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Effects of background music on attentional networks of children with and without ADHD: preliminary study

Camila Mendes, Jonas de Paula, Débora Miranda

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Table of Contents

Original Manuscript **4**
Supplementary Files **31**
Figures **32**
Figure 1 ..... **33**
Figure 2 ..... **34**
Figure 3 ..... **35**
Figure 4 ..... **36**
Figure 5 ..... **37**
Multimedia Appendixes **38**
Multimedia Appendix 1 ..... **39**
Multimedia Appendix 2 ..... **39**
Multimedia Appendix 3 ..... **39**
Related publication(s) - for reviewers eyes onlies **40**
Related publication(s) - for reviewers eyes only 0 ..... **40**

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Effects of background music on attentional networks of children with and without ADHD: preliminary study

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Abstract

Background: To sustain performance during a task that requires attention may be a challenge for children with Attention Deficit/ Hyperactivity Disorder (ADHD). It strongly influences the motivational salience of the task and has been integrated with the level of arousal.

Objective: The aim of this study was to analyze the effect of musical stimulus on attentional performance in children with ADHD and typically developing (TD) children.

Methods: Seventy-six boys (34 with ADHD and 42 typically developing) performed the Attention Network Test for Children in two experimental conditions: with music (MU) and without music (NM). Three attentional scores were calculated separately to reflect the efficiency of alertness, orienting, and conflict, and overall rate errors were obtained. Conc

Results: No difference in attention networks was found between the two conditions or between groups. However, when children performed the test listening to music, they made fewer errors than when performed in silent, whatever their group.

Conclusions: Music seems not to interfere in attentional networks in children and adolescents. Maybe the effect of the background music is on motivation. Future studies will be needed to validate this statement. Clinical Trial: The protocol of this study was initially registered at rebec.gov (U1111-12589039); see [https://ensaiosclinicos.gov.br/rg/RBR-8s22sh8] and approved by the University's Ethics Review Committee (CAAE: 97425218.4.0000.5149).

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Original Manuscript

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Abstract

Background: To sustain performance during a task that requires attention may be a challenge for children with Attention Deficit/ Hyperactivity Disorder (ADHD). It strongly influences the motivational salience of the task and has been integrated with the level of arousal.

Objective: This study aimed to analyze the effect of musical stimulus on attentional performance in children with ADHD and typically developing (TD) children.

Methods: Seventy-six boys (34 with ADHD and 42 typically developing) performed the Attention Network Test (ANT) for Children under two experimental conditions (with and without music). Four attentional measures were extracted from ANT. We tested the effect of the experimental condition and its interaction with the group using repeated measures-ANOVA.

Results: We found no significant main effects or interactions for the reaction times of Alerting, Orienting and Conflict attentional networks of ANT (all $P>.05$). Regarding ANT errors we found a significant main effect for music with moderate effect size ($F=9.83$, $P=.032$, $\eta_p^2= 0.06$) but the condition x group interaction was not significant ($F=1.79$, $P=.183$). Participants committed less errors when listening to music when compared to the control condition.

Conclusion: Music seems not to interfere in attentional network in children and adolescents. Maybe the effect of the background music is on motivation. Future studies will be needed to validate this statement.

Trial registration: The protocol of this study was initially registered at rebec.gov (U1111-12589039); see [https://ensaiosclinicos.gov.br/rg/RBR-8s22sh8] and approved by the University's

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Keywords: attention, background music, ADHD, children, music, attention network

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Introduction

Attention Deficit/ Hyperactivity Disorder (ADHD) is a common neurodevelopmental disorder characterized by harmful levels of inattention, impulsivity, and hyperactivity [1]. ADHD exhibits considerable heterogeneity, with individuals' symptoms reflecting impairments in cognitive aspects.

ADHD presents with heterogeneity and individuals' symptoms reflect cognitive impairment [2], causing distress or problems at home, at school, and with peers [3]. Impaired cognitive aspects in ADHD consist of frequent compromise in executive functions (i.e., working memory, inhibitory control, cognitive flexibility, planning, and problem-solving), self-regulation states (i.e., the effortful and automatic mechanisms that enable behavior to be adapted appropriately to a changing context), motivation (i.e., temporal reward discounting), and time perception (i.e., the ability to discriminate and compare time intervals) [4-6]. The hyperactivity and inattention levels of children with ADHD are noticeably higher than expected,

In attentional modeling in Posner [7], there is an appropriate theoretical framework to account for ADHD dysfunctions because most of the abilities mentioned above are conceptualized as part of the attentional networks, such as alerting (i.e., arousal of the cognitive system), orienting (i.e., allocating attentional focus in the visual field), and executive control (i.e., ability to control our own behavior, resolve conflict, and inhibit impulsive responses). A task that requires extra effort for the child to sustain performance may be a challenge for children with ADHD, especially in suboptimal conditions [8]. On the other hand, effort is determined by the motivational salience of the task and has been integrated with the level of arousal and activation [8,9]. This explains why children with ADHD, who are easily distracted by external stimuli, may benefit from stimuli that promote increased alertness and consequently improve performance in the task [10,11].

A recent systematic review showed listening to music without lyrics and chosen by the listener seems to improve the performance of tasks requiring attention [12]. The music enhances arousal, can affect mood and increases motivation, especially when are preferred by listener, potentially benefiting the learning process through emotional processes [13-15]. This heightened state of alertness and pleasant mood can enhance attentional resources, allowing you to concentrate better and sustain focus on cognitive tasks [16,17]. Nonetheless, music holds the potential to augment the emotion regulation

abilities and mood of young individuals in their daily experiences [18].

The effectiveness of music on the cognitive function of individuals with ADHD is still limited due to inconsistent results [19]. Among the studies that evaluated music as a form of stimulation in ADHD, two reported improvements in mathematical problem-solving [20,21], while another study assessing seatwork completion (including math, reading, reading comprehension, and language arts) showed no significant difference in cognitive function. Additionally, the heterogeneity in the methodology of these studies has made it difficult to conclude the true effect of music on task performance. Nevertheless, a recent review indicated that listening to music can reduce symptoms of ADHD and improve timing perception and regulation [22], which are important aspects for the functionality and well-being of this population.

At present, there is a lack of data assessing the impact of music listening on the attention networks of children with ADHD. Therefore, the aim of this study was to investigate the effects of music listening on the attention networks—namely, alerting, orienting, and conflict—in both children with ADHD and typically developing (TD) children, while also exploring the relationship with the attentional profile of these children. Given that previous studies involving ADHD [23,24] incorporated measures of error types alongside conventional assessments of the three attention networks, we will also examine whether music influences error rates during task performance. Our hypothesis is that music may enhance attentional performance in children with ADHD differently from their typically developing peers.

Method

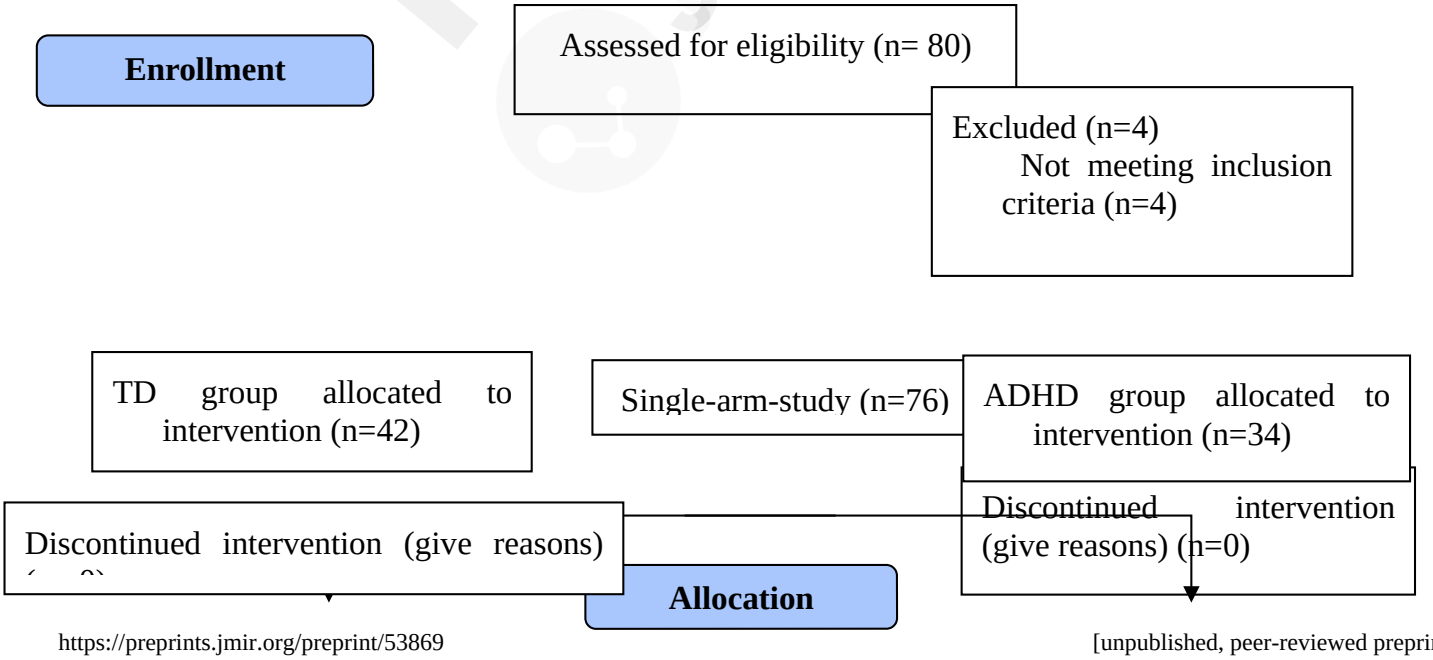
Study Design

This preliminary experimental repeated-measures design was conducted from 2019 to 2022 to explore the impact of music listening versus no music on attention performance. We enrolled boys

aged 10-12 years, both with and without ADHD, who completed the Attention Network Test (ANT) for children twice under randomized conditions. The study protocol was initially registered at rebec.gov (U1111-12589039) and approved by the University's Ethics Review Committee (CAAE: 97425218.4.0000.5149). Written informed consent was obtained from all parents or guardians, with minors providing written informed assent. The study adhered to the Transparent Reporting of Evaluations with Non-randomized Designs statement [25].

Recruitment

A total of 76 boys aged 10-12 years participated, comprising 34 with ADHD and 42 without ADHD (Figure 1). This age range was selected based on evidence indicating that children under 10 years old are still developing their musical preferences, while adolescents tend to be more receptive to unfamiliar music styles [26]. Given that the musical stimulus in our study needed to be familiar and preferred by the listener, we focused on the age range of 10 to 12 years.



Participants were recruited from a university hospital that provides psychiatric care for children and adolescents with ADHD, as well as pediatric follow-up for healthy individuals. Children with ADHD met DSM-5 criteria [1] and underwent assessment using the semi-structured Schedule for Affective Disorders and Schizophrenia for School-Age Children-Present and Lifetime (K-SADS-PL) [27]. Moreover, they achieved scores at or above the 10th percentile on the Brazilian version of Raven's Colored Progressive Matrices (CPM) intelligence test [28].

The control group was selected from the local community between 2021 and 2022. This group was matched with the ADHD group in terms of age and socioeconomic status, and they met the inclusion criteria by not having a diagnosis of ADHD or by not scoring above the cutoff points on screening questionnaires for ADHD. These cutoff points included having more than five ADHD symptoms identified by the Swanson Noland and Pelham-IV (SNAP IV) or having a T-score above 70 on the ADHD scale of the Child Behavior Checklist for Ages 6-18 (CBCL/6-18) [29,30].

Intervention

The intervention required participants to perform an attention task in two different conditions: with music and without music. The music selection comprised five songs chosen through interviews with children aged 10 to 12 years, who shared their favorite and most frequently listened-to songs. These songs were played during the test. It's important to note that the children interviewed about their favorite music weren't necessarily participants in the study.

To gauge the emotional connection between listeners and songs (including familiarity, preference, mood, and arousal), a questionnaire was administered. Participants listened to song excerpts and

answered questions such as "Do you know this song?" (yes, maybe, no), "Do you like this song?" (yes, neutral, no), and "How do you feel listening to these songs?" using the adapted Self-Assessment Manikin Scale [31]. A five-point Likert scale was utilized to rate subjective mood (1= very sad; 2= sad; 3= neutral; 4= happy; 5= very happy) and arousal (1= non-arousal; 2= low arousal; 3= neutral; 4= arousal; 5= very arousal) based on figures pointed out by the children. This questionnaire was administered before the Attention Network Test (ANT) to ensure that the results weren't influenced by the child's performance and can be found in Multimedia Appendix 1.

To prevent experimenter bias, the order of song plays was determined through a random drawing using Microsoft Excel (see Table 1). Music was played using a Samsung Galaxy J5 and Shure® 440Hz headphones, with the volume standardized to the same level for all participants.

Table 1. List of selected songs and their execution orders.

Order	Title	Duration
1	Fortnite OST - Battle Royale Menu Music (Rock Version)[a] https://www.youtube.com/watch?v=2q-k7ScMs0k	3:50
2	Alone (Mashmallo) – Modified[b] https://www.youtube.com/watch?v=ALZHF5UqnU4	3:19
3	Free Fire New EPIC Theme Song[c] https://www.youtube.com/watch?v=oCBMY0MSiWA	3:56
4	Herobrine's Life (Instrumental)[d] https://www.youtube.com/watch?v=Qk1FDPOP8ys	4:00
5	Olha a explosão (Mc Kevinho) – Modified[b] https://www.youtube.com/watch?v=3yd_eoMOvqk	3:07

[a] This song is part of Fortnite Game and used to be played in the Battle Royale Menu and when you win Battle Royale. It was composed by Rom Di Prisco and all content belongs to Epic Games.
[b] The original song was modified by Audacity Program Version 2.3.2 (audio editor) to remove the voices
[c] This song is theme song of Free Fire/2019.
[d] This song is a Minecraft parody of the song “Something Just Like This” by The Chainsmokers and Coldplay

Procedure

The task of atttention involved the Child version of the Attention Network Test (ANT) under two conditions (with and without music). The Child ANT was run using the E-prime program (version 2.0 professional) downloaded on a 15.6-inch Notebook Samsung from Jin Fan's webpage [33]. All participants faced the laptop on the table in a comfortable seated position (Figure 2). Prior to the ANT, the experimenter administered the Conner’s Continuous Performance Test – CCPT to the children. The entire procedure lasted approximately 1 hour and 30 minutes.

The first author contacted parents or caregivers via phone to arrange the experiment day. For the ADHD group, the experiment was scheduled on the same day as the psychiatrist appointment at the university hospital, or another agreed-upon day to enhance adherence to intervention. Children were individually escorted to a quiet office while parents completed behavior scales and a sociodemographic questionnaire in the waiting room. It's crucial to highlight that this sample is clinical. All children under psychiatry monitoring had a confirmed diagnosis of ADHD prior to participation.

For the control group, the experiment was scheduled on the most convenient day and location for caregivers, provided the child met all eligibility criteria. Screening for ADHD was conducted using SNAP-IV and CBCL scales completed by parents online. When the experiment was held at the participant's home, the child performed the task on a table in the quietest area of the house.

Additionally, all children and caregivers were asked to complete a semi-structured questionnaire, which can be found in Multimedia Appendix 2, before starting the task.

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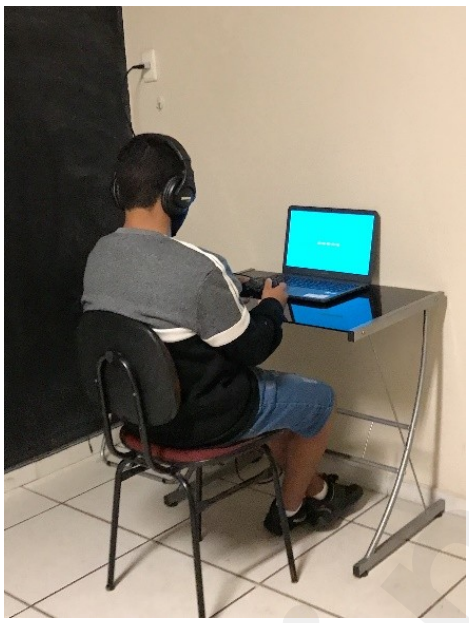


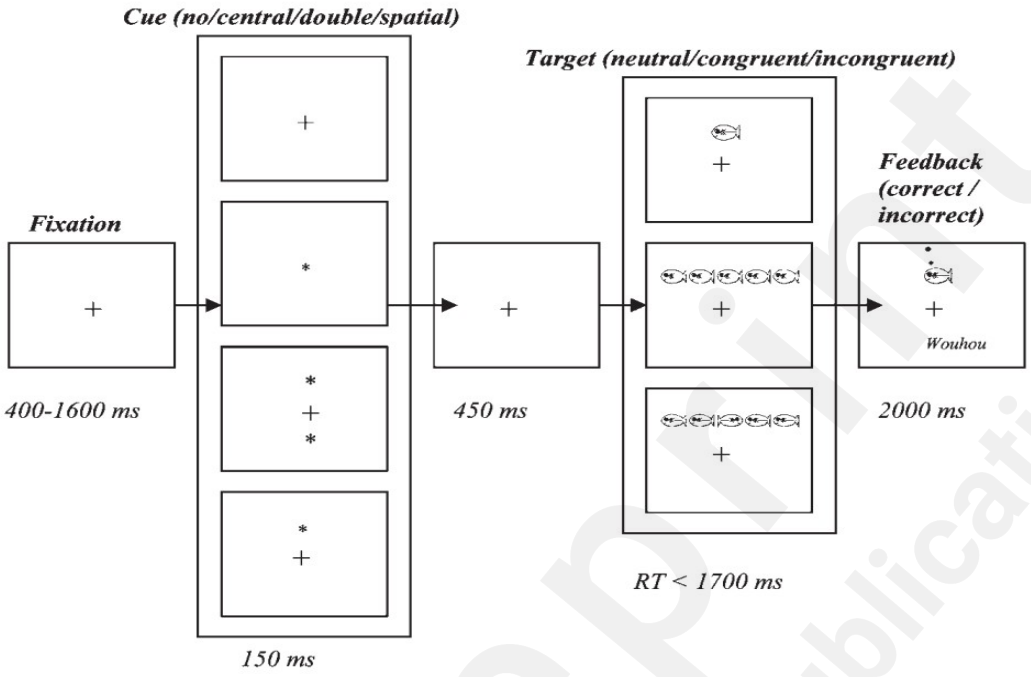
Measures

Primary Outcome Measure

The Attention Network Test - ANT (child version) was designed to assess three attention networks (alerting, orienting, and conflict) within a single task framework based on Posner's model [34]. In this version, participants are instructed to feed a central colorful fish by pressing a joystick button corresponding to the direction (left or right) in which it swims. The fish may appear alone or accompanied by other fish moving in the same or opposite direction (neutral, congruent, or incongruent stimuli) combined with various cueing conditions (no cue, central cue, double cue, and spatial cue) [34] (refer to Figure 3).

Originally, the task comprised 24 practice trials followed by three experimental blocks of 48 trials each. Since children completed the task twice (with and without music), practice rounds were administered separately. This procedure typically lasted approximately 45 minutes, including five minutes of practice and 15-minute rounds of 48 trials each, with 1-2 minute rest intervals. Psychometric properties of the ANT were assessed with a sample size of N=40, yielding test-retest

reliabilities of 0.52, 0.61, and 0.77 for the alerting, orienting, and conflict measures, respectively [35]. Additionally, with a sample size of N=104, test-retest reliabilities of 0.36, 0.41, and 0.81 were reported for the alerting, orienting, and conflict measures, respectively [36].



Secondary outcomes

The Swanson Nolan and Pelham-IV (SNAP IV) is a screening scale for ADHD and Oppositional Defiant Disorder (ODD) based on DSM IV criteria [30]. It consists of 26 items divided into subsets of symptoms (inattention, hyperactivity/impulsivity, and ODD) rated on a 4-point Likert scale ranging from 0 (not at all) to 3 (very much). Scores can be computed using three methods: averaging scores in each dimension, summing total scores, or counting the number of symptoms [30]. We utilized the symptom count to screen for ADHD, while the second and third methods were used for sample characterization. In a Brazilian sample, parental assessment of the SNAP-IV demonstrated robust psychometric properties with Cronbach's alpha values of 0.94 and 0.92 for the inattention and hyperactivity scales, respectively [30].

The Child Behavior Checklist for Ages 6-18 (CBCL/6-18) is a self-report questionnaire assessing behaviors with 118 items scored as 0 (not true), 1 (somewhat or sometimes true), or 2 (very true or

often true). Scores yield raw scores for eight narrow-band scales and three broad-band scales, which are then transformed into T-scores based on normative data [29]. The CBCL aids in ruling out other pathologies potentially confounding ADHD diagnosis and establishing inclusion criteria for typically developing children. Internal consistencies of problem scales ranging from 0.72 to 0.97 as measured by Cronbach's alpha [29].

The Conner’s Continuous Performance Test (CCPT) is a computerized test measuring sustained attention and vigilance in individuals aged 6 and older [37,38]. Performance metrics include measures of reaction times, errors and response variability. Participants respond to letters displayed on the screen by pressing the spacebar, except when the letter “X” appears. The CCPT-2, chosen as a baseline attention measure, demonstrates good internal consistency (Cronbach’s alphas ranging from 0.64 to 0.96) and adequate test–retest reliability (coefficients ranged from 0.48 to 0.79) [38].

The Brazilian Economic Classification Criterion (CCEB) assesses the socioeconomic status of families based on household properties, educational attainment of the family head, and access to infrastructure [39]. Scores categorize families into socioeconomic levels from A to E. Considering that economically vulnerable children may exhibit more ADHD symptoms and externalizing disorders, this assessment ensures the appropriate pairing of groups to mitigate bias [40].

In addition to standardized instruments, a questionnaire gathered information on children's musical experience, preferences, and listening habits at home. Details can be found in Multimedia Appendix 3. At the study's conclusion, children were asked about their preferred testing condition.

Statistical Analysis

The sample size of 46 was determined using G-power 3.010 software, considering $\alpha = 0.05$, a medium effect size of 0.25, and a power of 90%. Statistical analyses were conducted using SPSS 22.0 for personal computers. Descriptive statistics were employed to calculate the mean and standard

deviation (SD) for sample characterization. Attention network scores (alerting, orienting, and conflict) for each participant were derived by subtracting error rates, including omissions, perseverations, and outliers, as outlined by Fan [36].

To compute orienting and alerting scores per subject, the mean reaction time (RT) per cue condition across flanker conditions was calculated (orienting = RT for spatial cue – RT for central cue; alerting = RT for double cue – RT for no cue condition). Conflict scores were obtained by computing the participant's mean RT for each flanker condition across cue conditions (RT for incongruent – RT for congruent). Mean scores across subjects were calculated for each network using an Excel macro obtained from Fan's webpage [33]. Error rates were determined by averaging errors across all conditions (cue and flanker). Detailed calculations are illustrated in Figures 4 and 5, based on the Excel macro downloaded from Fan's webpage [33].

Average of PracSlideTarget.RT				cue				
outiler	practice	PracSli	FlankerType	center	double	no	orienting	Total Geral
1	1	1	congruent	578	682	644	666	641
			incongruent	611	740	882	670	724
			neutral	592	633	573	653	613
		1 Total		594	685	696	663	659
	1 Total			594	685	696	663	659
1 Total				594	685	696	663	659
Total Geral				594	685	696	663	659

subject:	1	session:	2					
		no	center	double	orienting		Alerting	**11**
	congruent	644	578	682	666		Orienting	**-69**
	incongruen	882	611	740	670		Conflict	**82**
	neutral	573	592	633	653	660		

Alerting (696 - 685) = 11
Orienting (594 - 663) = -69
Conflict (724 - 641) = 82

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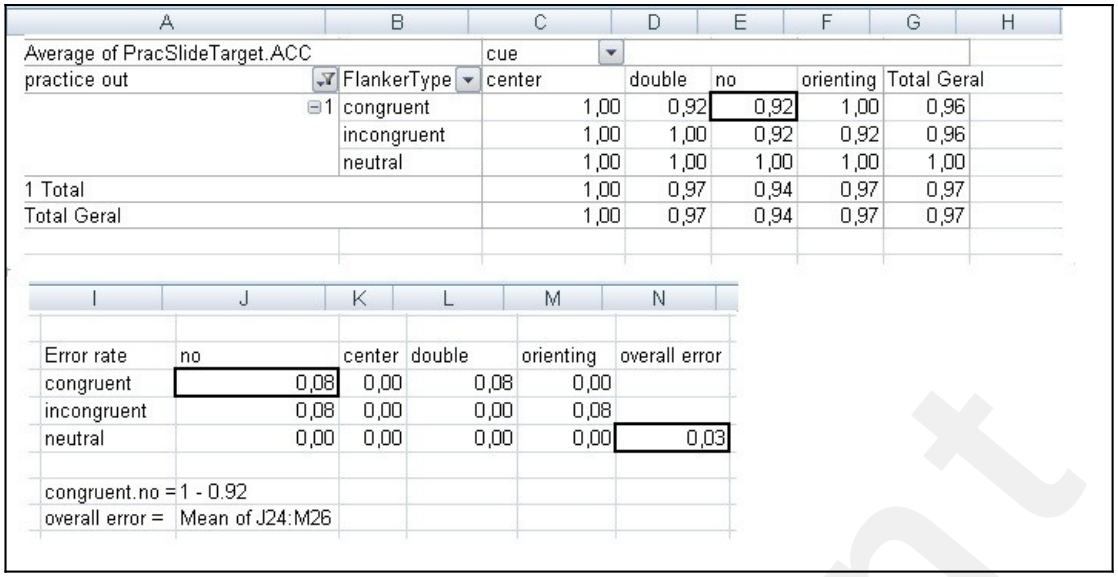

Average of PracSlideTarget.ACC		cue				
practice out	FlankerType	center	double	no	orienting	Total Geral
1	congruent	1,00	0,92	0,92	1,00	0,96
	incongruent	1,00	1,00	0,92	0,92	0,96
	neutral	1,00	1,00	1,00	1,00	1,00
1 Total		1,00	0,97	0,94	0,97	0,97
Total Geral		1,00	0,97	0,94	0,97	0,97

Error rate	no	center	double	orienting	overall error
congruent	0,08	0,00	0,08	0,00	
incongruent	0,08	0,00	0,00	0,08	
neutral	0,00	0,00	0,00	0,00	0,03
congruent.no =	1 - 0.92				
overall error =	Mean of J24:M26				

We used an Analysis of variance (ANOVA) with a repeated measures design to test if the experimental condition (music x no music), group (control x ADHD) and their interaction were related to changes in ANT scores. We used one model for each Attention network measure and error rate. To reduce potential biases of individual differences in attention on ANT scores we included fine-grained age-corrected measures of attention errors from CCPT test. Both commission (respond to a stimulus when you should not) and omission (not respond to stimulus when you should) errors were entered as covariates in each model.

Ethical Approval

Ethical approval for this study was obtained from the University's Ethics Review Committee (CAAE: 97425218.4.0000.5149). Written informed consent was provided by all parents or guardians, while minors provided written informed assent before participation in the trial.

Results

Descriptive behavioral characteristics of eligible participants are presented in Table 2. Additional information regarding participants' previous musical experiences and emotional connections with the

music selections can be found in the Multimedia Appendices. Nearly half of the children reported both familiarity with and enjoyment of the songs utilized in this study. Moreover, 57 out of 76 children (75%) expressed a preference for taking the test while listening to music compared to the no-music condition.

Independent sample t-tests revealed no significant age differences between the control and ADHD groups (t_{74} = 0.47, *P*=.634). Similarly, no significant disparities in socioeconomic status were observed between the groups (t_{71} = -1.158, *P*=.251).

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Characteristics		**TD group (n=42)**	**ADHD group (n=34)**
Age (years)[a]		11.0 (0.85)	10.9 (0.75)
Socioeconomic family score (CCEB)[a,b]		28.5 (11.32)	31.5 (11.15)
SNAP-IV Symptoms Score[c]			
	Inattention	1 (>5)	6 (>5)
	Hyperactivity/ Impulsivity	0 (>5)	5 (>5)
CBCL-ADHD Scale[d]		44.7 (>70)	61.6 (>70)
CCPT[a]			
	Omissions	11.7 (9.5)	11.9 (8.6)
	Comissions	25.0 (6.0)	25.4 (7.3)

Table 2. Demographic characteristics of participants (N=76).

[a] Numbers indicate mean and (standard deviation)

[b] CCEB = Brazilian Criteria of Economic Classification (0-16 = Class D and E; 17-22 = Class C2; 23-28= Class C1; 29-37 = Class B2; 38-44 = Class B1; 44-100 = A).

[c]Categorization of each SNAP-IV item as present (1 point, which mean all answers equivalente to 2= quite a bit or 3=very much) and absente (0 point, which mean all answers equivalent to 0=not all or 1=just a little), where present. Numbers indicate symptoms and (cut-off point to screening of ADHD)
[d] SNAP-IV = Swanson Nolandand Pelham -IV. CBCL = Child Behavior Checklist. CCPT = Conner's Continuous Performance Test. T-scores calculated with reference to Brazilian normative data [26]. Numbers indicate mean t-score and (cut-off point to screening of ADHD).

Effect of music on ANT attention networks and error rate

Table 3 presents the mean and standard-deviations for each ANT measure across different conditions and groups. Repeated-measures ANOVA models are shown in Table 4. We did not find significant main effects for Music or the interaction between Group and Music for the Alerting, Orienting and Conflict attentional networks (all non-significant, p-values ranging from 0.277 to 0.740). Regarding ANT errors we find a significant main effect for Music with a moderate effect size (F=9.83, *P*=.032, η_p^2= 0.06) but not for the group x music interaction (F=1.79, *P*=.183). Both the typical development (mean 0.041, SD 0.036 vs mean 0.039, SD 0.049) and ADHD (mean 0.066, SD 0.058 vs mean 0.052, SD 0.042) participants committed fewer errors in ANT while listening to music.

Table 3. Mean reaction time and standard deviations for correct responses in each condition (music and no music) and in both groups (ADHD and TD)

TD group[a]															
	No music								**Music**						
	center		**double**		**No**		**orienting**		**center**		**double**		**no**		**orienting**	
Congruent	639	(120)	626	(266)	692	(130)	619	(192)	635	(135)	614	(177)	675	(229)	612	(296)
Incongruent	702	(106)	689	(343)	736	(201)	680	(62)	674	(75)	680	(177)	723	(109)	660	(203)
Neutral	621	(167)	597	(115)	664	(227)	590	(182)	634	(205)	612	(255)	657	(63)	598	(246)
ADHD group[b]																
	No music								**Music**							
	center		**double**		**No**		**orienting**		**center**		**double**		**no**		**orienting**	
Congruent	686	(120)	668	(266)	743	(130)	663	(192)	689	(120)	672	(266)	734	(130)	648	(192)
Incongruent	763	(106)	722	(343)	796	(201)	693	(62)	759	(106)	708	(343)	781	(201)	710	(62)
Neutral	672	(167)	658	(115)	732	(227)	647	(182)	651	(167)	648	(115)	709	(227)	629	(182)

TD= typically development; ADHD= Attention Deficit Hyperactivity Disorder

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Table 4: Comparison of typical development and ADHD participants performance in ANT scores with and without music controlling for CCPT omission and commission errors (repeated measures ANOVA)

Measure	TD group (N=42)		ADHD group (N=34)		Main effect of Music				Interaction of Music x Group			
	No Music	Music	No Music	Music	F	df	p	η_p^2	F	df	p	η_p^2
Alerting	68.62 (52.67)	60.33 (81.28)	79.56 (54.64)	62.32 (64.75)	1.20	1	0.277	-	0.15	1	0.695	-
Orienting	26.69 (47.6)	24.29 (40.88)	38.62 (50.33)	44.03 (57.8)	0.86	1	0.357	-	0.28	1	0.599	-
Conflict	58.02 (47.06)	53.81 (38.28)	56.18 (47.35)	56.50 (38,28)	0.11	1	0.740	-	0.12	1	0.727	-
Error rate	0.041 (0.036)	0.039 (0.049)	0.066 (0.058)	0.052 (0.042)	8.83	1	0.031	0.06	1.79	1	0.183	-

ADHD: Attention Deficit Hyperactivity Disorder, ANT: Attentional Network Test, CCPT: Conner's Continuous Performance Test.

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Discussion

The results across both ADHD and control groups revealed no significant main effects of music in attention networks as indexed by the ANT neither than a significant interaction between music and group. However, a significant main effect was found in the overall number of errors during ANT performance, suggesting listening to music decreases the error rate.

This study hypothesized that listening to music during the test may improve attention performance of children with ADHD. However, our findings did not fully support this hypothesis. We found listening to music can improve the accuracy of the performance by decreasing the number of errors and this have happened in both groups. The deficits in the attentional networks of children with ADHD assessed through the ANT are still controversial and there are previous studies that also did not find differences in the efficiency of their networks when compared to non-ADHD [24,41]. Also, higher alertness seems to be associated with increased error rates [25, 42,43], so the music effect made the alertness level an optimal condition to not affect the accuracy of this study or its generated weak effect sizes to detect differences.

The effects of music on cognitive performance are affected by motivation especially if it's a favorite song [43]. In this study, most of the participants reported positive feelings (i.e like the song, feelings of happiness) about the pieces of music used and they preferred to perform the ANT listening to music. This may have increased the motivation to complete the task, consequently contributing to making fewer mistakes while listening to music, but this is only speculative. In the case of ADHD, they may have lower levels of motivation and self-regulation problems, which lead to the

devaluing of rewards that are not immediate in comparison to those typically developing [44,45]. Although we did not find a significant difference between the groups, our results suggested a tendency for the effect of music to be more significant in the group with ADHD, which corroborates studies on the role of motivation in achieving school tasks [46-48]. Children with ADHD when motivated are more likely to try harder when faced with difficulties or not to give up when something is difficult to finish or is not in their interests [49]. So, it is important to understand that strategies that motivate these children can directly affect the performance of a task and this does not necessarily have to be through an attentional route.

Also, previous studies demonstrated that when the music had lyrics it might impair performance attention [50,51], which can be another important factor that contributed to the reduction of errors during the performance of the task in our study. Still, our musical stimulus was composing of songs that could have create an atmosphere to captivate the player even three songs are part of games that are in the routine of these children. This may have generated the feeling of reward and motivated the children more during the test.

The concept of affect-matching music refers to the idea that individuals tend to seek out and prefer music that aligns with their current emotional state or desired emotional state. The improvements in cognitive performance are facilitated by listening to affect-matching music [52]. On the other hand, music is also capable of inducing emotions [12,15]. In this study, we chose to use music that was familiar and preferred by most participants, so it is possible that the combination of these factors: music that induces emotions, plus the listener's perception (emotion and arousal) led to the result found.

Since was developed, the ANT has been widely used by the scientific community in diverse cultures and investigations (i.e anxiety, ADHD, bilingualism, borderline

personality disorder, deafness, mindfulness training, schizophrenia, time of day) [41, 53], and the variant for the child [32] is the gold standard in this population, being more engaging and visually stimulating. Thus, it was the best tool to assess the effect of music on performance attention.

The current study has some limitations. First, the results are only generalizable to the specific music employed in this study and potentially to other music in the same genre and with a specific visual task in a laboratory setting. It would be necessary to carry out the same study with the same type of music while performing school tasks or in the classroom.

Second, the sample of children with ADHD was recruited from only one clinical care setting and this may have generated biases. Also, because is one clinical sample, the findings may not generalize to the broader population, limiting the external validity of the study.

Conclusion

Our findings, while preliminary, suggest that music does not appear to interfere with attentional networks. However, they do indicate that listening to music reduces the number of errors during directed attention tasks such as the ANT. Can similar results be observed during academic tasks? Could listening to music serve as a means to motivate children, thereby enhancing their engagement and accuracy in completing tasks? These questions warrant further investigation.

The motivational significance of a task plays a crucial role in channeling the additional effort required to sustain attention, potentially contributing to the reduction in errors observed. However, the effects of music on attention may vary among individuals with

ADHD. While some children may find certain types of music beneficial for enhancing attention, others may find it disruptive. Therefore, it is essential to consider personal preferences and sensitivities when assessing the impact of music on attention in children with ADHD.

Ultimately, our research underscores the importance of exploring alternative and complementary treatments for ADHD that incorporate music, as it possesses intrinsic motivating potential and is readily accessible in people's daily lives. Further studies are needed to deepen our understanding of how music can be effectively utilized to support attention and cognitive function in individuals with ADHD.

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Data Availability

The data analyzed during this study are available from the corresponding author on reasonable request.

Conflicts of Interest

None declared.

Multimedia Appendix 1: [Assessment of Emotional State]

Multimedia Appendix 2: [Frequency (percentage) of answers of questionnaire to assess the emotional relationship between listener-songs]

Multimedia Appendix 3: [Frequency (percentage) of answers of preview musical Experience Questionnaire]

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Supplementary Files

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Figures

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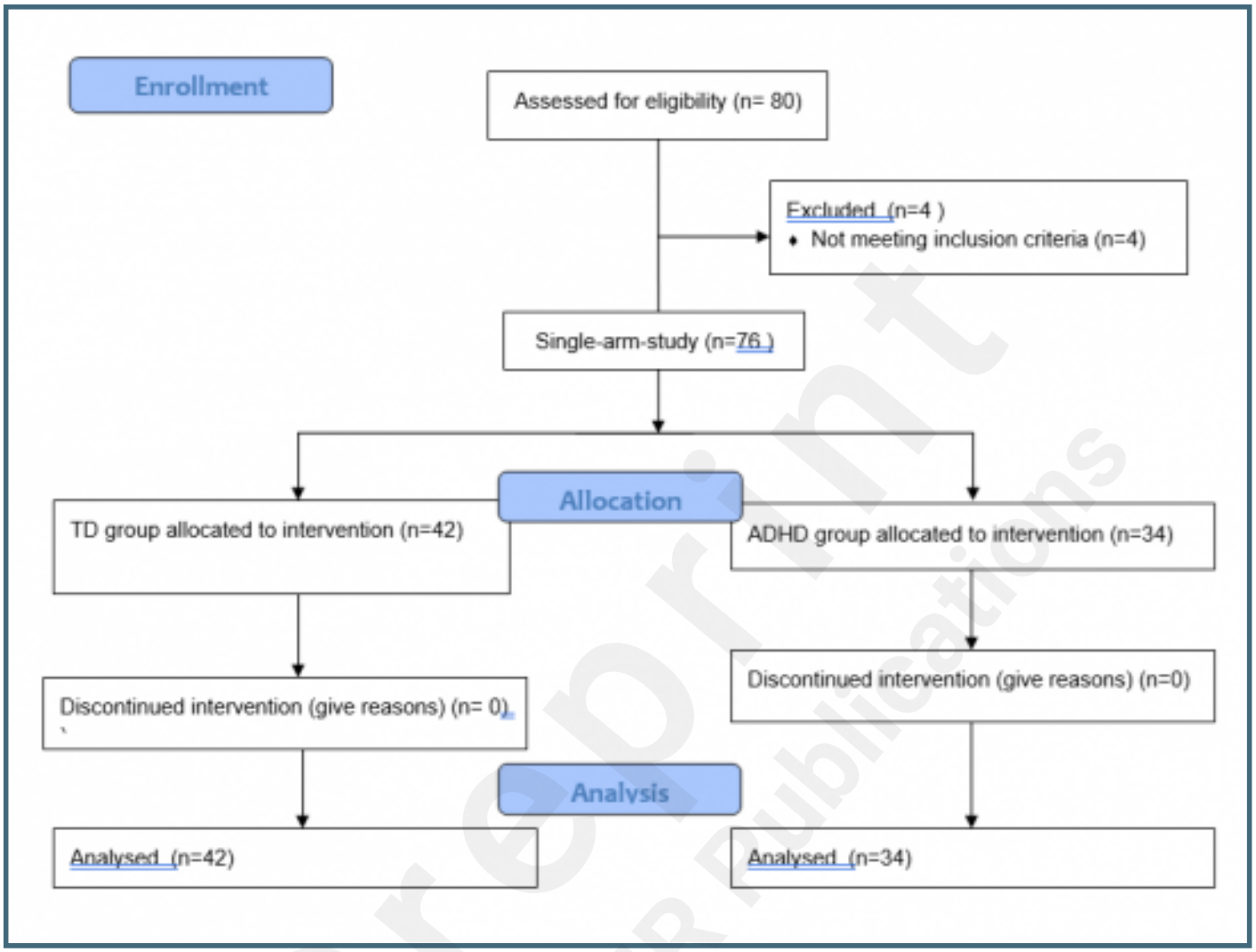
Flow diagram of the research process.



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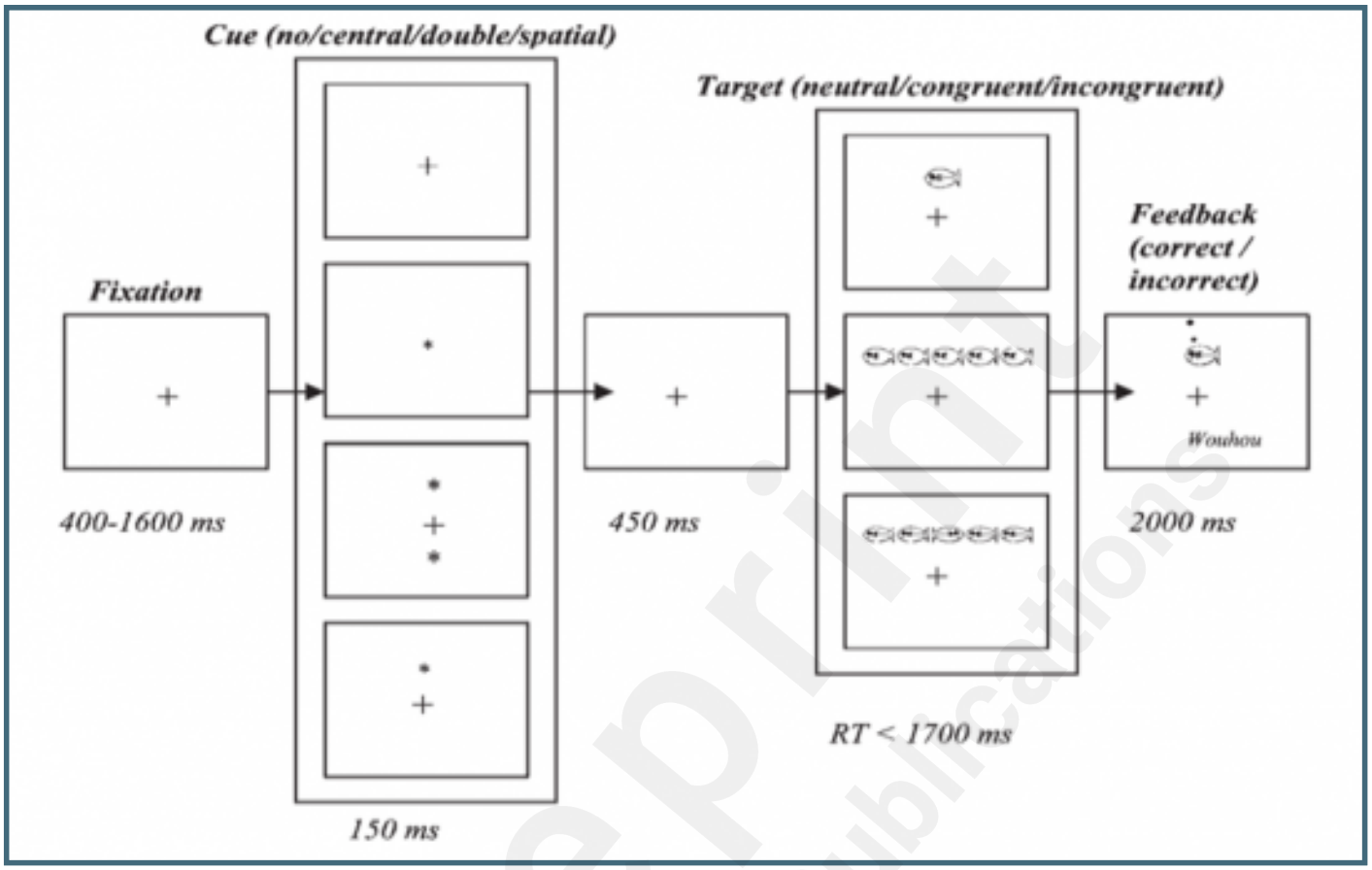
Experimental setup.

Schematic of the child version of the ANT. In the actual task, the background color for every display is blue while the fish appear in yellow, and the auditory feedback was used only to practice trials.



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Example of calculations of attentional networks of subject 1, session 2, using an Excel macro.

Average of PracSlideTarget.RT				cue				
outiler	practice	PracSli	FlankerType	center	double	no	orienting	Total Geral
1	1	1	congruent	578	682	644	666	641
			incongruent	611	740	882	670	724
			neutral	592	633	573	653	613
		1 Total		594	685	696	663	659
	1 Total			594	685	696	663	659
1 Total				594	685	696	663	659
Total Geral				594	685	696	663	659

subject:	1	session:	2					
		no	center	double	orienting		Alerting	**11**
	congruent	644	578	682	666		Orienting	**-69**
	incongruen	882	611	740	670		Conflict	**82**
	neutral	573	592	633	653	660		

Alerting (696 - 685) = 11
Orienting (594 - 663) = -69
Conflict (724 - 641) = 82

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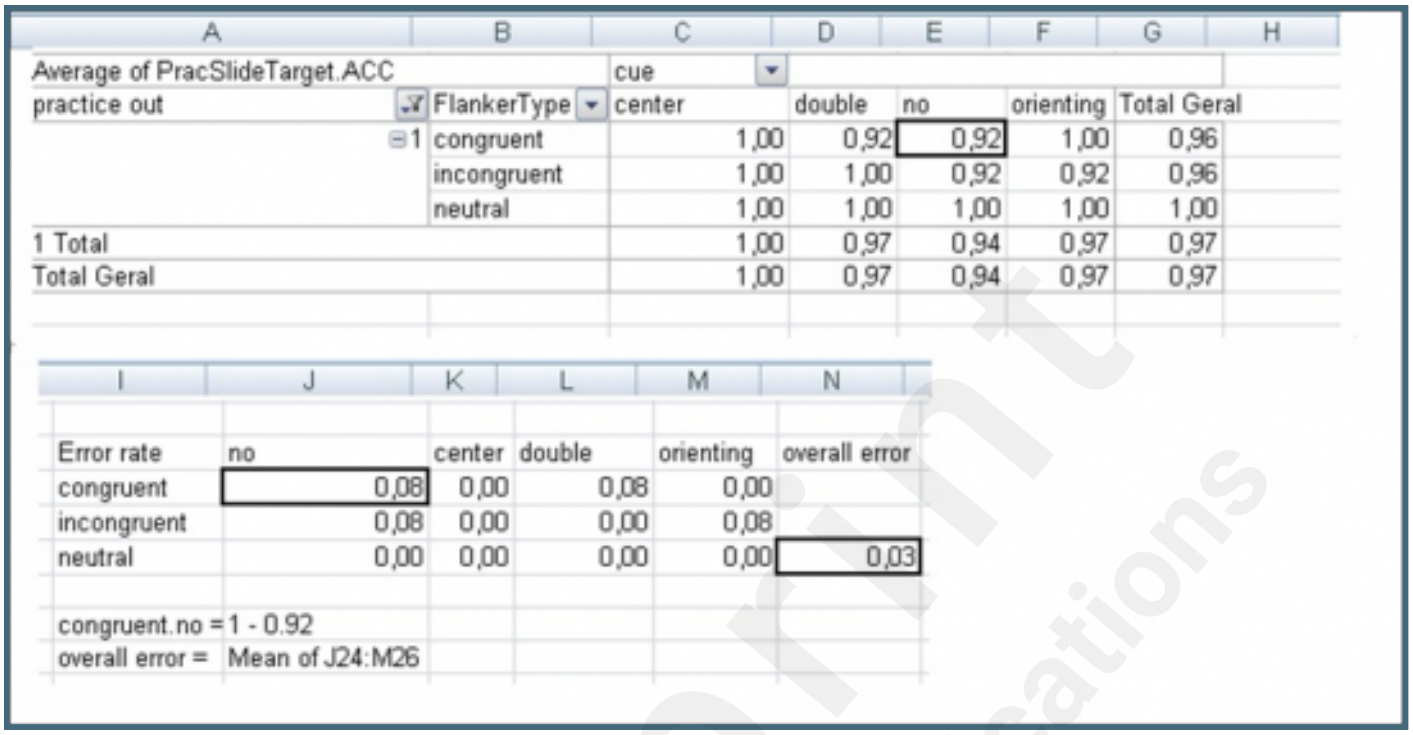
Example of calculations of overall errors of subject 1, session 2, using an Excel macro. Squares in bold indicate the values used for the calculations in the example.



Average of PracSlideTarget.ACC		cue				
practice out	FlankerType	center	double	no	orienting	Total Geral
1	congruent	1,00	0,92	0,92	1,00	0,96
	incongruent	1,00	1,00	0,92	0,92	0,96
	neutral	1,00	1,00	1,00	1,00	1,00
1 Total		1,00	0,97	0,94	0,97	0,97
Total Geral		1,00	0,97	0,94	0,97	0,97

Error rate	no	center	double	orienting	overall error
congruent	0,08	0,00	0,08	0,00	
incongruent	0,08	0,00	0,00	0,08	
neutral	0,00	0,00	0,00	0,00	0,03

congruent.no =	1 - 0.92
overall error =	Mean of J24:M26

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Multimedia Appendixes

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Assessment of Emotional State.
URL: http://asset.jmir.pub/assets/f3d860b9b2218972a20dbabe7135c5af.docx

Frequency (percentage) of answers of questionnaire to assess the emotional relationship between listener-songs.
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Frequency (percentage) of answers of preview musical Experience Questionnaire.
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