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The effects of sound and colour on responses to a computer game

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Abstract

Background colour (red/blue) and sound (loud/quiet) were manipulated in a series of computer games. Players using a blue screen improved gradually over the session, while red screen players peaked midway and then deteriorated. A similar pattern for heart rate was found, suggesting that arousal was implicated in the effect. Sound alone had little impact, but the red/loud combination was associated with perceptions of excitement and playing well. The results suggest that the aura of a computer game may affect cognitive and physiological responses. © 2000 Elsevier Science B.V. All rights reserved.

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1. The effects of sound and colour on responses to a computer game

Research suggests that sound and colour may influence responses to computer games. Stimuli such as bells, sirens, gongs, flashing lights and dramatic hues during a game can increase aesthetic satisfaction, provide feedback to the player, act as a reward for continued participation, and signify to bystanders that the player has achieved a success (see Griffiths, 1995a). White (1989) suggests that the aural and visual properties of a game can provide an impression of activity and fun, encourage initial participation and stimulate further play. The importance of the 'aura' of a machine, typified by characteristics such as music, lights, colours and noise, was highlighted in a questionnaire and interview study by Griffiths (1995b). He questioned 50 adolescent gamblers and found that 30% claimed that a gambling machine's aura was perceived as one of its most enticing features.

The psychological literature suggests that the effects of colour and sound might be partly due to the changes they bring about in people's level of *arousal*, the degree of

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activation of the parts of the body under the control of the autonomic nervous system. Indicators of arousal include increased heart rate, electrocortical activity, muscle tension, respiratory rate, blood pressure, skin conductivity, and the release of chemicals such as adrenalin.

A considerable amount of literature exists on the mediating effects of arousal on responses to sound (Glass and Singer, 1972; Jones, 1983), with the majority of the research examining the effects of environmental noise on health, academic and occupational performance. These studies consistently demonstrate that extreme noise levels can lead to a state of over-arousal, accompanied by counterproductive attentional effects and thus impaired performance in difficult tasks. This can occur whether people feel pleasantly excited or uncomfortably anxious.

Relatively little attention has been paid to the effects of sound in the context of computer game playing, but recent studies have suggested complex relationships between machines, audio interface, mood and performance (Hereford and Winn, 1994; Edworthy, 1998). For example, studies using simulated driving tasks suggest that loud, arousing background music can lead to slower driving (Beh and Hirst, 1999; North and Hargreaves, 1999), presumably because the music and task compete for limited processing resources. One study which encompassed a physiological measure (Smith et al., 1997) found that conglomerate noises which included music, speech and machinery led to concurrent increases in blood pressure and impaired performance on a vigilance task. Background sounds thus appear to be arousing and stimulating but can have negative effects on performance.

The arousal induced by sound may be an important factor in the initiation and maintenance of game playing behaviour. Casinos and amusement arcades capitalise on this by generating a noisy, exciting and stimulating environment with intermittent sirens, gongs and loud ringing bells (Hess and Diller, 1969). Such sound effects are not only arousing, but they also convey the impression that people are having fun and that winning is more common than losing. Thus the loud clangs of coins falling into metal trays, and loud buzzing and musical tunes after wins, are both arousing and enticing.

Colour has also been associated with arousal, emotional states and behavioural patterns in a variety of contexts (Bornstein, 1978; Mikellides, 1990). However, many reports on the role of colour are anecdotal rather than based on systematic investigation. For example, interior decorators often advise that red is a 'hot' arousing colour and blue a 'cool' tranquil one. A newspaper clipping (Argue, 1991) asserts that "red is an effective colour to use in restaurants because it leads people to eat more; red also makes people lose track of time, making it a good colour for use in casinos." Although these claims are consistent with research into the effects of arousal on attention, such observations lack empirical verification (Gorn et al., 1997).

Notwithstanding, a review of experiments into colour and emotions (Valdez and Mehrabian, 1994) does conclude that red colours are more physiologically arousing than blue colours. Wexner (1954) asked people to view colour samples and choose words with which they associated the colours. She found that the colour red was associated with terms such as *exciting* and *stimulating,* while blue was seen as *secure* and *soothing*. This kind of finding supports the view that red is perceived as more arousing than blue.

Gerard (1958) noted that red and blue represent the two wavebands of radiant energy at the opposite ends of the visible spectrum. He found that these colours exert differential biological influences on the individual, as measured by general activation in the nervous

system. Further support was given to Gerard's work in an experiment conducted by Ali (1972), who projected red and blue lights directly onto the eyes of 10 participants for 6 min. EEGs recorded throughout the period indicated greater cortical arousal following the presentation of red light and lower cortical arousal following presentation of blue light. Mikellides (1990) suggests that these studies demonstrate systematic relationships between colour and arousal through physiological measures.

Only one study (Stark et al., 1982) has examined the differential effects of red and blue colours on behaviour in a games context. These authors hypothesised that if red is arousing, gamblers should take more risks and stake more money when exposed to red lighting than those exposed to blue lighting. Their experiment supported this hypothesis, with red lighting having less of an inhibitory effect on gambling behaviour than blue lighting. They found that people exposed to red lighting while playing slot machines gambled more frequently, took more risks and played for larger stakes.

Not only might arousing sounds and colours lead to perceptions of exhilaration and anticipation, but arousal also appears to affect attentional style (Landers and Boutcher, 1993). People performing a task when minimally aroused are more likely to be slow, indifferent, and spread their attention across a wide range of stimuli. When highly aroused, people tend to be faster but less accurate, and they focus mainly on the most salient aspects of a task. Thus both high and low levels of arousal can have detrimental effects on performance. However, studies of habituation (Sokolov, 1963) suggest that changes in mood and performance due to arousal may not be long lasting, as adaptation to the stimuli serves to decrease their effects.

Unfortunately, none of these studies has investigated the combined influence of colour and sound. The present study was designed to examine such effects on arousal level, performance, and perceptions during a computer game playing session. A video game[1] was devised in which colour (red or blue) and sound (loud or quiet) could be systematically varied while other factors remained constant. The game allowed performance to be measured in terms of scores and errors while a continuous reading of heart rate was taken. Heart rate is widely used in psychological research as a relevant indicator of arousal, and previous research (Turner et al., 1983) has shown that video games can elicit what appear to be metabolically exaggerated heart rate increases in certain individuals.

The main hypothesis in the present study is that a combination of red colour and loud sound in the game will lead to higher levels of arousal and perceptions of excitement. High (red/loud) and low (blue/quiet) manipulations of arousal are also expected to be associated with poorer performance than moderate (red/quiet, blue/loud) conditions.

2. Method

2.1. Design

The study used a $2 \times 2 \times 5$ factorial design, varying colour of screen (red or blue) and accompanying musical sounds (loud or quiet) across five games. Each participant played

[1] Thanks to Mr Seth Glossop for designing the game.

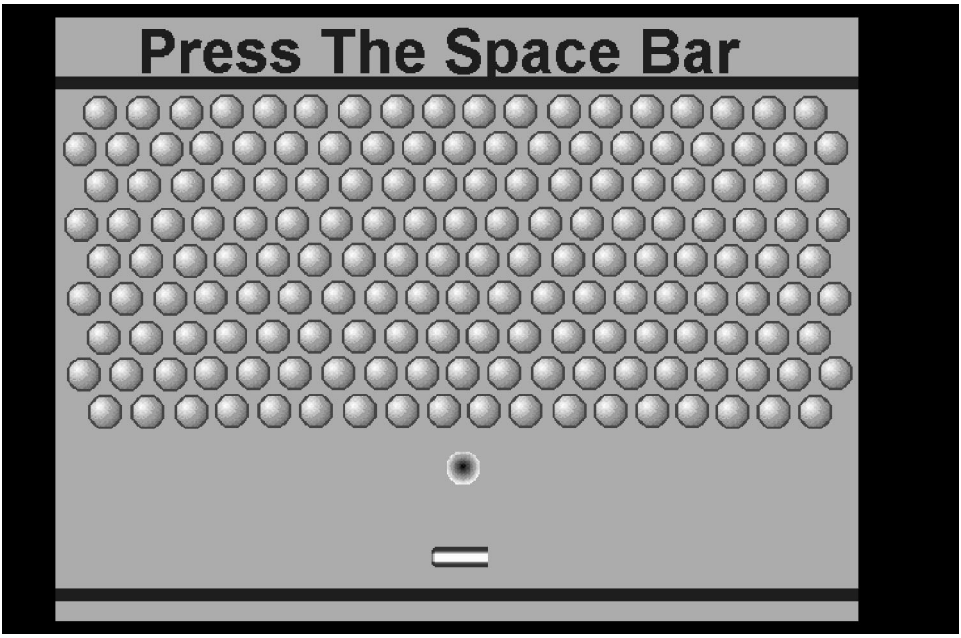

Fig. 1. Illustration of game.

the same five games but was randomly assigned to one of the four treatment conditions (red—loud; red—quiet; blue—loud; blue—quiet). The dependent variables were performance scores, number of errors, and heart rate levels for each game. Subjective perceptions of mood states were measured via questionnaire responses at the end of the five games.

2.2. Participants

One hundred participants were recruited via opportunity sampling. The majority was undergraduate university students from various departments. The data from three participants were excluded from the final analyses due to faulty heart rate measurement, and a fourth participant was eliminated to allow equal numbers in each experimental condition. The final sample consisted of 46 males and 50 females spread evenly across the four conditions. All participants stated they were not colour blind.

2.3. Materials/apparatus

A simple computerised video game was devised so that intensive practice was not required before participants could play the game. The game screen (see Fig. 1) consisted of nine rows of eight or nine circles, with a total of 166 circles; a paddle which the participant could move by pressing the left and right cursors on the computer keyboard; and a ball. The colour of the screen (bright red or pale blue) and the sound (loud—8 dB or

quiet—1 dB) could be manipulated before each session. The background sound was an obscure, continuous piece of upbeat, jazzy dance music.

A Nellcor Puritan Bennet (N100-P) pulse oximeter, attached via a finger clip to the index finger of the non-dominant hand (the left hand in 98% of cases), was used to provide a continuous print-out of heart rate expressed in beats per minute every 30 s during play. A post-game questionnaire consisting of 26 7-point Likert-format items was used to obtain measures of mood and perceptions of the game.

2.4. Procedure

Each participant was randomly allocated to one of the four experimental conditions and tested individually in an isolated cubicle. Participants were told that they would play a continuous series of five video games while their heart rate was being measured. They were given a demonstration of the controls for the game and allowed a practice trial.

Participants were instructed to rebound a continuously moving ball from a paddle which they controlled using the left or right arrow cursor on the computer keyboard. When contact was made, the ball would move upwardly and could hit one or more circles before returning to the bottom of the screen. Participants scored a point for each circle which they hit (upon being hit, the circle would disappear), and they accumulated an error score each time they failed to make contact with the ball and instead hit the bottom line on the computer screen. The full instructions were:

> You are going to be playing a game in which the object is to hit as many circles as possible. You will see a small bar at the bottom of the screen, which can be moved right or left to make contact with a moving ball. You will get a point for every circle that you hit, but you will get an error every time the ball fails to make contact with the bar and hits the bottom of the screen instead. You will have a practice trial to familiarise yourself with the game.
> Each trial will take 90 s, and you will be able to see your result. You will have one practice trial and then five more games that count. There will be a short rest period between each game. Please try to do as well as you can. Do you have any questions so far?
> I am also interested in your pulse rate during the game, so I'll be taking a measure with this pulsometer. Is that comfortable? If at any point you feel uncomfortable for any reason at all, please say so, and we can stop the game.
> Ready? Press the bar to begin.

Each game was programmed to last 90 s with a 5 s rest interval between each game. The experimenter remained in the cubicle during the session and recorded performance and error scores for each game. When participants completed the final game, the pulse oximeter was detached and they were asked to complete the questionnaire. Finally, they were thanked and debriefed.

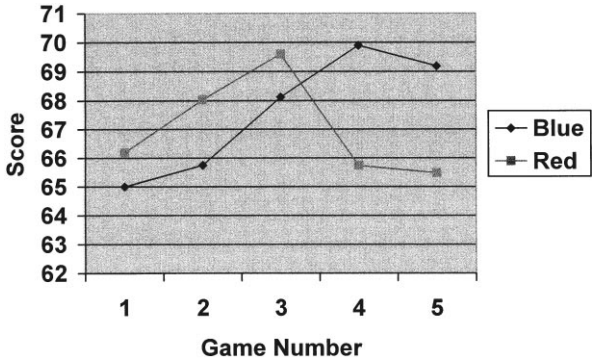

Fig. 2. Interaction of score and game number.

3. Results

3.1. Performance

Two measures of performance across the five games were analysed: the score, reflecting the number of circles hit by the ball, and the error rate, referring to the number of times the ball missed the moving paddle and hit the base of the screen instead.

A $2 \times 2 \times 5$ analysis of variance with two independent measures (colour and sound) and one repeated measure (game number) revealed a significant two way interaction between colour and game number, $F_{4,368} = 2.64$, $p \leq 0.03$, on performance scores (see Fig. 2). People playing with a blue screen background tended to improve over the course of the session, while the scores of those with a red screen peaked in Game 3 and then decreased. There were no other significant main effects or other interactions.

Another 3-way analysis of variance carried out on errors showed a significant main effect for colour, with people in the blue condition making more errors ($M = 28.92$) than those in the red condition ($M = 25.56$), $F_{1,368} = 5.77$, $p \leq 0.02$. No other effects were found.

3.2. Heart rate

The mean heart rate during each game was calculated and subjected to a 3-way analysis of variance. A marginal interaction effect, $F_{4,368} = 1.99$, $p \leq 0.09$, shows that the heart rate of people playing with a red screen decreased in Game 5, while the heart rate of those playing with a blue screen continued to increase (see Fig. 3).

3.3. Questionnaire responses

Participants were only minimally affected by the manipulations. There were no differences with regard to mood or descriptions of the game, aside from non-significant trends, $F_{1,92} = 2.42$, $p \leq 0.12$, for the game to be rated as more exciting with the red screen ($M = 4.02$) than the blue ($M = 3.52$), and $F_{1,92} = 2.03$, $p \leq 0.15$, for the Loud condition ($M = 4.00$) to be more exciting than the Quiet ($M = 3.54$). Estimates of the length of the

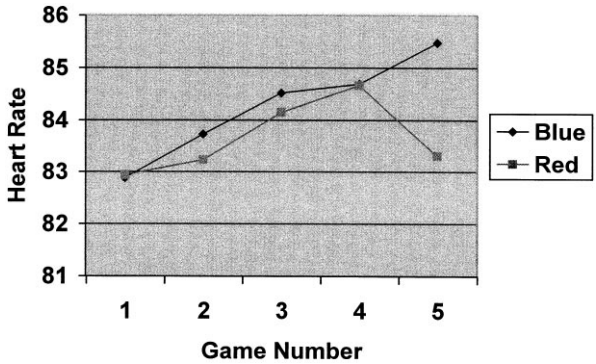

Fig. 3. Interaction of heart rate and game number.

game did not vary, nor were there differences in whether participants had enjoyed the game, would like to play again, or felt that luck and skill were important to success. A significant interaction, $F_{1,92} = 5.30$, $p \leq 0.02$, was found on responses to the question *Do you think you played well?*, with people in the Red/Loud condition expressing a more positive view than the other groups.

3.4. Manipulation checks

Participants were asked to indicate how loud the music was in the game. Those in the Loud condition gave a significantly higher response on the 7-point scale ($M = 4.71$) than those in the Quiet condition ($M = 2.65$), $F_{1,92} = 18.19$, $p \leq 0.001$. In addition, all but four participants remembered the screen colour correctly.

3.5. Gender differences

Males and females were compared on all performance, heart rate and questionnaire measures, and only two differences emerged. Males ($M = 3.89$) were more likely than females ($M = 3.26$) to think they had played well ($t = 2.46$, df $= 88$, $p \leq 0.02$), though such a belief was not supported by the performance measures, where no gender differences at all were found. Males ($M = 4.54$) were also more likely than females ($M = 3.84$) to believe that luck was important in the game ($t = 2.08$, $p \leq 0.04$).

4. Discussion

The results partially support the hypotheses. While a number of effects due to colour arose, it appears that sound level had little influence on performance scores, errors, or heart rate. The manipulation check included in the questionnaire did demonstrate that people in the Loud condition found the accompanying music significantly louder than those in the Quiet condition. However, the mean of 4.71 for the Loud group is only *relatively* higher than the mean of 2.65 for the Quiet group. Given that the ratings were made on a 7-point scale, the Loud group average is only slightly higher than the theoretically neutral point

of 4. Therefore, although the sound level of 8 dB in the Loud group was indeed louder than that of the 1 dB of the Quiet group, and experienced as such, it was not actually perceived as truly loud and may thus not have been arousing.

Another reason for the lack of effect for sound could be that the sound in this study was relatively consistent and predictable. Studies by Glass and Singer (1972) show that unpredictable noise is particularly arousing. Edworthy et al. (1991) and Haas and Edworthy (1996) also suggest that arousal is more likely when the pitch, loudness and speed of accompanying sounds increase in a pulsating manner, producing what has been termed *perceived urgency*. Future research might examine these aspects of sound, although ethical considerations would constrain the level of noise employed.

Finally, the lack of an effect for background sound might be due to the particular music adopted for this study. Level of distraction and mood change resulting from music has been shown to be a function of the type of music (McCraty et al., 1998) and the individual's personal perception of the music (Carter et al., 1995). Other types of music might thus be investigated in future research.

The manipulation of colour produced more interesting results. Both the Red and Blue groups improved from Game 1 through to Game 3; but whereas the Blue group continued to improve, the Red group experienced a decrease in performance in Games 4 and 5. Similarly, the heart rate of the Blue group continued to increase through the session, while the Red Group experienced a decrease in heart rate in Game 5.

Given that the scores of the Red group were slightly higher than those of the Blue group throughout Games 1–3, it is possible that the former were initially more aroused than the latter. Research suggests that red tends to be more arousing than blue (Wexner, 1954; Valdez and Mehrabian, 1994). Such an effect might have led to higher levels of activity and alertness on the part of the Red group at the beginning of the session, thus increasing their likelihood of attending to the game and feeling motivated to try hard. The Blue group's lower level of excitement might have led to their being less attentive and motivated, possibly accounting for their increased error rate. However, research (Sokolov, 1963) suggests that people eventually become desensitised to arousing stimuli during continuous exposure. This 'habituation effect' can reduce or eliminate the impact of stimuli which are initially arousing. Perhaps by the end of Game 3, the arousing effect of the red screen might have begun to dissipate, leading to a decrement in performance. The Blue group, on the other hand, may have been initially relatively unaroused, and their continued participation marked by a gradual increase in absorption in the game. This interpretation is supported by the interaction between screen colour and heart rate, wherein the Red group's heart rate decreased toward the final game while the Blue group's heart rate continued to rise.

Despite the performance and heart rate differences between the Red and Blue groups, very few differences emerged when the participants completed the questionnaire which measured their subjective perceptions. Only slight, non-significant trends emerged for the game to be rated as more exciting with the red screen and with the loud music. Interestingly, participants in the Red/Loud condition were more likely to feel that they had played well. It could be that their slightly higher levels of excitement made people feel more optimistic, even though this was not reflected systematically in their performance. Males were particularly likely to feel they had played well, possibly due to their greater level of

familiarity and confidence with computer games (Passig and Levin, 1999). Although Passig and Levin also found that boys preferred games with blue and green colours and girls red and yellow colours, the present study did not find any interactions of colour and gender.

The results of this study, then, do suggest that colour may be an important ingredient in the aura of a computer game. Sound level on its own did not emerge as an influential component, but it could be that louder and more unpredictable noises would indeed exert an effect on performance, arousal and perceptions of the game. Edworthy's (1998) more general examination of the auditory-computer interface warns of the complexities of background sound effects and argues that the outcome will vary depending upon the many stimuli and task variables involved.

Future research might examine more extreme and erratic sound levels and consider the possibility of individual differences in responses to various types of sound. It would also be useful to investigate a game requiring a more sophisticated and involving strategy. For example, colour and sound effects could be integrated more interactively into the game so that the participant's responses actually have an effect on the stimuli. This might increase the player's awareness of the sound and colour and thus make the structural characteristics of the game more salient. Landers and Boutcher (1993) suggested that high levels of arousal are more likely to affect games which encompass many stimulus characteristics such as number, intensity, clarity and duration, and also those which require complex decisions and actions.

In addition, future research might attempt to replicate this study in a more naturalistic setting in order to increase its ecological validity. Research into the psychophysiology of gambling, for example, has shown that larger increases in arousal occur outside the laboratory setting. Anderson and Brown (1984) found significant correlations between stakes and heart rate in a casino setting but not in a laboratory setting. It could be that the laboratory setting of this study made participants feel self-conscious and distracted, thus decreasing the impact of features of the game.

In summary, although the results are inconclusive, they do lend some support to previous research efforts which suggest that background stimuli within a computer game can affect physiological responses, performance and perceptions. Investigations of dramatic, intense stimuli suggest that bright colours and loud sounds should exert arousing influences, and that the process of habituation might lead to decreased effects over time. Nonetheless, in the present study, colour proved to have a greater impact than sound, and even here the effect was not straightforward. The manipulations in this experiment were relatively simple, and further research is needed to investigate more complex interrelationships between types of colour and sound with performance and mood outcomes. Individual differences such as gender and musical preferences might also be considered, as evidence indicates that people may not always respond uniformly to the identical stimuli.

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