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GREATER EFFECT OF AUDITORY STIMULI THAN VISUAL STIMULI ON ANTICIPATORY POSTURAL ADJUSTMENTS INCREASE

ORIGINAL ARTICLE

ABSTRACT

Purpose: The role of visual stimuli as the primary stimulus and the effect of auditory stimulus before external perturbation on Anticipatory Postural Adjustments (APAs) releases has been investigated, but which type of stimulus (auditory or visual) before perturbation has a more significant effect on initial APAs release, needs to be investigated. So, this study aimed to investigate the role of visual-auditory contributions before external perturbation on APAs and the effect of stimulus presentation on the release of APAs at different time intervals.

Methods: Participants in this study were fourteen physical education students (Meanage 22.4 ± 2.14 years) exposed to five trials of visual stimulus and five trials of an audible stimulus (80 dB) while standing on the Biodex balance sheet. Then, 1.4 seconds after presenting the stimulus, external perturbation was applied. Electromyography (EMG) activity of the postural muscles was recorded during all trials. APAs were extracted at intervals of -100 to 50 ms (APA1), 50 to 200 ms (APA2), and 200 to 350 ms (APA3). The mixed ANOVA and repeated measures analysis of variance with Bonferroni correction test were used for data analysis.

Results: The results showed that the presentation of visual and auditory stimuli increased the APAs of the postural muscles. According to these results, APA3 was greater than APA2 and APA2 than APA1($P \leq 0.05$). Also, the results showed that auditory stimulus increased the APAs of the postural muscles more than the visual stimulus ($P \leq 0.05$).

Conclusion: Generally, the researchers concluded that providing an auditory stimulus before perturbation has a greater effect on APA than a visual stimulus in healthy young girls. Therefore, it is suggested that in order to prevent imbalance or maintain greater balance, auditory stimuli with appropriate intensity can be used. Furthermore, subsequent research on this topic could include comparing APA release under the influence of visual and auditory stimuli in men and women, athletes and non-athletes, and healthy individuals with individuals with mobility impairments.

Keywords: Anticipatory Postural Adjustment, Auditory Stimulus, Electromyography, Muscles, Postural Balance

ANTİSİPATUAR POSTÜRAL DÜZENLEME ARTIŞINDA İŞİTSEL UYARANLARIN GÖRSEL UYARANLARDAN DAHA BÜYÜK ETKİSİ

ARAŞTIRMA MAKALESİ

ÖZ

Amaç: Eksternal perturbasyonlar öncesinde primer uyaran olarak verilen görsel uyarıların ve de işitsel uyarıların Beklenen Postural Düzeltmelerdeki (BPD) salınımlar üzerine etkisi araştırılmış olmakla birlikte hangi tür uyarının (işitsel veya görsel) perturbasyon öncesindeki başlangıç BPD salınımları üzerine etkisinin daha belirgin olduğunun incelenmesi gereklidir. Bu nedenle, bu araştırmada BPD'lerde dış perturbasyon öncesi görsel-işitsel katkıların rolünün ve farklı zaman aralıklarındaki uyaran sunununun BPD salınımlarına etkisinin tespit edilmesi amaçlanmıştır.

Yöntem: Bu çalışmanın katılımcıları, Biodex denge zemini üzerinde ayakta dururken beş görsel ve beş işitsel uyaran denemesine (80 dB) maruz bırakılan 14 beden eğitimi öğrencisi idi (ortalama 22,4±2,14 yaş). Uyaran verildikten 1,4 saniye sonra eksternal perturbasyon uygulandı. Tüm uyaran denemeleri sırasında postural kasların elektromyografi (EMG) aktivitesi kaydedildi. BPD'ler -100 ila 50 ms (BPD1), 50 ila 200 ms (BPD2) ve 200 ila 350 ms (BPD3) aralıklarında çıkarılmıştır. Veri analizinde kombine varyans analizi ve tekrarlı ölçümlerde varyans analizi Bonferroni düzeltme testiyle kullanılmıştır.

Sonuçlar: Sonuçlar, görsel ve işitsel uyaranların postural kasların BPD arttırdığını göstermiştir. Bu sonuçlara göre BPD3, BPD2'den ve BPD2, BPD1'den daha büyüktür ($P \leq 0.05$). Ayrıca sonuçlar, işitsel uyaranın görsel uyarana göre postural kasların BPD'lerini daha fazla arttırdığını göstermiştir ($P \leq 0.05$).

Tartışma: Genel olarak araştırmacılar, sağlıklı genç kızlarda perturbasyondan önce işitsel uyaran sağlamanın görsel bir uyarana göre daha büyük bir etkiye sahip olduğu sonucuna varmışlardır. Bu nedenle dengesizliği önlemek veya dengeyi daha fazla korumak için uygun yoğunlukta işitsel uyaranların kullanılması önerilmektedir. Ayrıca, bu konuyla ilgili sonraki araştırmalarda, görsel ve işitsel uyaranların etkisi altındaki BPD salınımı erkek ve kadınlar, sporcu ve sporcu olmayanlar, sağlıklı ve hareket bozukluğu olan bireyler arasında karşılaştırılarak incelenebilir.

Anahtar Kelimeler: Beklenen Postural Düzeltmeler, İşitsel Uyaranlar, Elektromiyografi, Kaslar, Postural Denge.

INTRODUCTION

To maintain the stability of the postural in leg and trunk muscles, the CNS uses two main mechanisms: Compensatory Postural Adjustments (CPAs) and Anticipatory Postural Adjustments (APAs) (1). APAs are an essential mechanism for maintaining the balance that ensures adequate readiness to prevent the occurrence of the disorder before work or dealing with the external environment (2). APAs arise when the perturbation is predictable and controlled by feedforward mechanisms (3). The feedforward mechanisms can be classified into early postural adjustment (EPA) or anticipatory. EPA can be perceived much prior to classical APA, and its goal is to "confirm sufficient mechanical situations" for imminent action. Although EPA and APA are different in quantity and quality in most studies, they are heeded to be one mechanism and are addressed as APA (4).

Previous studies have shown that muscle activation for APAs is related to the primary motor cortex, supplementary motor areas, basal ganglia, and spinal cord (5). Many factors such as the type of perturbation created, the person's level, the static and dynamic conditions, virtual reality, dual cognitive tasks, and attention affect APAs (6-8). On the other hand, research has shown that stimulus-driven attention modulates the onset of APA (2, 6). Furthermore, modulating the activity of sensory areas before presenting the primary stimulus leads to facilitating and inhibiting the processing of sensory information from the sensory stimulus in the presence and absence of attention (6).

The results of previous studies showed that directing attention to the auditory stimulus that was presented 1.4s before the primary visual signal resulted in changes in the release of APAs and their modulation (9). In another study, it was demonstrated that when step initiation is elicited by a "go" sign (for example, in a reaction time task), the presentation of an unpredictable, intense stimulus at the same time or just before the imperative signal was present could trigger early phases of APAs (10).

Also, the effect of differing intensities of auditory stimuli on the release of APAs varied, and higher intensity stimuli led to the production of larger APAs. The initial release of APAs by low or severe stimuli indicates the involvement of different mechanisms in APA initiation (11). It is unclear whether the releasing APAs depends on the attention given to the stimulus or on the stimulus characteristics such as stimulus intensity or type of stimulus presented (9). About comparing the effects of visual and auditory stimuli and their effects on body balance control during a reaction time task, studies have shown that as the complexity of the equilibrium task is greater, the presentation of auditory stimuli than the visual stimulus lead to more interference with the reaction time task. These results suggest that different attentional processes influence the sensory and motor elements of posture control (12).

As observed in previous research the type of stimulus presented is often related to the study of the stimulus auditory and its effect on the initial release of APAs before or at the same time as the main stimulus or external disturbance ('go' command for the subjects). No research, was found on the effect of visual stimuli on the release of primary APAs. It is also unclear whether the timing of stimulus delivery before external perturbation has a different effect on APA emissions. Therefore, the first hypothesis was that auditory and visual stimuli before external perturbation had different effects on the initial release of APAs. Also, the second hypothesis was that auditory and visual stimuli before external perturbation has different effects on APAs at different time intervals.

METHODS

Participants

Fourteen (13) female students of the University of Tehran (22.4±2.14 years) were selected based on inclusion criteria. They participated in the study through a call-up to the physical education and sport sciences faculty. The previous literature about the gender balance differences, examined and since that APA effect on balance, this subject considered (14, 15). The sample size calculated (n=14 people) with G-power software for repeated measure statistical method and considering with 80% power, effect size: 0.4, and α= 0.05.

Participants completed the informed consent form.

This research has been approved by the Department of Learning and Motor Control (local committee) in the form of meeting 27 and is on March 11, 2017. It has been done from December 2018 until the end of January 2019.

Inclusion criteria were that the participants were healthy and had no vision problems, no orthopedic injury, fracture, surgery history and no movement problems. They were in the age range of 22 to 25 years. The criterion for leaving the research was an unwillingness to continue cooperation or creating any inability to perform the test.

The test was performed in a laboratory setting. Other instruments and objects that might have affected the presentation of the visual stimulus were moved to another point in the laboratory, and additional auditory stimuli were controlled by performing a single test without the presence of additional individuals.

Instrument

Biodex Balance System

Biodex Balance System (BBS) (Biodex Medical Systems, Shirley, NY, USA, Model: SW45-30D-E617) is used to evaluate the balance. The person stands on a firm and stable platform, and then, the individual's response to an imbalance in the anterior-posterior and internal-external directions is measured (16). In the present study, the BBS was used to cause external perturbation.

Electromyography Apparatus

The 16-channel surface Electromyography (EMG) apparatus ME 6000 (Mega Electronics Ltd., Kuopio, Finland) was used. The electromyography data were recorded at frequencies of 2000 Hz. It is noteworthy that, in the present study, the band-pass filter with a cut-off frequency of 10 to 500 Hz is used to reject the out-of-band noise.

Software designed by the researcher for providing audio-visual stimuli

The researcher designed this software, which was installed on the laptop (Taban visual-auditory stimulus device, Tehran, Iran). Examiner after entering the desired time of and performance after the chosen time, presented the auditory or visual stimulus (the type of stimulus, its intensity, or the color of the stimulus) through the screen or laptop speakers. Visual stimuli were presented using a horizontal plate of red LED light located 1 m away from the subject's eye, and a speaker provided an 80 dB acoustic stimulus at the same distance (17).

Protocol

The electromyography with electrode installation was used to record the electrical activity of the selected postural muscles containing thighs such as rectus femoris (RF), tibialis anterior (TA), gastrocnemius (GA), vastus intermedius (VI), biceps femoris (BF), and erector spinae (ES). It is noteworthy that these lower limb muscles most frequently have postural stability (18-21). The electrodes were disposable, and their conductivity center diameter was one centimeter. The electrode method was bipolar, and both electrodes' center distance was 20 mm. The European project surface EMG for non-invasive assessment of muscles (SENIAM) was followed to determine the location of electrodes on selected muscles (22).

After installing the electrodes, the subject stood on the BBS without the shoe while his hands were next to his body. Visual (red LED light) or auditory stimuli (80 dB) appeared. In general, 10 trials, including audio stimulus, 5 trials, and 5 with visual stimulus inserted. The order of providing visual and auditory stimuli in the form of counterbalance was considered. It means that the presentation of visual and auditory stimuli was random so that the participants did not know whether the next stimulus was presented visually or auditory. Then, to exert external perturbation, the subject was placed in a state of instability and imbalance by moving the foot platform (platform mode at level 1 was located) (23) 1.4 seconds after the providing stimulus. EMG recording was performed at a frequency of 2000 during all trials.

The APA Calculation

APAs were calculated according to the previous study (1):

The stimulus presentation time was specified as the reference time (T0) on the EMG data. This value was approved by visual scrutiny by an experienced researcher. Data based on T0, in the range from -600 ms (before T0) to +1000 ms (after T0), were selected for analysis.

The integrals of the muscles' EMG activities (IntEMGi) were calculated over four intervals, each lasting 150 ms. Time windows for 4 epochs based on the study of Kankar and Aruin (24) were Include: a) from -250 ms to -100 ms (APA1), b)-100 ms to + 50 ms (APA2), c) + 50 ms to + 200 ms (compensatory reactions, CPA1) and + d) 200 ms to + 350 ms (CPA2). But given that in this study, external perturbation was 1.4 seconds after stimulus presentation. Therefore, time windows for 3 epochs containing: a) from -100 ms to + 50 ms (APA1), b) + 50 ms to + 200 ms (APA2), and c) + 200 ms to + 350 ms (APA3) were considered.

The IntEMGi of each of these three epochs was modified based on the IntEMGi of baseline activity from -600 ms to-450 ms for T0 as follows:

Formula 1 (25)

$$Int_{EMG_i} = \int_{tw_i} EMG - \int_{-600}^{-450} EMG$$

That IntEMGi is equal to the integral of the EMG activity of each muscle at time intervals from 150 ms (twi, i = 1)

And

$$\int_{-600}^{-450} EMG$$ **(25)**

150 ms of baseline muscle activity that is defined as the integral of EMG activity in the interval of -600 to -400 ms relative to T0. The peak of muscle activity then normalizes the EMG activity integral calculated from formula 1 according to formula 2.

Formula 2 (25)

$$IEMG_{NORM} = \frac{Int_{EMG_i}}{IEMG_{\max}}$$

Statistical Analysis

Shapiro-Wilk test was used to assess the normality of the distribution of the scores, and Levene's test was used for equality variances. 6 (muscles) × 2 (stimulus) mixed ANOVA was used to compare different stimuli at different APA time intervals separately. Also, 6 (muscles) × 2 (stimulus) mixed ANOVA was used for the effect of each stimulus (visual-auditory) on different APAs. Post hoc tests ($P \leq 0.05$) were conducted using the Bonferroni correction test. First, EMG data analysis was performed with MATLAB13a software. It should be noted that all of these analyzes were performed with IBM SPSS 21 software.

RESULTS

The information of 14 participants is shown in Table 1.

Table 1. The Information of Participants

	Mean	Standard Deviation
Age (years)	22.4	2.14
Height (cm)	165.3	5.8
Weight (kg)	60.8	6.3

Descriptive information on APA of postural muscles at different time intervals under the influence of visual and auditory stimuli is shown in Table 2. The Effect of Visual Stimuli on APA

The mixed analysis of variance showed that the main effect of the muscles (F (5, 78) = 64.214, P =3×10−2, n2p= 0.805) was significant. Post hoc analysis using Bonferroni correction showed the level of activity of RF (0.377), VI (0.340), BF (0.224), GA (0.24), and TA (0.187) had the highest. Furthermore, ER (0.121) had the lowest activity.

Also, the main effect of time (F (2.156) = 352.963, P =1×10−5, n2p= 0.819) and interaction time * group (F (10, 156) = 14/169, P =1×10−1, n2p= 0.476) were significant. Bonferroni correction for main effect of time showed that the APA3 (0.377 ± 0.008) was greater than APA2 (0.251 ± 0.008; P =41×10−2) and APA1 (0.126 ± 0.006; P =4×10−3) after visual stimulus presentation. Also, the APA2 was significantly greater than the APA1 after the visual stimulus presentation (P =1×10−2). Thus, the effect of visual stimulus presentation on APA released at different intervals and the difference in APA release at different intervals due to visual stimulus presentation in a balance task was significant.

Table 2. APA's descriptive information at different time intervals under visual and auditory stimulus conditions.

Stimulus	Muscle	APA 1 (- 100 to +50 ms)	APA 2 + (50 to 200 ms)	APA 3 + (200 to 350 ms)
		Mean ± SD		
Visual	RF	0.02 ± 0.04	0.24 ± 0.06	0.45 ± 0.06
	TA	0.04 ± 0.06	0.19 ± 0.05	0.32 ± 0.07
	GA	0.28 ± 0.05	0.34 ± 0.07	0.50 ± 0.07
	VI	0.22 ± 0.05	0.31 ± 0.08	0.47 ± 0.06
	BF	0.11 ± 0.05	0.32 ± 0.09	0.30 ± 0.10
	ES	0.07 ± 0.02	0.09 ± 0.04	0.19 ± 0.02
Auditory	RF	0.24 ± 0.06	0.50 ± 0.1	0.57 ± 0.07
	TA	0.19 ± 0.05	0.32 ± 0.06	0.44 ± 0.06
	GA	0.34 ± 0.07	0.47 ± 0.11	0.54 ± 0.07
	VI	0.31 ± 0.08	0.41 ± 0.07	0.52 ± 0.05
	BF	0.32 ± 0.09	0.33 ± 0.09	0.40 ± 0.09
	ES	0.06 ± 0.03	0.21 ± 0.03	0.29 ± 0.06

RF "rectus femoris", TA "tibialis anterior", GA "gastrocnemius", VI "vastus intermedius", BF "biceps femoris" and ES "erector spinae"

The Effect of Auditory Stimuli on APA

The mixed analysis of variance showed that the main effect of the group (F (5, 78) = 43.092, P =4×10−2, n2p= 0.734) was significant. Bonferroni correction test showed RF (0.33), VI (26.26), BF (0.22), GA (0.15), and TA (0.14) muscles had the highest level of activities. However, ES muscle (0.1) had the lowest activity.

Also, the main effect of time (F (2, 156) = 219.869, P =4×10−4, n2p= 0.738) was significant, meaning that the postural muscles' APA was significantly different at different time intervals. The Bonferroni correction showed that APA3 (0.466 ± 0.008) was greater than APA2 (0.378 ± 0.01; P =8×10−1) and APA1 (0.220 ± 0.007; P =1×10−3) after presentation of auditory stimuli. Also, the APA2 was significantly higher than the APA1 (P =3×10−2). Thus, the effect of auditory stimulus presentation on APA release at different intervals and the difference in APA release at different intervals was due to the presentation of an auditory stimulus in a balance task.

Comparison of Visual and Auditory Stimuli in APA1 of Different Postural Muscles

The mixed analysis of variance showed that the main effect of the muscles (F (5, 78) = 56.181, P =1×10−2, n2p= 0.783) was significant. The level of activity of GA (0.307), VI (0.245), ES (0.17), BF (0.122), and TA (0.092) had the highest. However, RF (0.063) had the lowest activity.

Furthermore, the main effect of stimuli (F (1, 78) = 202.257, P =2×10−2, n2p= 0.722) was significant. There was a significant difference between APA1 of postural muscles induced to visual and auditory stimuli. Bonferroni correction showed (Figure 1) that the APA1 of the postural muscles after the presentation of visual stimulus (0.126 ± 0.006) was significantly less than the auditory stimulus (0.204 ± 0.007).

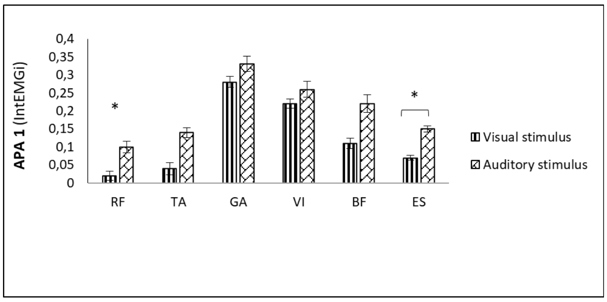

Figure 1. Comparison of visual and auditory stimuli in APA1 of different postural muscles. RF: Rectus Femoris, TA: Tibialis Anterior, GA: Gastrocnemius, VI: Vastus Intermedius, BF: Biceps Femoris, and ES: Erector Spinae. *P<0.05

Comparison of Visual and Auditory Stimuli in APA2 of Different Postural Muscles

The mixed analysis of variance showed that the main effect of the groups was significant (F (5, 78) = 28.134, P =3×10−1, n2P= 0.643). The level of activity of GA (0.409), RF (0.377), VI (0.366), BF (0.325), and TA (0.264), muscles had the highest. Nevertheless, ES (0.155), had the lowest activity.

Also, the main effect of stimuli (F (1, 78) = 150.519, P =6×10−2, n2p= 0.659) was significant, meaning that there was a significant difference between APAs of the postural muscles due to visual and auditory stimuli. The results of the Bonferroni correction showed that the APA2 after visual stimulus presentation (0.225 ± 0.008) compared to auditory stimulus presentation (0.378 ± 0.01;) was significantly less (Figure 2).

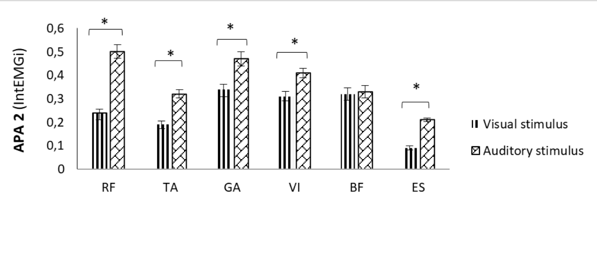

Figure 2. Comparison of visual and auditory stimuli in APA2 of different postural muscles. RF: Rectus Femoris, TA: Tibialis Anterior, GA: Gastrocnemius, VI: Vastus Intermedius, BF: Biceps Femoris, and ES: Erector Spinae. *P<0.05

Comparison of Visual and Auditory Stimuli in APA3 of Different Postural Muscles

The mixed analysis of variance showed that the main effect of the groups (F (5, 78) = 49.216, P =9×10−2, n2p= 0.759) was significant. The level of activity of GA (0.525), RF (0.513), VI (0.501), BF (0.354), TA (0.384), and ES (0.249) muscles had the lowest.

Also, the main effect of stimuli (F (1, 78) = 81.084, P =1×10−1, n2p= 0.510) was significant. In other words, there was a significant difference between APA3 of postural muscles induced to visual and auditory stimuli. Bonferroni correction results showed that the APA3 after visual stimulus presentation (0.377 ± 0.008) compared to auditory stimulus presentation (0.466 ± 0.008) was significantly less (Figure 3).

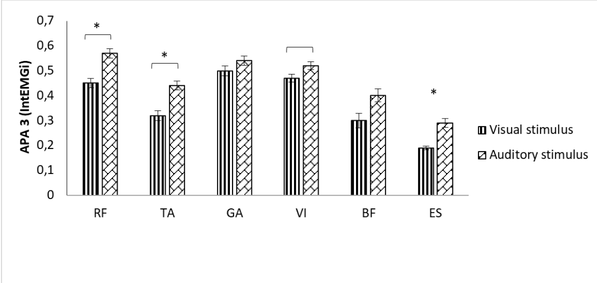

Figure 3. Comparison of visual and auditory stimuli in APA3 of different postural muscles; RF: Rectus Femoris, TA: Tibialis Anterior, GA: Gastrocnemius, VI: Vastus Intermedius, BF: Biceps Femoris, and ES: Erector Spinae. *P<0.05

DISCUSSION

The first finding of the present study showed that visual and auditory stimuli during a balance task increased the APA of the postural muscles. This increase starts simultaneously with the stimulus presentation (from APA1 to APA3) respectively gets bigger after stimulus presentation. These findings are consistent with the findings of research, which specified APAs could be induced by an acoustic stimulus or a visual stimulus. Visual information is usually serious to create effective APAs prior to postural disruption. Preceding studies similarly reported that healthy young adults could be dependent on an auditory cue to produce postural responses to outer perturbation (26). All the researchers stated that when larger APAs were produced for an external postural perturbation, less postural instability was detected. Thus, both visual and auditory cues can help maintain greater balance against perturbation by producing greater APA. Using the contribution of different senses, especially vision, can help a person produce the appropriate APA by providing a perturbation alerting cue. People rely seriously on past experiences to create the expected external perturbation and produce the suitable APA. These experiences are mainly obtained through vision and facilitate the production of APA for external postural perturbations. The important point is that when a move is triggered voluntarily by the person, the individual can optimize the APA. However, when the task is unexpected, APA is not optimized. The same reports have been confirmed for auditory cues, which, as a conditioning stimulus, can trigger APA in healthy individuals against an external perturbation in youth adult (26).

It is also in line with the results of studies that showed attention directed to stimuli moderates the onset of APA (2, 10). Delval et al., (2012) stated that APA is propagated during the preparation period between an alert stimulus to the original "go" initiation stimulus, although the release of APA occurred merely when individuals were told explicitly about the task to be performed. This means that in their research, when people were told to do no task and not respond to stimuli, release APA was not observed, however when they were told the stimuli were within a range of 5 to 10 seconds before the primary signal appeared for the gait, the release of APA is observed (10). Therefore, given that in the present study, similar to the study by Delval et al. (2012), subjects were explicitly told that visual or auditory stimuli appear before external perturbation, it is clear that the presentation of these stimuli would prompt early release postural adjustments before external perturbation.

In addition, study results showed that attention allocation occurs in the prediction of a postural disruption and during initial processing before motor adjustments against the perturbation. These findings are consistent with results by Redfern et al (2017), who compared the effects of visual and auditory stimuli and their effect on body balance control in a reaction time task. They showed that as the complexity of the balance task is greater, the presentation of auditory stimuli than the visual stimulus results in more interference with the reaction time task appeared (12). Recent studies have shown that higher cognitive resources are necessary to maintain balance and integrate functional systems involved in sensory-motor processing, especially in challenging environments. Modifications of sensory information processing related to attention lead to better motor performance involuntary movements in response to visual stimuli. Also, modulation of sensory information processing about attention has been observed for visual, auditory, and tactile information (12).

The second finding of the current study showed that APAs in postural muscles were more affected by auditory stimuli than visual stimuli. The benefits of this type of measurement were investigating of postural stimuli simultaneously and after stimulus presentation. This significant increase between postural adjustments at the concurrent time intervals (APA1) and after the presentation of stimuli (APA2 & APA3) under the influence of auditory stimuli is significant compared to visual stimuli. Hence, it indicates that auditory stimuli can support the balance than visual stimuli. The study results are mainly consistent with Watanabe et al. (2017). They stated that auditory stimuli had a more significant effect on APA than visual stimuli in a choice step reaction. However, investigation of this study is differed from their study. In their research, the APA period was as the interval between the reaction time to foot lift time when moving and they computed the amplitudes of APAs as a percent of body weight from the peak vertical force under the swing foot in the period of APA duration was considered. However, in the present study, APAs were evaluated for lower limb muscle activity. They also stated that when auditory stimuli are present, the amplitude of APA error in mistake attempts increases. Step initiation, in some times to avoid threatening situations, usually occurs under such conditions at which concurrently happening events may call for irreconcilable responses. If APAs are affected by those sensory inputs processed in the brain in negative ways, then it is likely for adverse or unsafe consequences, such as falls, to occur (17). These result repeated in the other study and researchers stated that auditory stimulus might assist a step initiation, credibly by enabling a stimulus identification process and increasing attentional control of stepping behavior, without inducing a decision-making procedure even in a cognitively demanding condition in patients with PD (27).

Thus, it can be said that auditory stimuli may have beneficial effects on APAs, although these effects can be moderated by the duration of stimulus presentation, frequency, and intensity of stimuli. Because, Delval et al (2012) investigated the effect of audible stimulus presentation at different intensities on APA release and observed that different auditory stimulus intensities produced different APAs, and the more intense the stimulus, the greater APA produced (10).

Also noteworthy is the magnitude of the impact of auditory stimuli on wrong responses. In a study, showed that APA error amplitude increases during the presence of auditory stimuli in error attempts.

Thus, auditory stimuli cannot be used to reduce muscle activity latency, especially under threatening conditions without sufficient research, particularly in those at higher risk of falls. For example, in some cases initiating steps to avoid threatening situations usually occur in situations where some concurrent events may require incompatible responses (17). In general, it seems that the mechanism of the auditory cue is different from the visual cue because the auditory cues provides people timing information. Therefore, the participants were able to rely on a new form of sensory information to calculate the postural perturbation and generate appropriate APA (26).

Finally, it can be said given that different perceptual processes can affect the sensory and motor elements of postural control while performing a balance task, APA decrease as a result of auditory stimuli relative to visual can be related to different mechanisms of visual and auditory processing. Because balance is also affected by APA and as a feedforward mechanism helps maintain balance through anticipation, auditory and visual stimulus evaluation in people at risk needs to be investigated.

The main limitations of in this study was to participants were explicitly told that after the stimuli presentation, there will a perturbation in the plate below their feet. So not using a baseline position in this study was one of the limitations of the study. Therefore, this suggest that future researchers consider the use of a baseline position, a position in which individuals are exposed to visual and auditory stimuli without any perturbation in the APA examination. In addition to, the other limitations were the low number of participants, and only young women. It suggests that the researchers in the future studies will be considered the higher number and with individual with the different genders (men). The last suggestion is to consider the combined presentation of visual and auditory cues to see if they will have a greater impact on APA.

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