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Sounds or Silence? Auditory Stimulus Effects on Fine Motor Skills[1]

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Unlike vision where we can select stimuli to either attend to or to avoid altogether, audition provides no such opportunity. Auditory stimuli, which permeate all aspects of life, can spur movement and set a pace for individuals performing tasks. If qualities of auditory stimulation were specifically controlled, task performance may be directly affected. The present study examined different controlled sound conditions during performance on a manual dexterity task (the game of Operation). It was found that, indeed, certain sound qualities do affect performance.

Introduction

There are many things that could potentially be a distraction to individuals. The area that is possibly the most detrimental to staying on task is the auditory system. Unlike your eyes which can exclude information by shutting or turning your head, the ear contains no physical ability to be so selective. Information is constantly stimulating your auditory system and entering your brain. If the amount of auditory stimulation needed to occupy active attention could be determined this information could be applied to environments in order to more precisely control the level of stimulation present. Ideally, doing such an adjustment would allow for the maximum performance on tasks.

Macken, Phelps and Jones (2009) explored factors causing auditory distraction. Task irrelevant sounds are stimuli such as clicking or tones that hold no significance to a task being performed. They concluded that task irrelevant sounds, specifically those of variable tones, caused the highest level of distraction among participants. They went on to infer that the volume of the irrelevant sound was not a contributing factor as much as the variability in the stimuli. They attributed this phenomenon to the brain's apparent obligatory response to direct attention to variable noise rather than consistent and repetitive sounds. The brain’s obligatory orienting response becomes significant when considering the level of concentration that is subconsciously applied to unintentional noise perception and comprehension.

The study by Macken et al. (2009) shows that an auditory stimulus can distract a subject from performing a memory task by occupying parts of working attention. Auditory stimuli, particularly music or rhythmic beat can also affect physical responses (Demos, Chaffin, Begosh, Daniels & Marsh, 2011; Madison, Gouyon, Ullén & Hörnström, 2011). Demos et al. (2011) explained the phenomenon of unidirectional movement, the subject independently making movements without being given specific direction, in sync with a presented audio and visual stimulus. The study demonstrated that auditory stimuli, not visual, were the primary determinates of movements of the individual when asked to dance. The ability of the subjects to conform to a beat was more quickly attained by hearing it than seeing someone else dance in sync with the beat.

While Demos et al. (2011) examined dancers' ability to dance to a presented stimulus, Madison et al. (2011) asked students with no musical background to listen to varying types of music from all over the world, and gauge how, and to what degree, it made them want to move to the beat as defined by the term *groove*. According to Madison et al. (2011) *groove* is defined as being composed of two primary components: a) The degree of repetitive rhythmical patterning around a comfortable movement rate (125-100 beats per minute or BPM) as was defined by van Noorden & Moelants (1999) and b) The density of sounds between beats generally. The subjects identified the amount of *groove*, which each sample of music evoked, consistently. This suggests a strong likelihood that the motivation for the movement can be found in one of the two primary components of *groove*. It also implies that these components, if isolated, could be manipulated to

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provide a strong effect on a subject's motor functioning.

Suied et al. (2008) examined the effects that a particular sound pattern had on reaction time. The important components of *groove* that Madison et al. (2011) discussed were evaluated in order to find the optimal tone length and rate for emergency alarms to evoke as quick a response as possible. Suied et al. used a test that required a subject to direct their attention to a task and then respond as quickly as possible when a particular series of tones was presented. The experimenters were evaluating the effectiveness of primary alert alarms found in everyday society such as fire detectors and alarms and collision sensors in cars. The length of the tone as well as the BPM were manipulated resulting in what they believed to be the best alert sound to elicit the fastest reaction time. These data were consistent with Macken et al's. (2011) findings that irregular tone use was most effective at capturing attention.

Optimal BPM for comfortable movement needed to elicit a unidirectional reaction (Demos et al., 2011; Madison et al., 2011), and the methodical task relevant stimuli for not providing an overt distraction (Macken et al., 2009) are both established in these studies as necessary parameters for an optimal testing scenario. Using these data, a testing procedure to evaluate the role that auditory stimuli plays on motor skills can be created.

An additional issue beyond the Suied et al. (2008) study is the possible contributing factor of emotional arousal to performance of motor tasks in the presence of auditory stimuli. Suied et al. (2008) only briefly discussed the influence of emotional arousal and attributes a small amount of their data to the aroused state of the subjects yet say that it did play a significant enough role that it influenced the data that were collected. The studies performed by Jones et al. (2006) and Riganello, Quintieri, Candelieri, Conforti and Dolce (2008) emphasize the influence of music on arousal and its effects on emotional arousal in greater detail. The Jones et al. (2006) study examined the effect of musical characteristics on emotional arousal and the correlation between self-reported arousal states and spatial performance. They did this by presenting the subjects with a piece of music by Mozart that the subjects described using positive adjectives such as happy and joyful while the other song, one by Philip Glass, was only described with negative adjectives such as sad or slow. The subjects who listened to the joyful music performed notably better than the group which listened to the sad and slow music. This demonstrates the influence of an emotional response on performing a motor task resulting from an auditory stimulus.

Further research into the effects of music on an individual are discussed in Riganello et al. (2008). Participants were asked to provide a self-report on their emotional states after listening to several different types of music. These musical selections were divided into groups containing two primary characteristics which separated them. These characteristics were a song’s formal complexity (its lack of predictability), and general dynamism (a selected piece’s volume, harmony, and rhythms). The participants’ self-report revealed that the higher the formal complexity the happier the song was perceived to be, while the higher the general dynamism the more aggressive the song was perceived to be. Applying the findings from Riganello et al. (2008) to those of Jones et al. (2006), a certain type of music which is up tempo and perceived as happy could be deconstructed to particular patterns and beats to promote spatial and motor task performance.

Music, as shown in Jones et al. (2006), can have a positive effect on motor performance when performing spatial tasks. Music can also exhibit positive effects on retention of information and sustained attention when presented as a primary component of a learning exercise (Wolfe & Noguchi, 2009). Wolfe and Noguchi presented music as a component of a lesson to kindergarten students, while other auditory stimuli were presented over the music as a distraction. The kindergarten students were asked to listen to a story and recall key components at the end of the story. Use of a song as a component of the story dramatically increased the sustained attention and retention of key story characteristics when compared to the other groups where music was not used. These data indicated that with the use of a sustained auditory stimulus such as a song from the beginning of a task, focus and ultimately performance of a task could be enhanced if the conditions of the optimal auditory stimulus previously discussed were met.

It should be noted that Jensen (1931) demonstrated that music can produce negative effects as well. Students performed a typing task under one of three possible conditions: silence, jazz music, or a funeral dirge. Performance was that jazz music, while demonstrating a slight, positive influence in speed, dramatically increased the amount of errors. The dirge resulted in markedly slower times with more errors than silence. This experiment contains pertinent data for the era and type of music used. However, due to the lack of experimental control, the results cannot provide conclusive evidence against the notion that an auditory stimulus that is manipulated in order to provide minimal distraction, with a high enough BPM and length of tones to promote unidirectional movement, could potentially enhance performance of a task.

The present hypothesis is that if a series of tones which meet the criteria of: (1) uniformity of tone in order to provide minimal distraction, (2) high enough BPM and length of tones to promote unidirectional movement and, (3) while also provoking a controlled and positive emotional response from that subject; then tasks which require motor skills could be performed more effectively.

Methods

Participants

In this study 30 college-aged students per condition were used, for a total of 90 subjects. Participants were recruited by the researcher by walking around the library and asking students if they would be willing to volunteer. Subjects in the present study were full time or part time enrolled at a small private university in western Pennsylvania.

Design

This experiment used a between subjects design where the independent variable, Auditory Simulation, contained three levels. These levels included a control group (silence), a group presented with an optimal regular-tempo stimulus (144 BPM), and a group presented with a random-tempo stimulus (144 BPM). The two dependent variables were the number of response errors made during the task and the time, in seconds, that it took subjects to fully complete the task.

Apparatus

The apparatus needed was a Hasbro™ *Operation* board game and an audio playing device capable of supporting the TempoPerfect Metronome software provided through nch.com. A set of headphones was used to block out extraneous auditory stimuli during the task. A standard digital stopwatch was used to time the subjects from start to finish.

Procedures

Each participant was randomly assigned to one of the three conditions. The experimenter explained to them that they would be performing a motor skills task while listening to a presented audio stimulus. The experimenter informed them that they were to only use the provided forceps (included in the board game) to remove all of the game pieces as quickly and accurately as possible.

Subjects were then instructed to place the provided headphones over their ears and place their hands palms down on the table in front of them and wait for the experimenter to reveal the game board before beginning the task. They were informed to return to this position upon completing the task.

The experimenter began the audio stimulus and allowed it to continue for three seconds prior to revealing the game board in order to allow the participants to acclimate to the tone. Timing began with the presentation of the game board and ended when the last game piece was removed and participants replaced their hands to the starting position. The experimenter recorded the amount of errors made (signaled by the buzzing sound generated by the game which occurred whenever the forceps came into direct contact with the game board).

Subjects were then thanked for their participation and asked if they had any questions. Following this, they were excused.

Results

A one-factor between subjects analysis of variance (ANOVA) was performed on completion times for each of the three sound conditions. An

ANOVA was also performed on number of errors by sound condition. The completion time ANOVA resulted in a significant main effect, $F(2,87) = 16.17$, $p < .01$. Also significant was the main effect for errors, $F(2,87) = 70.05$, $p < .01$. The means for completion times and errors across conditions are presented in Table 1.

Table 1. Means (and standard deviations) of completion times and errors for all sound conditions.

Sound Condition	Completion Times	Errors
Regular 144 BPM	135.4 (26.7)	11.7 (5.1)
Random 144 BPM	181.4 (26.0)	30.8 (5.1)
Silence	194.0 (62.5)	18.8 (8.2)

A comparison of means (Tukey HSD) revealed that the mean completion time for the regular 144 BPM condition differed significantly from both the random and silence conditions ($p < .01$) which did not differ from one another ($p > .05$). In terms of error scores, all conditions were found to differ significantly from one another ($p < .01$).

Discussion

The present hypothesis was based on the foundation criteria regarding a series of tones: (1) uniformity, to provide minimal distraction, (2) high enough BPM and length of tones to promote unidirectional movement and, (3) provoking a controlled and positive emotional response from a subject. Based on these criteria, it was predicted that tasks requiring motor skills would be performed most effectively. As conditions deviated from these criteria, performance was expected to suffer. The present research examined three conditions: Silence; Regular beats (144 BPM), and Irregular (random) beats of 144 BPM. The findings support the predictions.

As reported above, the regular tone not only positively affected performance in terms of errors but also in terms of completion times. Whereas a change of the same stimulus from regular to random resulted in relatively slower completion times as well as the greatest likelihood of error (nearly twice as many as the silent condition).

It is also important to establish that the results cannot be clearly attributed to a speed-accuracy tradeoff. Evidence for a speed accuracy tradeoff would require that the more quickly a person performed the more errors they would be prone to make. Or, literally, in order to achieve speed, subjects would have had to trade their accuracy. A tradeoff seems unlikely given that the fastest condition (regular 144 BPM) also resulted in the fewest errors. The condition with the greatest errors was the random condition which was not the fastest condition whatsoever. The proportion of errors observed for the silent and random conditions were significantly different, but completion times were not. Taken together, there does not seem to be any strong support for a speed accuracy tradeoff.

That the completion times were significantly faster in the regular than both the irregular and silent conditions illustrates the clear benefits of sound (at least those having specific qualities) to fine motor performance. The difference in time between the silence and irregular conditions was not significant which supports the present conclusion that it was indeed not the just sound, but a specific beat to that sound which benefits performance.

The present results indicate that a tone presented at 144 BPM can boost performance and shorten time needed to complete a given fine motor skills task. This supports the theory that there is some kind of optimal auditory stimulus that may be able to aid in performance. The next step will be to further explore the auditory stimulus options in an attempt to narrow down the parameters of what constitutes an optimal BPM and whether, or to what degree, other sound qualities (e.g., pitch, volume, complexity) may affect performance.

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