from stress (at 30min-post experiment) was similar in both groups in our experiment, the greater response in players in the music condition should be examined closely. Indeed, if a heightened stress response such as the one found in the music group can be measured after very limited playing time (only 10 minutes in our study), then this could lead, with increasing playing time, to abnormally high cortisol secretion levels in the long term, or, conversely, to a habituation response to stress. Chronically elevated cortisol levels have been associated with several diseases (for a review, see Lupien et al., 1999), and have also been associated with a hypo-response to stress with time, such as those found in bodily stress-related disorders (for a review, see Heim et al., 2000). What is even more of a concern in our study is that as is shown by the absence of relationship between the subjective and physiological stress levels, participants were unaware of that they were under stress. Given that the deleterious effects of rock music have been compared with the ones of noise (i.e., McCarthy et al., 1992; Umemura and Honda, 1998), and that long term effects of noise exposure are well documented as being harmful (e.g., Clark, 1992; Melamed and Bruhis, 1996; Babisch et al., 2001), what remains unclear is to what extent these two (video game music and noise) are comparable in their long term effects.

Conclusion

In conclusion, our findings are consistent with previous work conducted on the detrimental effects of music/noise on physiological reactivity. As the videogame market continues to mature (according to data from the NPD, 1/3 or video game software purchases were for gamers over the age of 18), should the long-term impact of video games on the organism be negative, both biochemically and behaviorally, the problem could well develop into a real public health issue.

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