



Research article

Investigation of the effects of auditory and visual stimuli on attention

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ABSTRACT

Attentional resources limit our perceptual capacities. One vital point is whether these resources are allotted severally to every sense or shared between them. We addressed this problem via means of topics to carry out a dual-task, both in the same modality or other modalities (visual and auditory). The primary task is to count the number of passes of the participants while watching the video that requires visual and auditory attention. Concurrently, they were also asked to notice the pure tones and visual events in the song during the video while counting their pass numbers. The results show that while the auditory task reduced the detection ability visual events task, the dual-task had a significant effect. Previous studies support that tasks requiring simultaneous auditory and visual attention affect each other. Our results have clear implications for showing that performance decreases in dual-task as the perceptual load increases.

1. Introduction

In order to successfully interact with the stimuli in the environment, we need to process the information most relevant to our task selectively. This mechanism is usually termed “attention” (James, 1950). In daily life, people often complete multiple tasks at the same time without any problems. Several studies have shown that the amount of information people can handle is very limited (Marois and Ivanoff, 2005). In other words, with the help of the attention mechanism, people can only selectively pay attention to the limited information in the environment and ignore other information in the environment. When dual tasks are completed simultaneously, people often do not do one or two tasks well compared with performing one task. So attention has a capacity. The attentional Capacity Model states that attention is a finite resource and limits a person's capacity to perform a cognitive task (Kahneman, 1973). However, in many everyday and expert situations, people carry out multiple tasks successfully, such as driving while conversing, playing a piano piece accurately, and expressively (Cocchini et al., 2017).

When multiple perceptual challenges are carried out on equal time, standard overall performance decreases due to underlying processing limitations. This occurs even for simple tasks such as detect color or identifying the pitch of a tone (Huang et al., 2004; Pashler, 1992; Pashler & O'Brien, 1993). In many pieces of research in psychology and psychophysics, interference between simultaneous perceptual tasks that perceive the same sensory modality has been consistently reported (Wahn and König, 2017).

Spence et al. (2000), found that when moving lips video that simulates distracting noise is displayed simultaneously, it is far more challenging to select the sound word stream that appears simultaneously as the second sound stream (distracting). Recent studies consistently showed that the problematic task influenced auditory stimulus detection in the visual scene. There are fewer attentional resources available to detect a brief auditory stimulus than when engaged in a less demanding visual object-based attention task (Macdonald and Lavie, 2011). Hein et al. (2007) studies using functional magnetic resonance imaging (fMRI) have shown that even without a competitive motor response, simple auditory solutions can disrupt the nervous system's visual processing, including the prefrontal cortex, the medial temporal cortex, and other visual areas. In summary, these results mean that visual and auditory resource constraints act on the central processing level, not on the surrounding auditory and vision.

Most of the above studies involve dual-task conditions, both of which are brief stimuli that need to be identified or distinguished. Although this is a typical requirement for many daily activities (such as reading or driving), few people consider the conditions under which a specific pattern must be continuously followed within a few seconds to perform a task (Arrighi et al., 2011).

Multitasking is vital for human life, and the brain cannot perform well when the attention is split. This study seeks to understand dual-task-between auditory and visual attention-in the current people by utilizing video, pure tones, and a quantitative methodology in the form of a survey of selected people. By understanding how auditory and visual

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attention are affected by each other, we can try to solve problems radically. According to the hypothesis of this study, multitasking situations affect auditory and visual attention.

2. Materials and methods

2.1. Study group

Hundred and eighty females participated in this study. The members of this sample ranged in age from 17 to 24 years (Mage = 21.07 years, standard deviation [SD] = ± 1.35 years). All were divided into different groups randomized. The participants did not have any hearing loss and had a normal or corrected-to-normal vision. Before conducting the research, written informed consent was obtained from all participants. Participants who have hearing loss and who do not know and like 'Despacito song' were discarded. Written informed consent was obtained from all subjects who agreed to participate before entering the study. The tests were conducted at the Audiology Laboratory, Istanbul Medipol University. Ethical approval was obtained from Istanbul Medipol University Ethical Committee.

2.2. Stimuli

In order to investigate the result of the interaction of auditory and visual tasks, we used different experiments. For visual stimuli, "Monkey Business Illusion (MBI)" was chosen. MBI was a video recording designed by Simons (2010). In this video, some events occur in the background while few girls throw a ball at each other. The participants were asked to count how many passes the ball each other in white t-shirts. When the girls play with a ball, a gorilla walking on the stage (Figures 1a and 1b), one girl in black t-shirts left the stage (Figures 1c and 1d), and the curtain color was changed (Figures 1c and 1d). We introduced five pure tone stimuli in different parts of Luis Fonsi's "Despacito" song for auditory attention. The reason for this song selection was that it is one of the most listened songs on YouTube. Acoustically mixed frequencies to the song were in octave frequencies of pure tones in between 500-6000 Hz. 500-1000-2000-4000-6000 Hz frequencies were selected because speech frequencies in daily life are comprised in between these frequencies. Also, the noise rate in the song we used in the video was measured with the sound level meter (SLM) device, and the ratio between the signal and noise (S/N) was determined as an average of 10–12 dBA for each frequency (75–90 dBA). We performed these song-edited adjustments using TechSmith Camtasia 8.

2.3. Procedure

Initially, all participants were tested for pure tone thresholds (0.5–6.0 kHz). All the participants received verbal instructions for performing the research. The research was conducted in a lighted-up room. The distance between each subject and the computer screen was set at 65 cm.

Participants were given different stimuli.

- While fifty-two participants watched MBI, a modified "Despacito" song with pure sound was played. Fifty-two participants requested to count the number of passing the ball to each other wearing white t-shirts in MBI as a visual task. Participants were also required to press the stopwatch whenever they detect the pure tones in the song as an auditory task. Since all pure sounds in the song are known, it was determined by the stopwatch whether the people heard the pure tone.
- Only forty-one participants listened to a modified "Despacito" mixed with pure tones. These participants were required to do the same auditory task.
- Forty-two participants watched only MBI. These participants were requested to do the same visual task.
- While forty-eight participants were shown MBI, only the "Despacito" song was played. Forty-eight were requested to do the same visual task, but they also listened to the "Despacito" song.

After the test, we also asked all participants to all variables in the video (Table 1). Each experiment was conducted over approximately 5 min.

In this study, three different paradigms were used in this research (Figure 2).

1. For the first research, music without pure tone stimuli was listened to, and a group watched the video. The other group watched only the video. (90 participants)
2. For the second research, the full stimulated group was watched the MBI and listened to pure tone stimuli inside the music, while the other group was watched the MBI and listened to music without pure tone stimuli. (100 participants)
3. For the third research, the full stimulated group has watched a video and listened to pure tone stimuli in the music, while the other group has listened only to pure tone stimuli in the music. This group has not watched a video. (93 participants)

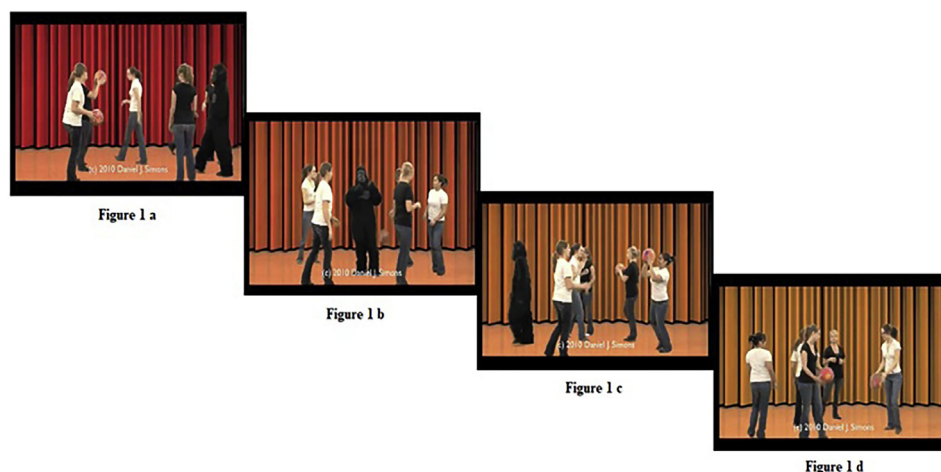


Figure 1. Photos from Monkey Business Illusion(MBI) video.

Table 1. Survey.

How many passes the ball you count during the test?		Have you heard the song “Despacito” before?		Do you like the song “Despacito”?		Did you notice a gorilla walking behind during the test?		Did you notice the curtain's color change during the test?		Did you notice during test that one of the girls wearing a black t-shirt leaves the stage?	
Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No

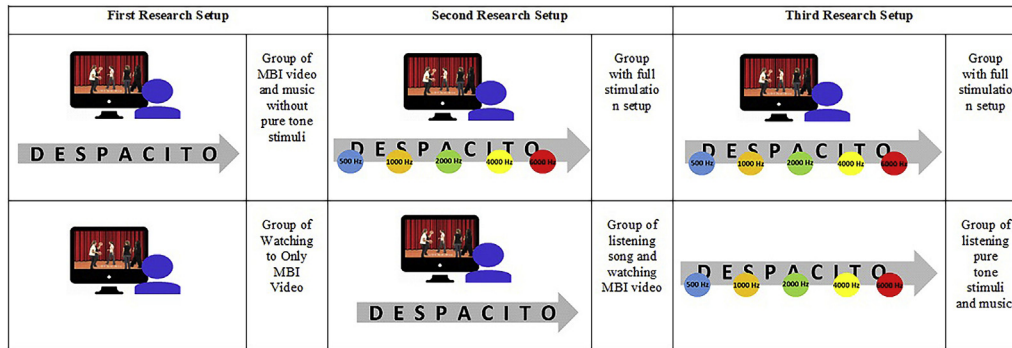


Figure 2. Schematic versions of researches setup.

2.4. Analysis

Statistical Package for the Social Sciences (SPSS, Version 26, IBM Corporation, Armonk, NY) was used for data analyses. One-sample Kolmogorov-Smirnov tested the normality of data. Descriptive statistics (percentages, means, and standard deviations) were calculated for all variables. The significance level was set up at $p \leq 0.05$. Respectively, non-parametric variables were compared using Mann Whitney U and Chi-square as appropriate. Mann-Whitney U test was used to test whether the number of balls obtained from comparisons differs significantly. In examining the relationship between the two categorical variables, the Chi-Square test was used, and the results are given in tables.

3. Results

3.1. First research

Participants who watched the video and listened to music without pure tone stimuli were compared with those who watched the only video. As indicated in Table 2, there was no statistically significant difference in noticing the gorilla, the curtain color, and the girl leaving the stage ($p > 0.05$).

No statistically significant difference was observed in comparing the number of balls made between the group in which there were no pure tone stimuli and the Group of only video presentation ($p = 0.799$) (Table 3).

3.2. Second research

As shown in Table 4, in comparing the group with no pure tone stimuli, while watching the video with the Group with full stimulation setup, there was no statistically significant difference regarding noticing the gorilla passed, the curtain color changed, and the girl left the stage ($p > 0.05$).

A statistically significant difference was observed in the comparison of the number of balls between the full stimulated group and with Group stimuli the group without pure tone stimuli ($p < 0.05$) (Table 5).

3.3. Third research

As shown in Table 6, a statistically significant difference was observed in detecting 4000 Hz compared to the full stimulated group and the group with only non-video pure tone stimuli ($p = 0.025$). No statistically significant difference was observed in detecting pure tone stimuli at 500 Hz, 1000 Hz, 2000 Hz, and 6000 Hz ($p > 0.05$).

4. Discussion

Simultaneous multitasking in both experimental and everyday tasks is to divide and distribute sources of attention effectively. It is important to note that the only tasks we performed consist of multiple components or processes and include switching or resisting brain regions (Rothbart and

Table 2. Comparison of the group without pure tone stimuli and the group with only video group stimuli.

			Test type		p
			Video + Music (48) n (%)	Only video (42) n (%)	
Gorilla getting on a stage	Yes	%	24 (50.0%)	26 (61.9%)	.257
	No	%	24 (50.0%)	16 (38.1%)	
The change of the curtain color	Yes	%	11 (22.9%)	8 (19.0%)	.654
	No	%	37 (77.1%)	34 (81.0%)	
Girl leaving the stage	Yes	%	15 (31.2%)	15 (35.7%)	.654
	No	%	33 (68.8%)	27 (64.3%)	

Table 3. Number of detected balls comparison of the group without pure tone stimuli and the group with the only video.

	Detected Number of Balls Mean ± SD	p
Video + Music	15.63 ± 1.003	0.799
Video only	15.57 ± 1.016	

Table 4. Comparison of the full stimulated group and the group without pure tone stimuli.

			Test type		p
			Video + Music + Pure tone stimuli (52) n (%)	Video + Music (48) n (%)	
Gorilla getting on a stage	Yes	%	21 (40.4%)	24 (50.0%)	.334
	No	%	31 (59.6%)	24 (50.0%)	
The change of the curtain color	Yes	%	10 (19.2%)	11 (22.9%)	.651
	No	%	42 (80.8%)	37 (77.1%)	
Girl leaving the stage	Yes	%	17 (32.7%)	15 (31.2%)	.877
	No	%	35 (67.3%)	33 (68.8%)	

Table 5. Comparison of the full stimulated groups with the number of detected balls without pure tone stimuli.

	Number of Balls Mean ± SS	p
Video + Music + Pure tone stimuli	13.02 ± 3.208	0.000*
Video + Music	15.63 ± 1.003	

Posner, 2015). However, in a world abundant with sensory information, it is impossible to perceive everything around us at any time. Therefore, selective attention is an essential mechanism because it allows us to focus on relevant information and give low priority to irrelevant, potentially distracting information (Awh et al., 2012; Chun et al., 2011; Dalton and Hughes, 2014).

This study has ensured that visual and auditory attention sources work simultaneously while performing dual tasks, particularly relevant for everyday functioning. Since the perceptual load will increase in dual-task conditions, it may decrease performance. The reason is that when two tasks rely on shared attention resources, compared to executing each task individually, performing both tasks at the same time will cause performance degradation. Our results confirm that performance decreases when tasks that require both visual and auditory attention are synchronized.

The first research in our study looked at the effect of music on the visual task. While counting the number of passing balls by women wearing white T-shirts as a visual task, it was also checked whether the participants could follow the events in the background. One group only played this process while the other group also listen to music at the same

time. Accordingly, among the situations that require visual attention; there was no statistically significant difference concerning the number of gorilla getting on a stage ($p = 0.257$), curtain color change ($p = 0.654$), girl leaving the stage ($p = 0.654$), and passing the ball ($p = 0.799$) (Table 2 and Table 3). All of the participants enjoyed the song given, but this did not affect attention. It has been shown that listening to the auditory stimuli containing grammatical information such as music with

everyday words in the literature has shown that it may reduce *inattentional blindness* (Beanland et al., 2011; Peretz and Coltheart, 2003). In another study, it was suggested that music increases the human emotional state and therefore increases the subject's attention (Olivers and Nieuwenhuis, 2005). In our study, we preferred music with a high level of awareness. Because we wanted to observe that listening to music before would give an emotional reminder in the limbic system, although the music has a positive emotional effect, attention may not be disturbed because the cognitive load increases due to the verbal music input.

Music is a complex human skill that involves and integrates various cognitive resources in the processing period (Medina and Barraza, 2019). Musical training is related to changes in the auditory cortex and the subtle difference in pitch between two notes (Bermudez et al., 2009; Gaser & Schlaug, 2003; Schneider et al., 2002; Tervaniemi et al., 2005). Musical training can improve the understanding of some subtle features of musical auditory stimuli and simultaneously affect other complex auditory stimuli (Medina and Barraza, 2019). The fact that the people who participated in our study did not have professional musical training may negatively affect terms of noticing the pure tones.

In our second research, the effect of the additional auditory task on visual perception was examined. While the same video was given as a visual task, participants were asked to notice the pure tone sounds mixed with the music as an auditory task. Both participants listen to music with no pure tones and listen to music with pure tones; they both noticed the events in the background in the video in a statistically similar way. However, as indicated in Table 5 the group without the auditory discrimination task in the passed ball counting process found results close to the actual pass ball count (16) (mean = 15.63 ± 1.003) and found to be

Table 6. Comparison of the full stimulated group and the group without video.

			Test type		p
			Video + Music + Pure tone stimuli (52) n (%)	Music + Pure tone stimuli (41) n (%)	
500 Hz	Yes	%	37 (71.2%)	36 (87.8%)	.052
	No	%	15 (28.8%)	5 (12.2%)	
1000 Hz	Yes	%	15 (28.8%)	15 (36.6%)	.428
	No	%	37 (71.2%)	26 (63.4%)	
2000 Hz	Yes	%	36 (69.2%)	32 (78.0%)	.341
	No	%	16 (30.8%)	9 (22.0%)	
4000 Hz	Yes	%	46 (88.5%)	41 (100.0%)	.025*
	No	%	6 (11.5%)	0 (0.0%)	
6000 Hz	Yes	%	8 (15.4%)	11 (26.8%)	.174
	No	%	44 (84.6%)	30 (73.2%)	

significantly different from the group which the auditory discrimination task (mean = 13.02 ± 3.208) ($p = 0.000$). The results of this research may derive from increased perceptual load in multiple tasks. If the perceptual load is high and all current attention capacity is allocated only to a single task, there may be no more resources to process any additional stimuli. As a result, task-related extraneous auditory stimuli can affect performance at the primary task in low-load search, but not in the case of high load search (Tellinghuisen et al., 2016).

As attentive resources are limited, the stimuli demanding extra attention for a perceptual task exceed system capacity. For example, in a visual search task where an object (target) must be found in an unrelated element (interference), the response time directly increases with the number of interferences (Arrighi et al., 2011). This correlation reflects the limited ability of selective attention, which prevents the viewer from controlling all elements simultaneously (Arrighi et al., 2011). Our study supports this issue. The primary aim of this study was to investigate the effectiveness of auditory input on decreasing visual attention performance, as determined by accuracy in a dual-task (visual-auditory) scenario. We hypothesize that auditory and visual attention affect each other. Overall, the findings provided partial support for our hypotheses. In a study by Arrighi et al. (2011), participants performed multiple object tracking tasks and visual or auditory discrimination tasks in dual-task design. They found that the multiple object tracking task selectively disrupted the visual discrimination task without affecting the auditory discrimination performance.

Finally, the effect of visual tasks on auditory attention was examined. Here, an additional MBI video was given to this task of discerning pure tones in music. In general, while the participants heard the pure tones of 500 Hz, 2000 Hz, and 4000 Hz better in both groups, they were less successful in detecting 1000 Hz and 6000 Hz tones. At the same time, one of the reasons why the participants failed to detect 1000 Hz and 6000 Hz was thought to be due to the frequency spectrum of the song being chosen. Participants detected pure tones more when there was no visual task, but the difference was statistically significant only at 4000 Hz ($p = 0.025^*$) (Table 6). This increase had shown that when visual attention was demanding besides auditory attention, the perceptual load will be negatively affected. The difference at 4000 Hz may be that this region of the cochlea is more sensitive. While the human cochlea is less sensitive to low frequencies, it is thought to be better heard due to its maximum sensitivity at 3–4 kHz (Behrman, 2017; Fastl et al., 2007; Gopal, 1986).

Macdonald and Lavie hypothesized that people who are engaged with visually demanding object attention tasks have fewer attention resources available to recognize short auditory stimuli than people who are engaged with visually less demanding attention tasks. According to performing less visually challenging tasks, they found that participants detected significantly less auditory stimuli when performing visually challenging tasks, indicating that attention resources were allocated between sensory modalities (Macdonald and Lavie, 2011). In another study, in several experiments, it has been consistently shown that the recognition of auditory stimuli is affected by the difficulty of the visual search task (Raveh and Lavie, 2015). Our findings in the second and third research confirm the findings of these studies in terms of attention modalities.

On the other hand, according to Wahn and König (2017), if attentional resources are distinct, performing two tasks at the same time will not cause performance degradation compared to performing two tasks separately. Significantly, these two tasks are performed in the same sensory modality or separate sensory modalities. We used separate modalities such as visual and auditory sensory modalities in this study. Allocating attention resources to low difficulty enables free attention resources to be allocated to another task that can be performed simultaneously. However, performing complex tasks have exhausted attentional resources, and it is not allowed to reallocate attention resources to another complex task (Wahn and König, 2017). In this study, participants were asked to perform complex tasks simultaneously, such as counting

the number of balls and noticing pure tones while watching a video. This situation may have prevented the fulfillment of every task.

Our results are significant in showing how attention affects performance in dual tasks. Increased perceptual load in dual tasks made it difficult to sustain attention. These results can provide important information about daily life. For example, our results confirm that people are less likely to notice auditory stimuli when performing tasks with high visual exposure. It is a skill that can occur over time for athletes to perform their responsibilities without being affected by the atmosphere in sports competitions. The test paradigm we used can be applied for training purposes in situations or professions that require multiple attention tasks. It can also be used for rehabilitation in children with hearing loss and attention distorts.

Declarations

Author contribution statement

Kerem Ersin and Oğulcan Gündoğdu: Conceived and designed the experiments; Performed the experiments; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Sultan Nur Kaya: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Dilşad Aykırı: Performed the experiments; Wrote the paper.

Mustafa Bülent Şerbetçioğlu: Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Data availability statement

The data that has been used is confidential.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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