**How can creativity be impacted by binaural beats**

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***Abstract* —One of the most creativity inducing chemical produced by the brain is dopamine, a human mood altering drug. This inherently suggests that the human mood is something which, by definition, can be manipulated for processes that are dopamine related or dopamine dependent. This paper aims to relate binaural beats, an auditory illusion that is considered a form of cognitive entrainment that operates through stimulating neuronal phase locking , to how it can impact creativity. The idea is to draw a correlation between binaural beats affecting divergent thinking, convergent thinking and the apparent improvement in performing creative tasks under the influence of binaural beats. Binaural beats considered here are presented in a beta frequency. The eye blink rate has been proposed as a level indicator for analyzing the effectiveness for measuring creativity levels. An attempt is also made to draw a relation between the effectiveness of performing convergent and divergent thinking tasks of an individual and the kind of binaural beat that the individual is exposed to.**

***Index Terms – binaural, creativity, eye blink rate, convergent thinking, divergent thinking***

**Introduction**

Creativity is an important aspect of the human cognitive system, but research into creativity is rather cluttered and mechanistic models about how creativity might work are not available (Dietrich and Kanso, 2010). Although there is no widely accepted definition of what creativity means, many subject experts agree that multiple cognitive processes seem to be involved, and that sub-functions underlying creativity depends on both state (Baas et al., 2008; Davis, 2009) and trait (Akbari Chermahini and Hommel, 2010) characteristics. Of all the processes involved in creativity, Guilford (1950, 1967) identifies divergent and convergent thinking as its two main ingredients. Together with insight (a possible sub-component of convergent thinking; (Bowden et al., 2005), these are nowadays still considered the most important processes in creativity (Dietrich and Kanso, 2010). Accordingly, it was these two processes that we considered in the present study.

Both divergent and convergent thinking has been assumed to be influenced by the positive mood (e.g., Baas et al., 2008; Davis, 2009), but the mechanism underlying this impact remains unclear. The availability of dopamine in the mesolimbic and nigrostriatal systems of the brain (Ashby et al., 1999), which again is likely to facilitate cognitive search operations and related processes underlying creative behavior (Akbari Chermahini and Hommel, 2010; Hommel, 2012). If so, factors or techniques that are likely to modulate dopamine production or transmission could be suspected to have an impact on cognitive operations underlying creativity.

One phenomenon that has been suspected to propagate creativity is known under the name of “binaural beats”, an auditory illusion that can be considered a kind of cognitive or neural entrainment (Vernon,2009; Turow and Lane, 2011). This phenomenon has encouraged sweeping claims about mind enhancement, and some websites even went as far as calling the illusion a “digital drug”. While binaural beats indeed seem to exert some effect on cognitive functioning and mood (Lane et al., 1998), and on neural firing patterns in the brain (Kuwada et al., 1979; Karino et al., 2006; Pratt et al., 2009; but see Vernon et al., 2012), it is as yet unclear how they do so. The binaural-beat illusion arises when two tones of a slightly different frequency are each presented to different ears. For instance, when a tone of 335 Hz is presented to the right ear and a tone of 345 Hz to the left ear, this results in a subjectively perceived binaural beat of 10 Hz. Hence, instead of hearing two different tones, most individuals will hear just one tone that fluctuates in frequency or loudness: a beat (Oster, 1973).

How exactly the brain produces the perception of these beats is unclear, but the reticular activation system and the inferior colliculus seem to play a role (Kuwada et al., 1979; McAlpine et al., 1996; Turow and Lane, 2011). In animals, binaural-beat producing stimulus conditions have been shown to produce particular neural patterns of phase locking, or synchronization, beginning in the auditory system and propagating to the inferior colliculus (Kuwada et al., 1979; McAlpine et al., 1996). Even though the neural response to objectively presented beats is stronger, binaural beats seem to elicit similar neural responses in both humans and animals (Kuwada et al., 1979; McAlpine et al., 1996; Schwarz and Taylor, 2005; Karino et al., 2006), suggesting that the illusion arises through pathways normally associated with binaural sound detection (Kuwada et al., 1979; Pratt et al., 2010). As in humans binaural beats have been found to affect cognitive functioning and mood (Lane et al., 1998; Vernon, 2009), and responses to binaural beats are detectable in the human EEG (Schwarz and Taylor, 2005; Pratt et al., 2009), it can be assumed that neuronal phase locking spreads from the auditory system and the inferior colliculus over the cortex. As suggested by Eysenck (1993) and Ashby et al. (1999), creative performance seems to depend on an individual’s basic supply of (striatal) dopamine.

**Method**

**Student description**

Twenty one students belonging to the Computer sciences department of Gandhi Institute of Technology and management were considered for this study as subjects( 16 male, 5 female ). All of the subjects had eyesight that was normal or was corrected to normal. The subjects had no history of hearing loss of any kind. The subjects were explicitly asked if they had ever experienced any issues with regard to their neurological or psychological health, to which all the subjects replied in the negative. All the participants were tested between 1 PM and 4 PM on the same day, to ensure a lesser variation in the fluctuating mood patterns, neural pathway interaction and other variables.

After the required subjects were gathered for the experiment, written consent was obtained from all the subjects in question. The subjects were not made aware of the goals of the experiment beforehand, but were informed about the intent and nature of the experiment after the session was completed. Throughout the entire duration of the experiment, absolute silence was ensured. The subjects were kept in relative isolation with no apparent auditory disturbance in sight.

**Method of evaluation**

The participants in question were given a questionnaire during a single session. The experiment essentially consisted of five segments. The first segment consisted of the introduction (consisting of the generic details of the subjects and a confirmation that they had full knowledge that the task was going to be performed and they had given the authors their written consent that the results could be used in a manner deemed fit. The next four segments consisted of the four tasks given to the subjects, each of which will be described in the segments that follow. It is to be noted that the same four sets of tasks were completed twice by all the subjects, the first time without the influence of any other sound, and the second time, while listening to the binaural beats.

The participants were exposed to two kinds of auditory stimuli. The first one was the stimuli for the adaptation of the subject’s ears to the auditory stimuli, which consisted of a binaural beat of frequency 350 Hz. After the subject had demonstrated the ability to listen to the 350 Hz stimulus, the gamma frequency (44 Hz) binaural beat stimuli was introduced. The order in which the subjects answered the questions was determined to be constant. In the session, the participant would complete the same tasks in the same order. The items chosen by the subjects was left to their discretion, to ensure results for questions that the subjects were most comfortable with.

The participants first listened to a two minute file, consisting of the 350 Hz rendition, without performing any task. After the subjects had demonstrated a level of comfort with the auditory signals and devices being used, the subjects were allowed to answer the creative tasks while listening to the 44 Hz rendition. The experiment does not take into question the mood changes that might have been caused during the course of the experiment.

**Auditory devices used**

The auditory device used for this experiment was a standard Nokia issue audio plugin device with stereo audio. The frequency response of the device stood at a standard 20 to 20,000 Hz. The speaker impedance stood at 32 Ohm. The connectivity was through a standard 3.5 mm stereo headphone connector. The auditory device was operated well within the specified ambient temperature range of -5 to +40 degrees Celsius. The device weighed 16 grams with a cable length of 120 cm.

**Divergent thinking: diagram extension task**

The purpose of this exercise was to test the subjects on how well they could let the divergent segment of their mind to function, both with and without the impact of binaural beats. In this task, the participants were given a random image, essentially consisting of a single line having multiple curves decided by random. The participants in question were then asked to extend the image and transform it in a manner deemed fit by them. While there is no mathematical criteria based on which the results can be determined, there are however a set of factors which have been considered for distinguishing between the diagram completed with and without listening to the binaural beats.

**Convergent thinking: Multiple word combination into a cohesive paragraph task.**

For this task, the subjects were given a set of random words, chosen by random from a list compiled by the authors. The objective of this experiment was to make the subjects wrote a cohesive paragraph, preferably in the form of a story, while using as many of the words as possible. The subjects were explicitly advised to provide the authors with the most comprehensive paragraph or story that could be generated by them. As the subjects were given the option of continuing with the same paragraph or story in the second segment of the experiment, some subjects choose to extend the story they had written in the first segment of the experiment. The purpose of this segment of the experiment was to have a task that focussed on the convergent thinking skills of the subjects, and the effect that the binaural beats had on their thought process. The subjects were evaluated on the basis of two criteria: the total number of words used in each of the scenarios and the ratio between the sum of the total number of words in between the given words and the total number of words.

**Divergent thinking: Thinking of associated words based on a given stimulus.**

For this task, the subjects were given a choice of words. The task assigned to them was to choose a word of their choice and then come up with a train of thought beginning with the chosen word. (For instance, lemon-yellow-sun-light-hot-food-chicken-grill-barbeque.) The instruction given to them was to come up with the maximum number of associations that they could. The purpose of this exercise was to test the divergent thinking abilities of the subjects and the changes that could be observed while the binaural rendition was on. The subjects were evaluated on the basis of the number of words that were included in the association in both the cases.

**Impact of auditory stimuli on thinking: Looking at an image for a specified time**

For this task, the subjects were asked to look at an image with the utmost focus, and while doing so, they also had to measure and mention the approximate value of the number of times they had blinked per minute. The purpose of this segment of the experiment was two fold. It is known that the blink rate of an induvidual drops when the activity being conducted takes up the focussed attention of the induvidual. The purpose of this segment was to draw observations between the change in blink rates without and with the presence of binaural beats and the ability of a subject to focus on the given task when a secondary task of measuring their blink rate was given to them. The subjects were evaluated on the basis of the blink rate values mentioned by them.

**Results**

For the second segment of the experiment, if we consider the values on the x and y axis to be the number of words used in both cases, respectively, the mean x and y values stand at 14.619 and 14.905, with a covariance of 17.3446, for a total of 21 cases. If we consider the values on the x and y axis to be the ratio between the sum of the total number of words in between the given words and the total number of words in both the cases, the mean values stand at 5.822 and 5.358 respectively, with a covariance of 5.1367 for a total of 21 subjects.

In the third segment of the experiment, if we consider the values on the x and y axis to be the total number of associations generated in both the cases, respectively, the mean x and y values stand at 10.429 and 10.619 respectively, with a covariance of 36.59, for a total number of 21 subjects.

For the fourth segment of the experiment, if we consider the values on the x and y axis to be the total number of eye blinks in both the cases, respectively, the mean x and y values stand at 11.905 and 9.905 respectively, with a covariance of 32.24, for a total of 21 subjects.

**Observations**

For the first segment of the experiment, the results were graded on three aspects: The total number of elements present in both the cases, a clear distinction between the various elements at play and the level of detailing. In almost all of the cases, it was found that the total number of elements present when the binaural beat was provided far exceeded the elements present when the audio file was not playing. In most of the cases, it was also observed that there was a clear distinction between the various elements present in the picture. In other words, in the first case, the formation of ideas was not very coherent and the subject did not have a clear mental picture of what to put on paper. In the second case, the subject showed a clear distinction between the various elements at play. The level of detailing was also something which showed a great level of difference. Around 60 to 70 percent of the subjects chose to draw the same image for the second time, but the attention to detail that was observed in the second case was far greater.

For the second segment, although the results present a picture that the difference between the mean values obtained between the various cases is not very different, analysis of individual case shows that individuals who showed an improvement in the number of words used had values that were significantly higher. The change, although not noticeable, is still apparent.

For the third segment, similar results were observed as with the second segment. The results present a picture that the difference between the mean values obtained between the various cases is not very different, analysis of individual case shows that individuals who showed an improvement in the number of associations made had values that were significantly higher. The change, although not noticeable, is still apparent.

For the fourth segment, there is a very noticeable change in the blink rates. Even when the brain was performing two tasks simultaneously (concentrating on the image at hand and keeping track of the number of times the subject had blinked), the change in the mean values is very apparent. The individual data values show an even higher difference in values between both the cases.

**Graphs**

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