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Conditioned Place Preference and Aversion for Music in a Virtual Reality Environment

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Abstract

The use of a virtual reality environment (VRE) enables behavioral scientists to create different spatial contexts in which human participants behave freely, while still confined to the laboratory. In this article, VRE was used to study conditioned place preference (CPP) and aversion (CPA). In Experiment 1, half of the participants were asked to visit a house for two min with consonant music and then they were asked to visit an alternate house with static noise for two min, whereas the remaining participants did the visits in reverse order. In Experiment 2, we used the same design as Experiment 1, except for replacing consonant music with dissonant music. After conditioning in both experiments, the participants were given a choice between spending time in the two houses. In Experiment 1, participants spent more time in the house associated with the consonant music, thus showing a CPP toward that house. In Experiment 2, participants spent less time in the house associated with the dissonant music, thus showing a CPA for that house. These results support VRE as a tool to extend research on CPP/CPA in humans.

Keywords

Virtual reality environment; Music; Conditioned place preference; Aversion

Abundant research has been devoted to understanding the neural mechanisms of brain reward. Among the experimental approaches that have been used in laboratory animals, conditioned place preference (CPP) is one of the most popular (Bardo & Bevins, 2000). Although methodological details differ among laboratories, a typical CPP experiment involves giving an animal a choice between spending time in two compartments, one previously associated with a rewarding stimulus (e.g., drug, social interaction, music) and the other serving as a control (no reward). Animals are typically tested in the absence of the rewarding stimulus. The classical result is an increase in time spent in the reward-associated compartment relative to the control compartment. This preference is thought to reflect a Pavlovian conditioning process in which a previously neutral compartment becomes preferred due its association with the rewarding stimulus (Bardo and Bevins, 2000).

Although the literature is consistent in acknowledging that CPP with laboratory animals has numerous advantages to study brain mechanisms of reward (see Bardo & Bevins, 2000; Carr, Fibiger, & Phillips, 1989; Mueller & de Wit, 2011; Tzschentke, 1998), there is debate over whether or not the results of the rich existing literature on CPP is applicable to humans. To date, there are only two published reports showing that humans evaluate a room

associated previously with amphetamine more positively than a room associated with placebo (Childs & de Wit, 2009; 2012). While providing evidence of CPP based on a self-report measure, the procedures used in those studies differed from traditional CPP studies in laboratory animals. In particular, during conditioning, participants were invited to fill out questionnaires, read, relax, and watch TV in their respective room, which does not mimic the exploratory behaviour inherent in the laboratory animal procedure. In addition, on the test, participants were asked to give self-reports about how much they liked the rooms, which does not mimic the behavioural choice used in the laboratory animal procedure. As Mueller and de Wit (2011) stressed, even though the amount of time spent in the two rooms was not used as the dependent variable, such a measure might be preferable. They suggested that the next step would be to find in humans an appropriate procedure that more closely parallels the behavioural measure used in CPP with laboratory animals. The current study addressed this issue. Further, since aversive stimuli also may be associated with an environmental context in laboratory animals (e.g., lithium; Cunningham & Niehus, 1993), we sought to determine if conditioned place aversion (CPA) could be established in humans.

A virtual reality environment (VRE) was chosen as the procedure to implement for assessing CPP and CPA in human participants. This is an ideal tool that allows participants to behave freely in a controlled environment while still confined to the laboratory. In recent years, many researchers have used engaging, computer-generated VREs to create different spatial contexts. For example, VRE has been used to examine context conditioning and behavioural avoidance (Grillon, Baas, Cornwell, & Johnson, 2006), cue reactivity and addiction (Bordnick, Traylor, Copp, Graap, Carter, Ferrer, & Walton, 2008), interpersonal distance and social behaviour (Bailenson, Blascovich, Beall, & Loomis, 2003), spatial integration and navigation (Molet, Bugallo, & Gambet, 2011).

The procedures chosen for the current studies were selected to fulfill two practical objectives. First, for conditioning, we sought to provide a rationale for participants to walk around and explore each context. This was accomplished by asking participants to visit two different houses in a VRE. Second, for the test, we sought to provide a credible reason for giving participants a choice between spending time in the two contexts. This was accomplished using a cover story that asked participants to re-visit both houses before making a choice of their favourite house.

Concerning the stimuli used to establish CPP or CPA, laboratory animal research has shown that sound and music can be used to enhance the rewarding effect of 3,4-methylenedioxymethamphetamine (MDMA; Feduccia & Duvauchelle, 2008), as well as serving as conditioned stimuli to induce cocaine-induced CPP (Polston & Glick, 2011). Therefore, we decided to use music for the sake of simplicity and for practical reasons. Pleasant emotion was induced by a two-minute extract from *A little night music* (Mozart), which is joyful and mainly consonant music (see Mitterschiffthaler, Fu, Dalton, Andrew, & Williams, 2007). An electronically manipulated (frequently dissonant) counterpart of this piece was used to induce unpleasant emotion (see Sammler, Grigutsch, Fritz, Koelsch, 2007). This approach was based on the well-documented finding that sensory dissonance (in the sense of roughness of a stimulus; see Bigand, Parncutt, & Lerdahl, 1996) is generally perceived as unpleasant in humans (Koelsch, Fritz, Cramon, Mueller, & Friederici, 2006). We used static noise as a control sound.

Music-induced CPP was assessed in a VRE using an “unbiased” approach, in which the participants were exposed to consonant music or static noise in either of the two virtual houses, based on counterbalanced assignments. There is now an emerging consensus that the unbiased procedure is preferable over the “biased” procedure in which subjects are exposed to the stimulus in the least preferred room, as determined by the pre-conditioning test (see

Mueller & de Wit, 2011; Schechter & Calcagnetti, 1998; Tzschentke, 2007, for detailed reasons). After conditioning trials were completed, participants were given free access to the two houses in order to evaluate whether a CPP developed toward the house associated with the consonant music. In a second experiment, we replaced the consonant music by a dissonant version, with the goal of establishing CPA.

Experiment 1

The purpose of the first experiment was to test CPP for consonant music in a VRE. If the consonant music was more pleasant than the indoor background noise, then it was expected that participants would show a CPP toward the house associated with the consonant music over the house associated with static noise.

Method

Participants—Sixteen undergraduate students from the University of Lille participated in Experiment 1 (8 women and 8 men). They were between 18 and 25 years old and had no experience with the videogame used in our experiment. They were non-musicians who had no formal music training (besides typical school education). All participants reported normal hearing. The data from 1 participant were discarded because of an error by the experimenter.

Apparatus—Participants performed the experiment using a Dell Latitude E540 computer. The procedure was implemented with the life-simulation videogame *The Sims 3* that allows its player to control a human-like avatar in virtual environments. The virtual environment used in this study comprised of a two distinct houses separated by a road used as a starting point. Dimensions of length x height were measured in virtual units (vu). Both houses measured 44 × 44 vu. The two houses differed along several characteristics such as location of the rooms in the house, size and shape of the rooms, floor color or wallpaper of the rooms, location of furniture in the rooms, types of lamps and carpets. Both houses consisted of a living room with one table and eight chairs, a television, a Hi-fi sound system, a carpet, three couches, two lamps, and a plant. Adjoining the living room was a study room with a couch, a desk, a chair, a lamp, a plant and two shelves. There was a fully equipped kitchen. A bathroom had a bathtub, a shower, two sinks and a toilet. Finally, there were two bedrooms, both with a double bed, two night tables, two closets, and a carpet. Screen capture of the VRE from an aerial view (never seen by participants) is shown in Panel 1 of Fig. 1.

A MacBook computer was used to play the auditory stimuli. They consisted of MP3 files of consonant and dissonant versions of *A little night music* (Mozart), and a static noise that was obtained by recording the indoor background noise of the cubicle before starting the experiment. We used GarageBand software to create the sound file of the dissonant version of *A little night music*. The three auditory stimuli were two min each and were presented with the software program of VLC Media Player.

The experiment was conducted in a cubicle containing a table, a chair, and a computer for the participant placed in the center of the cubicle. The videogame *The Sims 3* was run on the computer used by the participant. For the experimenter, there were another table, chair and computer. The experimenter was positioned behind the participant. The auditory stimuli were played on the computer used by the experimenter.

Procedure—Participants were run individually. The experiment involved three phases: a 1-min familiarization phase, a conditioning phase that consisted of two 2-min sessions and a testing phase (unlimited time) that assessed CPP. All screen activities during the three phases were recorded with a screen-recording tool in *The Sims 3*. Upon arrival to the

laboratory, the participant was placed in the experimental cubicle. Before starting, participants had one min to explore a demonstration house (different from the ones used in conditioning) in the VRE in order to get familiar with navigating. The verbal directions were read to the participant by the experimenter once the participant was seated and were as follows:

“You are about to play a game in which we will ask you to visit two houses in a videogame. But first, you are going to navigate in a demonstration house to familiarize yourself with moving in the virtual environment for one min. You will use the arrows on the keyboard to move and the mouse to control your perspective. When you are ready to begin, please start. I will inform you when you can stop visiting”

Participants moved using the cursor navigation keys of the keyboard: ↑ (forward), ↓ (backward), ← (left), and → (right). Moving the mouse to the right or left controlled rotational movements. Participants navigated from a first-person perspective, at a constant velocity. The computer screen displayed a view from the perspective of the participant within the 3-D virtual environment; therefore, this arrangement is analogous to an individual's view of the natural environment (see Panel 2 in Figure 1).

Each session of the conditioning phase consisted of visiting a house for two min. At the beginning of each session, the participant's avatar was placed in the center of the road separating the two houses and the experimenter instructed the participant to start the visit by the house located on the right or left of the road (counterbalanced across participants). Half of the participants visited the house associated with consonant music and then they visited the house associated with static noise, whereas this visit order was reversed for the remaining participants. We used a cover story to play the music during the visits. The participant was told that the experimenter was making recording of different music for an unrelated experiment that he will conduct soon. The experimenter asked if the participant agreed that he might proceed to the recordings. All the participants accepted. The following instructions concerning the first session of conditioning were given to the participant:

“You are now about to visit the first house of interest. You will start in the middle of a road. I will give you the directions to go visit the house once you are ready to play. As in the demonstration, you will use the arrows on the keyboard to move and the mouse to control your perspective, and I will also inform you when you can stop visiting.”

Once the experimenter had indicated the first house to visit (on the right side or the left side of the road, counterbalanced across participants), he started to play a sound file on his computer (i.e., consonant music or static noise, counterbalanced across participants). When the sound file had finished playing, the experimenter interrupted the participant's visit, and brought his/her avatar back in the middle of the road so that the second session could proceed (i.e., visit of the second house). The participant received the following instructions:

“Now you will be visiting the second house of interest. I will give you the directions to see this house once you are ready to play. Same as before, I will inform you when you can stop visiting.”

The procedure was the same as before, except that the experimenter played the other sound file.

In testing, no sound file was played and the following instructions were given:

“We are about to ask you to choose your favourite house. But before doing that, you are given the opportunity to visit again. You are free to visit one house or the

two houses. Once you think you have had enough time to make a decision, then you can stop visiting and call me”

The participants’ behavior in the VRE was screen-recorded; an observer blind to the conditions watched video recordings off-line and calculated the time spent in each house. The two dependent variables of main interest to measure CPP were: (1) number of participants that choose to visit the house associated with consonant music first; and (2) time spent in each house. There were two brief post-experimental questions in which participants were asked: (1) their favourite house; and (2) if they thought that the music influenced their choice. After the participants answered those questions, they were debriefed about the purpose of the study, thanked and dismissed.

Results and Discussion

The majority of participants (13 out of 15) chose to visit the house associated with consonant music first, rather than the house associated with static noise. A binomial test indicated that this was significantly different from chance, $p = .003$. The data shown in the two left columns of Table 1 represent the time (sec) spent in each of the two houses during testing. The percentage of time spent in the house associated with the consonant music was 85.1%, an effect that was statistically different from chance (50%), $t(14) = 4.60$, $p = .0004$, two-tailed. All participants verbally reported that the house associated with consonant music was their favorite. None of the participants thought that the music influenced their choice, which is highly suggestive of the absence of potential compliance.

Overall, these results show that VRE may be used to induce CPP for music in humans. This is the first demonstration of CPP in humans that measured actual time spent in either context in a free choice procedure. In rats, while music can be used as a conditioned stimulus to establish cocaine-induced CPP, music alone does not appear to induce CPP (Polston & Glick, 2011). Thus, humans may be unique in their propensity to find music to be rewarding.

Experiment 2

The goal of the second experiment was to determine if dissonant music induce CPA.

Method

Participants—Sixteen undergraduate students from the University of Lille, similar to those who participated in the first experiment, participated in Experiment 2 (ages 18-23 years, 50% of each sex).

Apparatus and Procedure—The apparatus and procedure were the same as that used in Experiment 1, except that the consonant version of *A little night music* (Mozart) was replaced by a dissonant version.

Results and Discussion

The results of Experiment 2 were opposite to those obtained in Experiment 1. All of the participants chose to visit the house associated with static noise first, rather than the house associated with dissonant music. The percentage of time spent in the house associated with the static music was 95.7%, an effect that was statistically different from chance (50%), $t(15) = 15.21$, $p < .0001$, two-tailed. Additionally, participants’ verbal reports of their preferred house were congruent with their behavioral responses.

Complementary with Experiment 1, which used a consonant music to induce a CPP toward the house associated with it, the results of Experiment 2 indicate that the use of a dissonant music induced a CPA.

General Discussion

The current experiments demonstrate that music can be used as a stimulus to produce either CPP or CPA, depending on the type of music associated within a VRE. This work parallels the work conducted with laboratory animals using the place preference procedure (Bardo & Bevins, 2000; Cunningham, Groblewski, & Voorhees, 2011; Tzschentke, 1998). While this procedure has been used primarily to study the incentive value of drugs of abuse, several studies indicate that it is useful for examining the incentive value of non-drug stimuli such as palatable fluids (Agmo & Marroquin, 1997; Delamater, Scalfani, & Bodnar, 2000), sexual opportunity (Hughes, Everitt, & Herbert, 1990; Meisel, Joppa, & Rowe, 1996) and novel objects (Bevins & Bardo, 1999; Douglas, Varlinskaya, & Spear, 2003). The current results extend this work to show that music is able to condition either CPP or CPA in human participants.

In comparing to these results to studies using laboratory animals (Bevins and Bardo, 2000; Carr et al., 1989; Tzschentke, 1998), some limitations in the current experiments are acknowledged. In particular, possible inherent differences in house preference were not obtained, which differs from most laboratory animal studies in this area. In addition, in contrast to the typical 15-min test used with laboratory animals, humans were given unlimited time to choose between houses. Further, the current experiments did not include all possible conditioning stimuli (e.g., consonant vs. dissonant, sound vs. sound, sound vs. silent, etc.). Future work could address these limitations.

Regarding the musical stimulus used here, previous work shows that auditory stimuli can induce either positive or negative mood states. While mood states are often induced using classical music combined with pictorial slides with strong affective content (Goodwin & Sher, 1993; Perkins, Grottenthaler, Ciccocioppo, Conklin, Sayette, & Wilson, 2009a; Perkins, Grottenthaler, & Wilson, 2009b), some work has shown that auditory stimuli alone can be used to induce mood. For example, different pieces of classical music from various composers (Mozart, Adagio and Barber) will induce either positive or negative moods in adult males during sexual arousal (Mitchell, DiBartolo, Brown, & Barlow, 1998). In that study, however, visual imagery also was paired with the music by instructing subjects to imagine events in their personal life that matched the music-induced mood induction. In another study, a positive mood was induced by having subjects bring to the laboratory a compact disk of their preferred music (Perkins *et al.*, 2009b). Playing the preferred music was found to serve as a reinforcer; in addition, termination a loud (106 dB) acoustic burst served as a reinforcer. Although these studies show clearly that auditory stimuli have hedonic value that motivates behaviour, the current results are the first to demonstrate that music can induce CPP or CPA.

There are several advantages inherent with the procedures used to establish CPP and CPA in the current study. First, the stimulus materials needed are readily available, which allows for dissemination across various research domains. Second, the time needed to establish CPP or CPA is relatively brief, requiring only one test session. This allows for reduced expense and labor. Third, the current VRE procedure is potentially adaptable to modern neuroimaging technologies such as magnetic resonance imaging (MRI) and positron emission tomography (PET), which require a fixed head position during testing. Although the brain regions involved in the perceptual and emotional processing of music have been studied (Brattico, & Jacobsen, 2009; Koelsch, 2010), the current procedure might be useful for studying the neural mechanisms involved in conditioned responses to music.

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References

- Ågmo A, Marroquin E. Role of gustatory and postingestive actions of sweeteners in the generation of positive affect as evaluated by place preference conditioning. *Appetite*. 1997; 29:269–289. [PubMed: 9468761]
- Bailenson JM, Blascovitch J, Beall AC, Loomis JM. Interpersonal distance in immersive virtual environments. *Personality and Social Psychology Bulletin*. 2003; 29:819–833. [PubMed: 15018671]
- Bardo MT, Bevins RA. Conditioned place preference: what does it add to our preclinical understanding of drug reward? *Psychopharmacology*. 2000; 153(1):31–43. [PubMed: 11255927]
- Bevins RA, Bardo MT. Conditioned place preference by access to novel objects: antagonism by MK-801. *Behavioural Brain Research*. 1999; 99:53–60. [PubMed: 10512572]
- Bigand E, Parncutt R, Lerdahl F. Perception of musical tension in short chord sequences: The influence of harmonic function, sensory dissonance, horizontal motion, and musical training. *Perception & Psychophysics*. 1996; 58:124–141. [PubMed: 8668513]
- Bordnick PS, Traylor A, Copp HL, Graap KM, Carter B, Ferrer M, Walton AP. Assessing reactivity to virtual reality alcohol based cues. *Addictive Behaviors*. 2008; 33:743–756. [PubMed: 18282663]
- Brattico E, Jacobsen T. Subjective appraisal of music: neuroimaging evidence. *Annals of the New York Academy of Sciences*. 2009; 1169:308–317. [PubMed: 19673799]
- Carr, GD.; Fibiger, HC.; Phillips, AG. Conditioned place preference as a measure of drug reward. In: Liebman, JM.; Cooper, SJ., editors. *The neuropharmacological basis of reward*. Clarendon Press; Oxford: 1989. p. 264–319.
- Childs EH, de Wit H. Amphetamine-induced place preference in humans. *Biological Psychiatry*. 2009; 65:900–904. [PubMed: 19111278]
- Childs EH, de Wit H. Contextual conditioning enhances the psychostimulant and incentive properties of d-amphetamine in humans. *Addiction Biology*. 2012 doi: 10.1111/j.1369-1600.2011.00416.x.
- Cunningham CL, Groblewski PA, Voorhees CM. Place conditioning. *Neuromethods*. 2011; 53:167–189.
- Cunningham CL, Niehus JS. Drug-induced hypothermia and conditioned place aversion. *Behavioural Neuroscience*. 1993; 107:468–479.
- Delamater AR, Scalfani A, Bodnar RJ. Pharmacology of sucrose-reinforced place-preference conditioning: effects of naltrexone. *Pharmacology, Biochemistry & Behavior*. 2000; 65:697–704.
- Douglas LA, Varlinskaya EI, Spear LP. Novel-object place conditioning in adolescent and adult male and female rats: effects of social isolation. *Physiology & Behavior*. 2003; 80:317–325. [PubMed: 14637231]
- Feduccia AA, Duvauchelle CL. Auditory stimuli enhance MDMA-conditioned reward and MDMA-induced nucleus accumbens dopamine, serotonin and locomotor responses. *Brain Research Bulletin*. 2008; 77:189–196. [PubMed: 18722516]
- Goodwin AH, Sher KJ. Effects of induced mood on diagnostic interviewing: evidence for a mood and memory effect. *Physiological Assessment*. 1993; 5:197–202.
- Grillon C, Baas JMP, Cornwell B, Johnson L. Context conditioning and behavioral avoidance in a virtual reality environment: effect of predictability. *Biological Psychiatry*. 2006; 60:752–759. [PubMed: 16950216]
- Hughes AM, Everitt BJ, Herbert J. Comparative effects of preoptic area infusions of opioid peptides, lesions and castration on sexual behavior in male rats: studies of instrumental behavior, conditioned place preference partner preference. *Psychopharmacology*. 1990; 102:243–256. [PubMed: 2274607]
- Koelsch S. Towards a neural basis of music-evoked emotions. *Trends in Cognitive Sciences*. 2010; 14:131–137. [PubMed: 20153242]
- Koelsch S, Fritz T, von Cramon DY, Muller K, Friedrici AD. Investigating emotion with music: an fMRI study. *Human Brain Mapping*. 2006; 27:239–250. [PubMed: 16078183]

- Meisel RL, Joppa MA, Rowe RK. Dopamine receptor antagonists attenuate conditioned place preference following sexual behavior in female Syrian hamsters. *European Journal of Pharmacology*. 1996; 309:21–24. [PubMed: 8864688]
- Mitchell WB, DiBartolo PM, Brown TA, Barlow DH. Effects of positive and negative mood on sexual arousal in sexually functional males. *Archives of Sexual Behavior*. 1998; 27:197–207. [PubMed: 9562901]
- Mitterschiffthaler M, Fu CHY, Dalton JA, Andrew CM, Williams SCR. A functional MRI study of happy and sad affective states induced by classical music. *Human Brain Mapping*. 28:1150–1162. [PubMed: 17290372]
- Molet M, Bugallo M, Gambet B. Spatial integration using a 3D virtual environment with humans. *Behavioural Processes*. 2011; 88:198–201. [PubMed: 21907769]
- Mueller D, de Wit H. Conditioned place preference in rodents and humans. *Neuromethods*. 2011; 50:133–152.
- Perkins KA, Grottenthaler A, Ciccocioppo MM, Conklin CA, Sayette MA, Wilson AS. Mood, nicotine, and dose expectancy effects on acute responses to nicotine. *Nicotine & Tobacco Research*. 2009a; 11:540–546. [PubMed: 19351782]
- Perkins KA, Grottenthaler A, Wilson AS. Lack of reinforcement enhancing effects of nicotine in non-dependent smokers. *Psychopharmacology*. 2009b; 205:635–645. [PubMed: 19488740]
- Polston JE, Glick SD. Music-induced context preference following cocaine conditioning in rats. *Behavioral Neuroscience*. 2011; 125:674–680. [PubMed: 21688895]
- Sammler D, Grigutsch M, Fritz T, Koelsch S. Music and emotion: Electrophysiological correlates of the processing of pleasant and unpleasant music. *Psychophysiology*. 2007; 44:293–304. [PubMed: 17343712]
- Schechter MD, Calcagnetti DJ. Continued trends in the conditioned place preference literature from 1992 to 1996, inclusive, with a cross-indexed bibliography. *Neuroscience & Biobehavioral Reviews*. 1989; 22:827–846. [PubMed: 9809314]
- Tzschentke TM. Measuring reward with the conditioned place preference paradigm: a comprehensive review of drug effects, recent progress and new issues. *Progress in Neurobiology*. 1998; 56:613–672. [PubMed: 9871940]

Panel 1

Panel 2

Figure 1.
Panel 1: Screen capture of the VRE from an aerial view (never seen by the participants).
Panel 2: Sample image from the first-person perspective within the VRE as seen by the participants.

Table 1

The two left columns display the individual time (sec) spent in each house in which participants were exposed either consonant music or static noise in Experiment 1 (CPP). The two right columns display the individual time (sec) spent in each house in which participants were exposed either dissonant music or static noise in Experiment 2 (CPA). The mean (S.E.M.) and percentage for each condition are shown in bold.

Experiment 1 CPP		Experiment 2 CPA	
Consonant Music	Static noise	Dissonant Music	Static noise
105	28	0	70
65	0	0	85
111	0	0	45
94	0	0	81
143	0	0	64
40	35	0	55
157	0	0	90
43	0	0	103
95	34	0	72
38	0	0	96
135	0	23	42
103	83	0	63
0	102	0	115
74	0	38	53
92	0	0	88
-	-	0	74
86.33 (11.2)	18.80 (8.5)	3.81 (2.7)	74.75 (5.2)
84.1%	15.9%	4.3%	95.7%