

Influence of intensive ensemble music training on children
from a lower socioeconomic status: An ERP study

by

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Abstract

Low socioeconomic status (SES) children may experience positive outcomes through interventions. OrKidstra, an intervention program, provides musical training to low SES children in an intensive, ensemble, and social setting. This study examined the effect of OrKidstra training on children through an auditory Go/No-Go task with tone-locked (1100 and 2000Hz) Event-Related Potentials (ERPs). OrKidstra children demonstrated higher auditory discrimination than the comparison group for tones at 500, 1000, and 2000Hz during a hearing test, but accuracy and reaction times did not differ for the Go/No-Go task. ERP analyses revealed that OrKidstra children showed a greater spread of neural activity for auditory perception (pre-P300), they had earlier but smaller P300 peaks (associated with stimulus evaluation), and the late potentials (associated with inhibitory control) were more widely distributed. This study suggests that OrKidstra children tend to experience faster and more efficient neural processing to auditory stimuli, and emphasizes the importance of such interventions.

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1 Chapter: Introduction

Children from a low socioeconomic status (SES) background are at a heightened risk for poor health and well-being, however, interventions may reduce this risk and lead to more positive outcomes. One way of intervening is getting the children involved in an intensive, collective, and ensemble music program. This idea originated in Venezuela through a musical education and intervention program called “El Sistema”, which has flourished worldwide serving approximately 700,000 child musicians in over 400 El Sistema-inspired programs (Creech et al., 2016). The El Sistema-inspired program located in Ottawa, Canada is called OrKidstra, and it is run by the Leading Note Foundation. The beneficial outcomes of involvement with El Sistema in Venezuela has been studied, but there is no research on how these outcomes might benefit children growing up in Canada, and more specifically, in Ottawa. The current study examined the influence of OrKidstra on these child musicians through neuroscientific means.

Music can induce neuroplasticity, in which the environment contributes to the shaping and molding of the brain (Hedayati & D’Angiulli, 2015). These changes can be *positive* and may contribute to the development of resilience in individuals from disadvantaged backgrounds. To date, however, only a handful of studies have looked at how the collective nature of an El Sistema-inspired program impacts the brains of child musicians, and none of these studies have looked at OrKidstra, specifically. The goal of the present paper is to provide a background on low socioeconomic status, music, and the brain by linking them together, and to present a study that recorded Event-Related Potentials (ERPs), paired with an auditory Go/No-Go task, which was used as the neuroscientific tool to investigate the brains of children with and without OrKidstra

training. Details of ERPs and the Go/No-Go task will be described. Implications and areas for further research will be discussed.

1.1 Poverty

Poverty is not only present in developing nations, but may also be found in developed nations with advanced economies like Canada. In Canada, children belong to a group that may be at risk for poverty (Collin & Jensen, 2009). In fact, the UNICEF Innocenti Research Centre (2012) reported that the childhood poverty rate in Canada exceeded the poverty rate of the broader population (13.3% and 11.4%, respectively). These rates are for overall or relative poverty, which UNICEF defines as living in a household, where the household income is less than 50% of the national median income, when adjusted for family size and composition. In broader terms, relative poverty refers to an insufficient family income, such that the family lives below their society's average standard of living (Jensen, 2009). Another way of defining poverty is in absolute terms. Absolute poverty refers to a lack of basic necessities, such as access to shelter, running water, and food (Jensen, 2009). Families living in absolute poverty tend to focus their attention on day-to-day survival (Jensen, 2009). Absolute poverty appears to be less common in Canada than relative poverty (Sharma, 2012). As such, this paper will have a greater emphasis on relative poverty.

1.2 Socioeconomic Status

Socioeconomic status (SES) is a construct that is related to poverty. Some of the dimensions included in SES are education, occupation, and income. Bradley and Corwyn (2002) claim that SES can be best defined as an individual's personal capital, which contains three subcomponents: financial capital or material resources; human capital,

which include non-material resources like education; and social capital, which contains the social, professional, and neighbourhood connections. However, the manner in which SES is defined varies across studies. Some researchers only include human capital (e.g., maternal education level) in their definition, while others incorporate a combination of all three subcomponents.

In developmental studies, often the parental SES is measured when trying to assess the SES of the child. The parental level of education has been argued to be the most significant predictor of socioeconomic effects on the cognitive outcomes of children (Noble, Norman, & Farah, 2005). In a study by Noble et al. (2005), the performance of kindergarten children on a series of executive function and language tasks were correlated with the parents' level of education, despite the children's parental occupation or income-to-needs ratio.

Furthermore, research evidence supports the notion that children from low SES backgrounds are more likely to exhibit poor health and well-being compared to their higher SES counterparts (see Spencer, Thanh, & Louise, 2013 for a review). However, interventions targeting low SES children may prove beneficial and lead to better outcomes. One form of intervention can be through musical involvement.

1.3 Music and Poverty

1.3.1 El Sistema: A musical education and intervention program.

El Sistema ("the system") is an international musical education and intervention program that originated in Venezuela for children living in extreme poverty. This program supports children's well-being by providing music lessons in a cooperative and ensemble setting. The goals of El Sistema are to promote positive change and to

empower children coming from disadvantaged backgrounds by providing an alternative to juvenile crime, fighting the risk factors associated with social unease, stimulating a feeling of emancipation, and providing professional opportunities to the children (Majno, 2012). In Venezuela, children in this program play for their lives since the alternative could be to cave in to the pressures of extreme poverty like joining a gang. El Sistema is viewed as a social change promoter, and the children in this program are viewed as role models for other Venezuelans. The collective nature of El Sistema is of great importance since it aids the children in learning and supporting one another.

The main themes of El Sistema are: 1) It is accessible; 2) Regular and intense musical training is provided; 3) Courses and practices are done in a collective and ensemble setting; and 4) Musical production of high quality is pursued (Majno, 2012). The benefits of a musical intervention program like El Sistema appear to be beneficial for Venezuelan children, but there is no research exploring how an El Sistema-inspired program can impact the lives of children growing up in poverty in Canada, and what this means in terms of the targeted skills.

1.3.2 OrKidstra: An El Sistema-inspired program.

OrKidstra, an El Sistema-inspired program, was developed by The Leading Note Foundation (LNF) to help alleviate the impacts of living in poverty and to introduce the transformative power of music to children living in disadvantaged communities in the Ottawa, Canada region. Children involved in OrKidstra are provided with free or low-cost intensive music lessons and opportunities to play a musical instrument in an orchestra, or sing and move in an ensemble setting. OrKidstra is open to all children between the ages of 5-18 years regardless of family income, but family earnings

determine if there is a cost to participate in the program. The program is free for all low-income families (The Leading Note, 2013).

Different types of ensemble musical training are available through OrKidstra, and the type that the children join depends on their age, previous musical exposure, and choice. Options range from a music and movement program geared towards younger children, choral singing, and learning to play woodwind, brass, or string instruments. The LNF provides donated instruments to children in OrKidstra whom cannot afford their own.

Cooperation and mutual respect for one another are key philosophies of OrKidstra, and these are gained as the children build their confidence and learn in a group setting. The program strives to create a sense of community and appreciation for the diverse backgrounds of the children and their families, and to promote the impact of music, in order to ameliorate the challenges faced by children from low SES backgrounds. If music is used as a tool to improve the lives of these children, can music, itself, induce changes in the brain?

1.4 Music and the Brain

Musical involvement can activate the emotional and reward brain circuitry through neuroplasticity, which is the ability of the environment to alter the brain (Hedayati & D'Angiulli, 2015). These neuroplastic changes can be *positive*, such that they may help build resilience for individuals living in disadvantaged communities, like those coming from a low SES background. Croom (2012) explains that neuroscience and psychology fields are now beginning to explore how music can influence the developing brain, and he argues that musical activity may enhance one's well-being, which could

lead to a *flourishing* life, as defined in Seligman's (2011) book. According to Seligman (2011), an active promotor of the Positive Psychology field, five areas characterize human flourishing and well-being, and they are: positive emotion, bonding in relationships, engagement, achievement, and meaning. Music making can positively affect all five areas (see Croom 2012 for a review), and it can help alleviate the higher stress levels that are often associated with growing up in poverty (Chen, Cohen, & Miller, 2010; Evans & Kim, 2007; Lupien, King, Meaney, & McEwen, 2000).

1.4.1 Neuroplasticity and music training.

Based on past research on music and the brain (e.g. Rosenkranz, Williamon, & Rothwell, 2007), El Sistema and El Sistema-inspired programs like OrKidstra may contribute to neuroplasticity. The brains of musicians differ from the brains of nonmusicians with respect to their shape, size, density, connectivity, and functional activity, and the most significant differences are found in the frontal, motor, and auditory regions (Merret & Wilson, 2011). Studies support a direct correlation for the differences seen in the brains of musicians and the skills practised during training, like enhanced cortical space used for the discrimination of musical tones (Pantev et al., 1998), larger cortical representation for fingers of the left hand (Elbert, Pantev, Wienbruch, Rockstroh, & Taub, 1995), and more gray matter in various brain regions that involve auditory, speech, motor, sensory, and visual processing (Gaser & Schlaug, 2003).

In Hyde et al.'s (2009) study, a significant improvement of right hand finger control was seen in six-year-old children who had received private keyboard lessons over a span of 15 months, compared to children who had not received music training, and the difference for the left hand was marginally significant, as was indicated by the larger

relative voxel size in the right precentral gyrus and the corpus callosum. Additionally, the children who had received musical training, had a larger relative voxel size in the right primary auditory region, which behaviourally translated to improvements on the auditory melodic and rhythmic discrimination task. Children were also tested on other skills that may be influenced by music learning, but do not necessarily result from musical training, which included tasks assessing visuospatial memory, vocabulary, and phonemic awareness; however, none of these tasks were significant between groups.

Rickard, Bambrick, and Gill (2012) had similar findings, where children who took part in a standard classroom musical training program showed no differences in cognitive abilities when compared to children in standard drama or art programs. However, children who participated in an intensive instrumental music program within their respective school in socioeconomically disadvantaged regions demonstrated an improvement in learning and immediate recall for verbal information after one year of the program, whereas these benefits were not seen in children who took part in a musical program in a standard classroom and in children who took juggling classes for a year (Rickard, Vasquez, Murphy, Gill, & Toukhsati, 2010). These studies suggest that music instruction appears to be most beneficial when the training is intensive and when the target students are children from socioeconomically disadvantaged communities.

1.4.2 Influence of intensive ensemble music training on children from lower SES.

Learning to play a musical instrument has been documented to have a positive influence across many skill sets, including: improved performance on executive function tasks (Moreno et al., 2011; Winsler, Ducenne, & Koury, 2011; Schibli & D'Angiulli,

2014) verbal intelligence (Moreno, Marques, Santos, Santos, Castro, & Besson, 2008); verbal memory (Ho, Cheung, & Chan, 2003); reading skills (Moreno, Friesen, & Bialystok, 2011); spatial and sequential memory (Bilhartz, Bruhn, & Olson, 2000); self-esteem (Hietolahti-Ansen & Kalliopuska, 1991; Costa-Giomi, 2004); empathy (Hietolahti-Ansen & Kalliopuska, 1991); and general IQ (Schellenberg, 2006). These studies demonstrate the transfer effects of music (i.e., where music seems to enhance a skillset that appears to be either untrained but related to music [near transfer] or completely unrelated to music [far transfer]; Moreno & Bidelman, 2014; Benz, Sellaro, Hommel & Colzato, 2016). However, not many studies have examined the collective influence of music training involving children from low SES (Kraus, Hornickel, Strait, Slater, & Thompson, 2014; Schibli & D'Angiulli, 2014).

One study that has examined this, found that children from lower SES (between the ages of 6-10 years) with higher attendance and rankings of participation by music teachers in a community-based music program, demonstrated more consistent auditory brainstem responses to speech and an improvement in performance on a reading task (Kraus et al., 2014). Using a preliminary analysis, Schibli & D'Angiulli, (2014) found that children (9-12 years) in an OrKidstra program showed an improvement on an auditory Go/No-Go task relative to comparison children. The OrKidstra children responded more quickly to the Go tone at 2000Hz, and showed greater early neuronal processing in response to this frequency relative to children not involved with OrKidstra. These effects were found both within and between groups, therefore, Schibli and D'Angiulli (2014) concluded that this may demonstrate a practice effect, where intense musical exposure through OrKidstra ameliorates sound discrimination, and that these

children may shift from top-down frontal processes to more “sensory” centroparietal processes.

1.5 The Current Study

The purpose of the current study is to expand on these preliminary findings by analyzing the Event-Related Potential (ERP) amplitudes and latencies during an auditory Go/No-Go task in children with and without OrKidstra training. This was accomplished through the administration of tones that were synced with the children’s electroencephalographic (EEG) recording. Averages were calculated using ERPs. Grand averaged ERP data was converted into 25ms binned intervals covering the entire epoch. Differences in ERP activity were examined for three parts of the ERP epoch, where 0ms corresponded to the moment when the stimulus was presented: pre-P300 (0 to 249ms), P300 region (250 to 499ms), and post-P300 (500 to 1000ms). The pre-P300, P300, and post-P300 regions may contain waveforms associated with auditory perception, stimulus evaluation, and response control, respectively. Participants involved in OrKidstra were matched with the comparison group in terms of age, sex, and across all screening measures, as much as possible. This ensured that differences in the ERP data during the auditory Go/No-Go task were more likely due to underlying neural differences between groups rather than from extraneous variables.

The hypotheses for the current study were that OrKidstra children, relative to the comparison children, would:

- 1) have superior auditory discrimination on the pediatric hearing test by displaying lower auditory thresholds to tones between 500 to 4000Hz
- 2) have shorter reaction times, but similar accuracy rates on the auditory Go/No-Go task

3) show more efficient and automatic neurocognitive functional activity by displaying:

- a) smaller ERP amplitude peaks (more efficient processing, so less cognitive resources were being used)
- b) shorter ERP latencies (more automatic processing; a shorter amount of time would be needed for the brain to respond).

Hypothesis 3 was followed by a broader research question: Are these effects specific to certain areas of the brain or is it a global effect? Despite the modest spatial resolution of the ERP techniques, this question is still valid if coarse localization is analyzed and interpreted in the context of ERP activity dynamics over time (see Marmolejo-Ramos et al. 2015).

2 Chapter: Method

2.1 Participants

Participants were recruited through a partnership between the Neuroscience of Imagination Cognition and Emotion Research (NICER) Laboratory and the Leading Note Foundation, a charitable organization that runs an El Sistema-inspired ensemble musical program (called OrKidstra) for children. Participants between the ages of 9 and 12 were recruited from OrKidstra and from a comparison group, outside of OrKidstra, with and without musical training. Recruitment methods included the use of posters, flyers, word-of-mouth, phone calls, in-person recruitment, and presentations in community centres.

Thirty families were initially recruited. Of those, 21 children (and their parents) took part in the screening session and experimental testing. After a strict as possible match-sampling procedure, the final sample consisted of 16 children. The details are summarized in Table 1 for the two groups (i.e., OrKidstra and comparison).

2.2 Procedure

The participants came into the laboratory with a parent/guardian. As the parent/guardian reviewed the informed consent form, the child was explained the general procedure of the study in developmentally-appropriate terms. The researcher obtained verbal assent from the child and ensured that the parent/guardian had signed and understood the consent form prior to continuing with the study. The parent/guardian remained in the room and completed questionnaires on a laptop as the child participated in the tasks.

Children completed the Peabody Picture Vocabulary Test – IV (PPVT– IV), a standardized test of receptive vocabulary and word comprehension (Dunn & Dunn, 2007). The PPVT-IV was used to screen for language development, but its results were not used as a dependent variable or measure for hypothesis testing. A hearing test was conducted with the use of an audiometer. After participants were fitted with an EEG cap, they took part in an auditory Go/No-Go task.

Table 1

Match-sampling of OrKidstra children and the comparison group (n = 8; 4 females per group)

	Group	
	OrKidstra	Comparison
	Mean (standard deviations)	Mean (standard deviations)
Child age	10.25 (1.31)	9.76 (0.66)
Parental/guardian age	43.00 (5.26)	43.00 (4.62)
DASS-D	8.29 (9.62)	2.86 (3.62)
DASS-A	7.71 (9.20)	2.57 (3.41)
DASS-S	9.71 (6.47)	9.14 (7.90)
EHI	48.00 (63.14)	45.00 (65.34)
HSESI	41.62 (15.75)	53.62 (12.32)
MEQ	193.57 (25.11)	175.14 (33.72)
PPVT	168.88 (18.04)	170.14 (28.99)
PSS	12.00 (6.32)	10.86 (5.79)
RRS	36.43 (10.86)	31.43 (7.09)
SDQ Total	7.86 (6.47)	9.86 (5.05)
SDQ-E	3.62 (3.50)	5.57 (3.51)
SDQ-I	3.25 (3.33)	4.29 (4.07)

Note. DASS = *Depression Anxiety Stress Scale* (Lovibond & Lovibond, 1995); DASS-D

= *Depression* subscale of the *Depression Anxiety Stress Scale*; DASS-A = *Anxiety*

subscale of the *Depression Anxiety Stress Scale*; DASS-S = *Stress* subscale of the

Depression Anxiety Stress Scale; EHI = *Edinburgh Handedness Inventory* (Oldfield,

1971); HSESI = Modified *Hollingshead Socioeconomic Status Inventory* (Bornstein et al., 2003); MEQ = *Music Experience Questionnaire* (MEQ; Werner, Swope, & Heide, 2006); PPVT = *Peabody Picture Vocabulary Test – IV* (Dunn & Dunn, 2007); PSS = *Perceived Stress Scale* (Cohen, Kamarck, & Mermelstein, 1983); RRS = *Ruminative Responses Scale* (Nolen-Hoeksema, 1991); SDQ = *Strengths and Difficulties Questionnaire* (Goodman, 1997); SDQ Total = *Total* score for the Strengths and Difficulties Questionnaire; SDQ-E = *Externalizing* score for the Strengths and Difficulties Questionnaire; SDQ-I = *Internalizing* score for the Strengths and Difficulties Questionnaire.

2.3 Ethical Considerations

This study has obtained ethical clearance from the Carleton University Research Ethics Board. The parent/guardian of children in the study signed informed consent forms. Children provided verbal assent. Upon completion of the study, participants were financially compensated for their time (flat rate of \$15) and transportation costs to and from the NICER Laboratory, and the child selected from a series of toys that were donated to the laboratory. The parents'/guardians' and the children's participation in the study was completely voluntary and they had the right to withdraw at any time. All personal information that was collected will be kept anonymous, in a locked cabinet for seven years, and will be kept strictly confidential.

2.4 Screening Measures Used for Matching Participants

The questionnaires listed below were used only to match participants between groups and were not used as outcome variables.

2.4.1 Edinburgh Handedness Inventory (EHI).

The EHI is a 10-item quantitative assessment of handedness with two additional items that relate to the feet and eyes (Oldfield, 1971). These additional items were not analyzed in this study since they do not directly measure handedness. A modified version of the EHI was used, where the parent/guardian responded on the child's behalf. The EHI response options for this modified version were "always left", "usually left", "no preference", "usually right", "always right", and "no experience". Four additional questions were asked to enquire whether the father, mother, brother(s) and/or sister(s) of the child is/are left-handed. The response options were "yes" and "no". The answers to these four questions were not included in scoring the EHI.

To minimize a possible source of variance in our data, the EHI was used to screen for right-handers, which was determined as at least 40% handedness in the Laterality Quotient of this inventory (Oldfield, 1971). The scores range from -100 (extremely left-handed) to +100 (extremely right-handed). A score of zero was not identified with a label by Oldfield (1971).

The EHI is the most widely used tool to assess handedness in neuroscience and psychology laboratories (Edlin et al., 2015). To demonstrate how often this tool is used, a Web of Science search conducted on July 18, 2016 showed that the EHI has been cited in the literature over 18,200 times.

2.4.2 Hollingshead Socioeconomic Status Inventory (HSESI).

The modified HSESI enquires about the marital status, education, employment status, and occupation of the child's parents/guardians to measure socioeconomic status (Bornstein, Hahn, Suwalsky, & Haynes, 2003). It was filled out by the parent/guardian of the child. A

composite score is obtained by combining the subcategories of the HSESI. The marital status of the child's parents determined if an average score (if married) or not (if not married) needed to be calculated. Education was scored on a 7-point scale ranging from 7 (graduate professional training or graduate degree obtained) to 1 (less than seventh grade education). The occupation type was ranked on a hierarchy ranging from 9 (e.g., higher executive, proprietor of large businesses, major professional) to 1 (e.g., farm laborers, menial service workers, students, housewives, no regular occupation). To determine the total score for the parent, the education score was multiplied by 3 and the occupation score was multiplied by 5, and then these scores were added together.

2.4.3 Music Experience Questionnaire (MEQ).

The MEQ is a 53-item questionnaire used to measure reactions to music (Werner, Swope, & Heide, 2006). The MEQ has six scales, which are:

1. *Commitment to Music*, pursuing musical experiences in one's life. (Sample item: "It is important for me to see music being performed and not just hear it.")
2. *Innovative Musical Aptitude*, the ability to perform musically and the ability to create musical themes. (Sample item: "People have applauded my performance of music.")
3. *Social Uplift*, experiencing an uplifted feeling through music in a group setting. (Sample item: "I wish my family had sung together more when I was growing up." [Reverse-scored].)
4. *Affective Reactions*, reacting to music in a spiritual or affective manner. (Sample item: "I love some kinds of music.")

5. *Positive Psychotropic Effects*, reactions to music that are soothing, energizing, or integrative. (Sample item: “Music unites my mind and my body.”)
6. *Reactive Musical Behavior*, reactions involving movement, which include humming and swaying to the sound of music. (Sample item: “Certain music draws me strongly to dance.”)

Responses were presented on a 5-point Likert-type scale, where 1 = very untrue, 2 = somewhat untrue, 3 = equally true and untrue; unsure, 4 = somewhat true, and 5 = very true. The total score was obtained by reverse scoring negatively worded items and summing all items across the six scales.

2.4.4 Perceived Stress Scale (PSS).

The PSS measures the degree to which situations in one’s life are appraised as stressful (Cohen, Kamarck, & Mermelstein, 1983). It is the most popular scale for measuring stress (Karam et al., 2012). Originally, Cohen et al.’s (1983) PSS had 14 items, but it was reduced to 10 items. The 10-item PSS has superior psychometric properties compared to the 14-item PSS (Lee, 2012), and its inferences appear valid (Taylor, 2015). As such, the 10-item PSS was used in this study.

The items on the PSS examine to what extent a person’s life is unpredictable (e.g., “In the last month, how often have you been upset because of something that happened unexpectedly?”), uncontrollable (e.g., “In the last month, how often have you felt that you were unable to control the important things in your life?”), and overloaded (e.g., “In the last month, how often have you felt difficulties were piling up so high that you could not overcome them?”). Responses were presented on a 5-point Likert-type scale, where 0 = never, 1 = almost never, 2 = sometimes, 3 = fairly often, and 4 = very often. Four of the

items in the PSS were positively stated (e.g., “In the last month, how often have you felt that things were going your way?”) instead of being negatively stated, so the responses for these items were reverse scored (i.e., 0 = 4, 1 = 3, 2 = 2, 3 = 1, and 4 = 0) to maintain scoring consistency. To obtain the overall PSS score, the value assigned to these responses were reversed, and then summed across all the scale items.

The PSS was designed to be used on community samples that have at least a junior high school education. Since the participants in our study were children between the ages of 9 and 12, and since these children had not yet completed junior high school, the PSS was filled out on their behalf by their parent/guardian.

2.4.5 Ruminative Responses Scale (RRS).

The tendency to ruminate (i.e., a way of responding to distress, where a person repetitively and passively focuses on the symptoms of distress and on its possible causes and effects; Nolen-Hoeksema, Wisco, & Lyubomirsky, 2008) was assessed by the RRS (Nolen-Hoeksema, 1991). The 22-item RRS was filled out by the parent/guardian of the child, where the parent/guardian was asked to indicate how often their child engaged in ruminative thoughts or behaviours when their child felt sad or blue. Responses were presented on a 4-point Likert-type scale, where 1 = almost never, 2 = sometimes, 3 = often, and 4 = almost always. A sample item was “When faced with problems, I think about my feelings of fatigue and achiness”. The total score was obtained by adding the scores for all items. There were no reverse-coded items.

2.4.6 Depression Anxiety Stress Scale (DASS-21).

The DASS-21 has three scales, which assess depression, anxiety, and stress (Lovibond & Lovibond, 1995). The DASS-21 has satisfactory psychometric properties, and

exploratory and confirmatory factor analysis has supported its factor structure (Lovibond & Lovibond, 1995). The DASS-21 contains 21 negative emotional symptoms. The parent/guardian of the child rated the degree to which their child had experienced each symptom during the previous week. A 42-item DASS also exists, but for the interest of time, we decided to use the shorter version.

Responses were presented on a 4-point Likert-type scale, where 0 = did not apply to me at all, 1 = applied to me to some degree, or some of the time, 2 = applied to me to a considerable degree, or a good part of the time, 3 = applied to me very much, or most of the time. There were seven items in each scale of the DASS-21. Each score was multiplied by 2 since we used a shortened version of the DASS-42. Each scale had a possible score that ranged from 0 to 42.

2.4.7 Strengths and Difficulties Questionnaire (SDQ).

The SDQ is a 25-item questionnaire that has been validated for use on children between the ages of 4 and 16 years of age (Goodman, 1997). It is divided into five scales, which assess emotional symptoms, conduct problems, hyperactivity-inattention, peer problems, and prosocial behaviour. There are five items per scale. Two versions of the SDQ exist: a parent version (intended to be filled out by parents with a child aged 11 years and under) and a child version (intended to be filled out by children over the age of 11). Both the parent version and child version of the SDQ have the same questions and categories with only minor changes in the terminology (for example, the word “children” is replaced with the word “youth”). Since our target age group for this study was on the lower end of the age group (i.e., 9 to 12 years), we did not feel it was necessary to provide both versions of the SDQ. Only the parent version was administered.

The total difficulties score was obtained by adding scores from all scales, except the prosocial scale. The possible score range is between zero and 40, and was recorded as missing if one of the four scales was missing. The externalizing score was the sum of the conduct problems and hyperactivity scales. The internalizing score was the sum of the emotional symptoms and peer problems scales. Both the externalizing and internalizing scores have a possible range of zero to 20 each, with a higher score indicating more difficulties. A supplement page contained seven additional questions to provide a possible impact score ranging from zero to 10, using the same method for scoring as the previous SDQ scales. If the parent selected “No” for the first supplemental question (i.e., “Overall, do you think that your child has difficulties in one or more of the following areas: emotions, concentration, behavior or being able to get on with other people?”), then the child automatically received a score of zero for the impact score and the parent did not need to answer the remaining supplemental questions. A higher impact score indicates more difficulties.

2.5 Event-Related Potentials

2.5.1 Auditory Go/No-Go task.

Prior to the auditory Go/No-Go task, participants underwent a pediatric hearing test using the GSI 61 audiometer (Grason-Stadler, Eden Prairie, MN, USA) to ensure their hearing was within the typical hearing range (i.e., the children could hear the tone anywhere between -10 to 25dB). Children were tested at 20dB Sound Pressure Level (SPL) with pure tones within the range of 500 to 4000Hz in each ear. Children were instructed to listen and push a button whenever they heard the tone. To prevent movement and to

ensure children would have their back facing the researcher, a sticker was placed on the wall where children were told to maintain their focus.

Prior to the testing portion of the Go/No-Go task, children took part in a practice session of four blocks of 10 trials, which gave a total of 40 trials. The first block was paired with visual feedback by flashing the word “GO!” during the go trials. All blocks after that and the test trials did not contain any visual feedback. Children were asked to stay as still as possible and look directly ahead at the white cross fix on the black screen. They were asked to respond by pressing a green button on the response pad using their dominant hand.

The Go/No-Go task tested the children’s auditory selective attention, working memory, inhibition, and reaction times, where the children were asked to respond to the Go tone (either a pure tone at 1100Hz or 2000Hz depending on the block) by pressing a button and withholding their response to the No-Go tone, which was the pure tone at the other frequency (either a pure tone at 1100Hz or 2000Hz depending on the block). The children were asked to respond as quickly and accurately as possible. Each stimulus was presented for 100ms and the interstimulus interval was 1000-1400ms. An interval was used for the interstimulus to increase the likelihood that the participant is responding or withholding their response due to the tone being presented and not due to random behavioural responses. The attended sound was presented 70% of the time (Go trial); whereas the unattended sound was presented 30% of the time (No-Go trial). Four blocks of 100 trials were presented giving a total of 400 trials, with two blocks having the Go tone as 1100Hz and the remaining two blocks having the Go tone as 2000Hz. The classification of the Go and No-Go sounds were randomized across blocks and

participants. Children were presented with the Go and No-Go sounds prior to completing a testing block, and were given the option of having them repeated before beginning the task. Accuracy and reaction times were recorded.

2.5.2 EEG recording.

Participants were fitted with a noninvasive 32-channel Brain Vision actiCAP electroencephalography (EEG) cap (actiCAP, Brain Vision LLC, Morrisville, NC, USA). All electrodes were inserted into their appropriate location on the cap, using a referential montage and the International 10-20 system (see Figure 1; Picton et al., 2000). Two additional drop-down electrodes were placed on the outer canthi of the eyes, along with the ground electrode which was placed on the participant's left collarbone. It was ensured that electrical impedances were kept below 5 k Ω . Low impedances help provide an effective electrical signal and they may reduce bioelectric noise in the recorded data (Luck, 2005).

A biological calibration was completed prior to testing. Artifact correction for blinks, horizontal and vertical eye movements, and interpolation of noisy EEG raw data for specific electrodes were completed using Brain Electrical Source Analysis (BESA, GmbH Freihamer Str. 18 82166 Gräfelfing, Germany) based on the 32-channel configuration. The classification of artifacts required that they match the prototypical artifacts set out by BESA with a minimum threshold of 80%, which increased the likelihood that true artifacts were removed. Filters had a High cutoff of 20 and a slope of 12dB/octave.

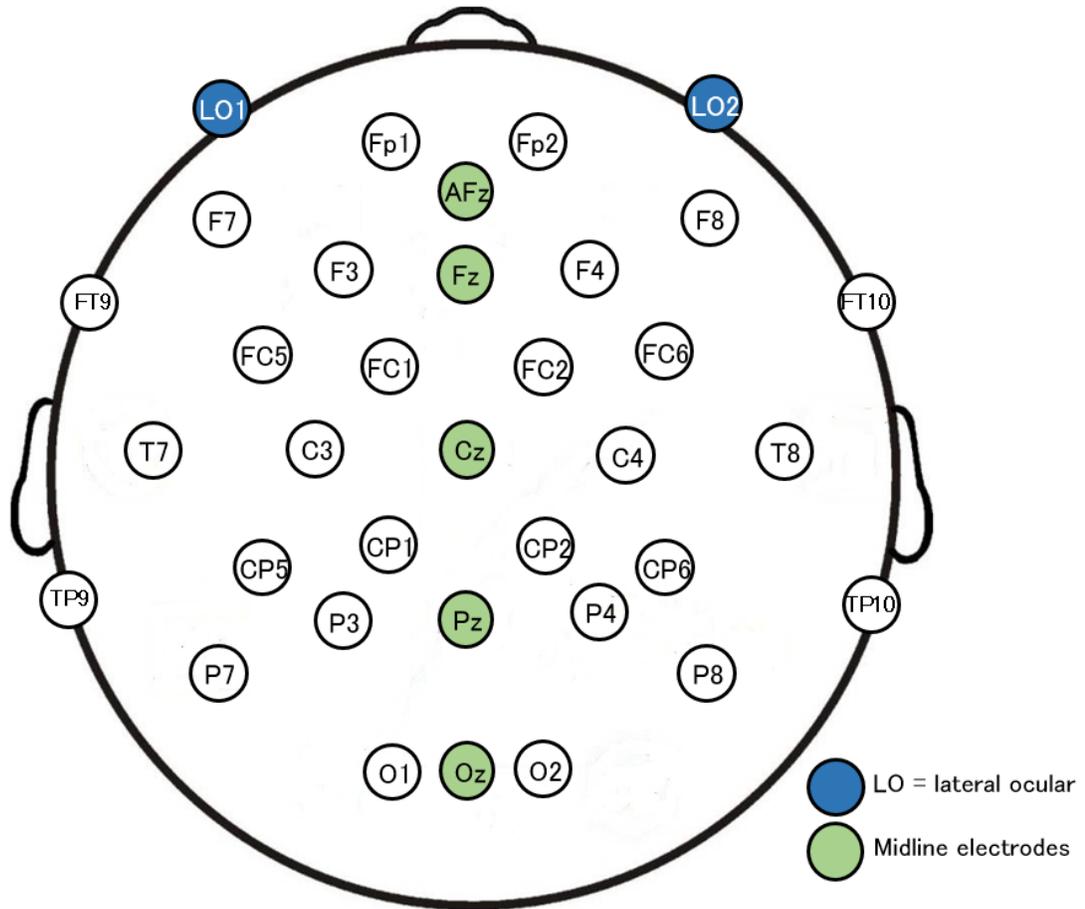


Figure 1. Top view of the head displaying the International 10-20 electrode placement system for a 32-channel EEG cap. Electrode positions are represented as small circles. The following nomenclature applies to the labelling of the electrodes: Frontal pole (Fp), Frontal (F), Frontocentral (FC), Central (C), Parietal (P), Centroparietal (CP), Temporal (T), Parietal (P), Temporoparietal (TP), and Occipital (O). Lateral ocular (LO) electrodes are shown in blue. Midline electrodes are shown in green, and their labels are followed by the letter z, which stands for zero. Odd number labels represent the electrodes that are placed over the left hemisphere, and even numbers represent those over the right hemisphere.

2.6 Analytic approach

Participants involved in OrKidstra were matched with the comparison group in terms of age, sex, and across all screening measures, as much as possible (see Table 1). This ensured that the differences we saw in the ERP data during the auditory Go/No-Go task were more likely due to underlying neural differences between groups. A time series analysis of the individual and group averaged ERP data points (1200 data points per group) was simplified using a standard binning (or vincentization) procedure. Through vincentization (Ratcliff, 1979), 25ms consecutive bins were assigned that covered the entire epoch (-200 pre-stimulus to 1000ms post-stimulus), and averaged amplitudes were assessed for 26 electrodes that recorded evoked activity from regions of interest. This included all electrodes, except ground, reference, eye electrodes, and three occipital electrodes. The average waveforms for all channels were computed for the OrKidstra group and comparison group separately by tone frequency and Go/No-Go condition, and were partitioned into averaged 25ms bins, producing 48 time intervals.

Exploratory MANOVAs showed no relationships between questionnaire variables and behavioural or ERP data primarily due to low statistical power (more variables than subjects!), hence, we did not pursue the multivariate analysis approach further.

ANOVAs and contrasts were conducted based on the ERP binned data and by item analysis, which is a standard method of analyzing neuroimaging data (see Bedny, Aguirre, & Thompson-Schill, 2007). As applied to our study, the 25ms bins that included ERP grand averaged data across all participants for each electrode were treated as random variables (“the subjects”). By doing so, the results of the study could be generalized to both subjects and items. Additionally, the same partitioned variance could

be used to support hypothesis testing for either sampling distributions when using the appropriate degrees of freedom (df).

3 Chapter: Results

3.1 Behavioural Findings

There were no significant differences for the mean reaction times and the mean accuracy in the Go/No-Go task as a function of tone (1100 vs. 2000Hz) and Go/No-Go conditions between OrKidstra ($M_{RT} = 479.49\text{ms}$; $SD_{RT} = 62.12$; $M_{Accuracy} = 92.53$; $SD_{Accuracy} = 12.86$) and the comparison group ($M_{RT} = 492.93\text{ms}$; $SD_{RT} = 65.03$; $M_{Accuracy} = 94.42$; $SD_{Accuracy} = 8.17$).

In the pediatric hearing test, all participants displayed thresholds that were within the typical hearing range for their age. However, after performing a 2-block stepwise mixed-model GLM analysis (P_F : entry = .05, removal = .10), the combined auditory thresholds were significantly lower for the OrKidstra children (*mean threshold difference* = - 4.45dB; $CI_{95\%} = [-0.35, -8.86]$; $F(1,14) = 4.74$; $MSE = 166.10$; $p < .05$) than the comparison children for tones at 500, 1000, and 2000Hz, but not when tones at 4000Hz were entered into the second model (*mean threshold difference* = - 3.92dB; $CI_{95\%} = [-0.29, -8.13]$; $F(1,14) = 4.04$; $MSE = 202.08$; $p = .07$). No significant effects for the side of auditory stimuli presentation (left vs. right ear) were found. The interactions between group and tone were also nonsignificant.

3.2 ERP Patterns

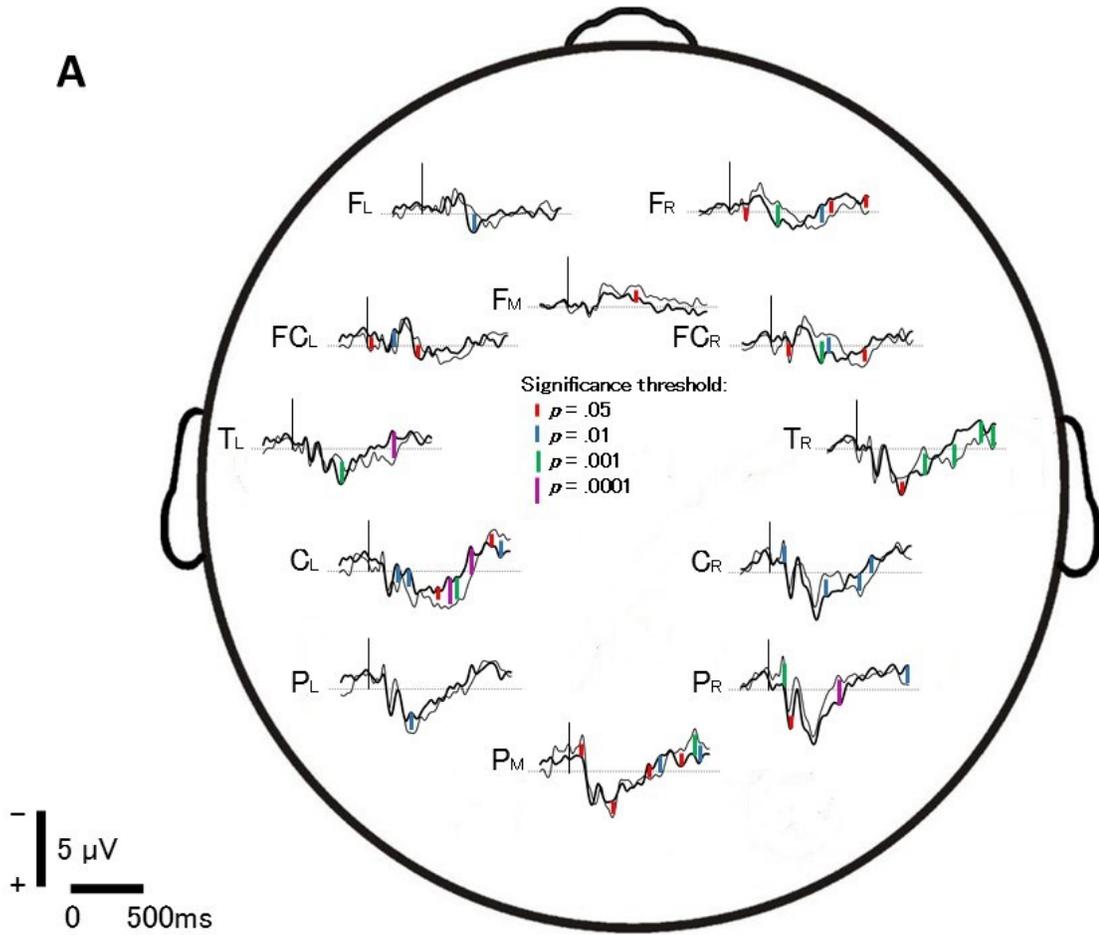
An omnibus analysis was conducted for exploratory reasons using a mixed-model four-way (Type III SSE; Greenhouse-Geisser within-subjects correction) ANOVA with the following factors: Electrode (within-subjects: 26 electrodes) \times Tone (within-subjects:

1100 vs 2000Hz) \times Condition (within-subjects: Go vs No-Go) \times Group (between-subjects: OrKidstra vs Comparison). The main effects were all significant (All F s (1, 47) > 8.74 ; MSE s > 91.86 ; all p s $< .05$), except for the main effect of Tone ($F(1,47) = 3.83$; $MSE = 83.11$; $p = .06$). The four-way interaction was nonsignificant. The only significant three-way interaction was for the interaction of Electrode \times Tone \times Group ($F(1, 47) = 2.91$; $MSE = 79.29$; $p = .01$). The following two-way interactions were found to be significant: Electrode \times Group ($F(6.5, 47) = 3.04$; $MSE = 153.71$; $p = .01$), Condition \times Group ($F(1, 47) = 24.92$; $MSE = 91.86$; $p = .001$), and Tone \times Condition ($F(1, 47) = 31.93$; $MSE = 91.86$; $p < .001$). There were no other significant effects.

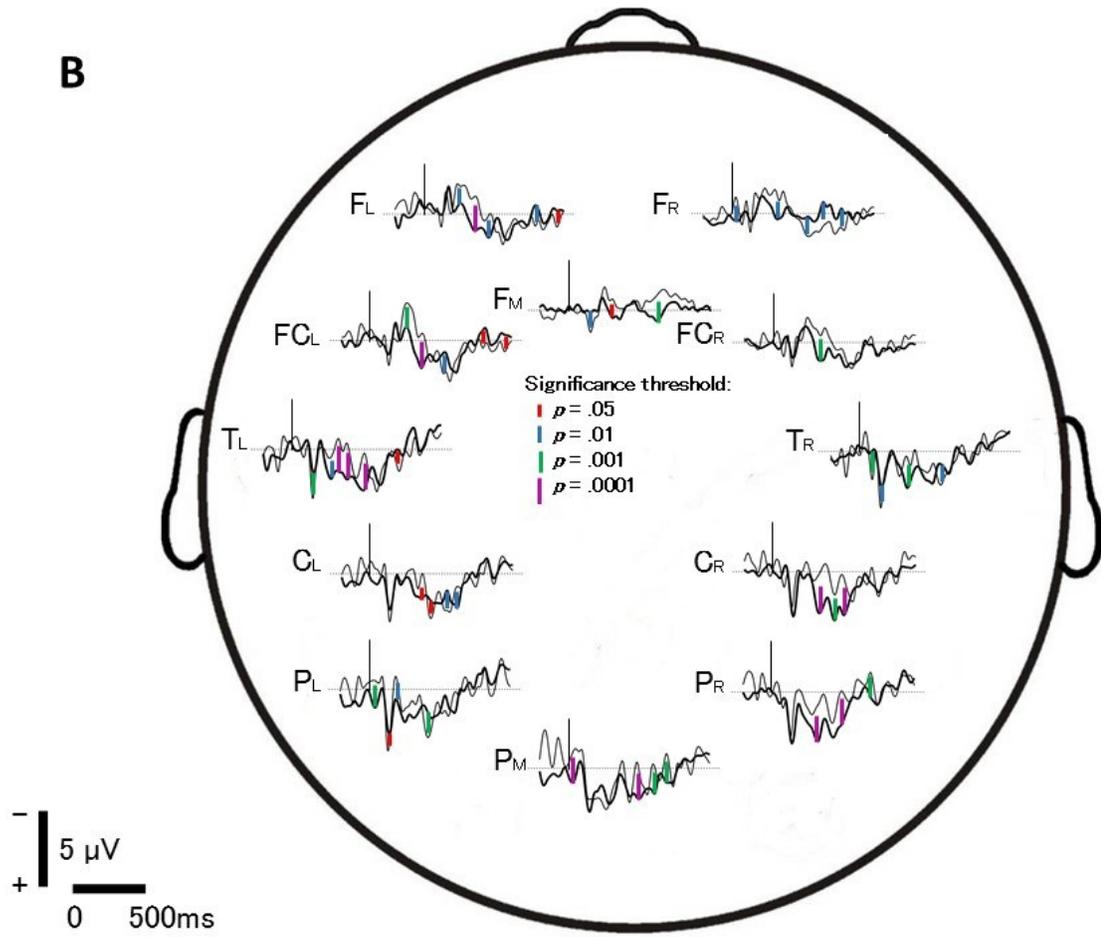
To simplify the interpretive complexity of the multiple interactions and to test the more specific predictions, simple significant ERP amplitude thresholds were calculated for binned intervals using focused ANOVA-based contrasts and the combined graphic “stick-measure” method, as described in D’Angiulli, Griffiths, and Marmolejo-Ramos (2015) and Marmolejo-Ramos et al. (2015). As applied to this study, the difference in absolute mean amplitudes (in μ V) between groups was calculated for the 48 binned intervals by computing the mean difference between pairs of same time-interval bin microvolt values. Then, focused t -contrasts between the paired binned mean amplitudes were conducted. The error factor entered in the contrasts was the highest-order (four-way) interaction MSE obtained from the omnibus analysis ($MSE = 80.97$) so that the minimum significant standardized absolute difference could be derived by the critical significance threshold at 0.05 ($t_{crit}(47) = 2.01$, two-tailed). Mean ERP amplitude differences were represented graphically using different coloured vertical distance-bars in Figures 2(a)-2(d), with significant differences corresponding to 0.80μ V ($p = 0.05$, red;

$t(47) = 2.01$), $1.1 \mu\text{V}$ ($p = 0.01$, blue; $t(47) = 2.68$), $1.4 \mu\text{V}$ ($p = 0.001$, green; $t(47) = 3.51$), and $1.7 \mu\text{V}$ ($p = .0001$, purple; $t(47) = 4.25$). In these figures, the grand average ERP data from single electrodes were re-averaged, relabelled and redrawn as twelve EEG source imaging (ESI) sets (i.e., Frontal Left, Frontal Right, Prefrontal Left, Prefrontal Right, Temporal Left, Temporal Right, Central Left, Central Right, Parietal Left, Parietal Right, Frontal Midline, and Parietal Midline), which are topographically equivalent to the original twenty-six sites (see Figure 2 caption). In terms of latency, the patterns of differences in ERP activity were summarized with the help of figures and organized by three time-windows: *Pre-P300* (0 to 249ms), *P300* (250 to 499ms), and *Post-P300* (500 to 1000ms). The probability of obtaining significant ps was controlled by binomial permutation testing (Ernst, 2004; i.e., the chance of our number of effects over 2304 comparisons not being significant was extremely small $p < 1.0 \text{ E-}8$).

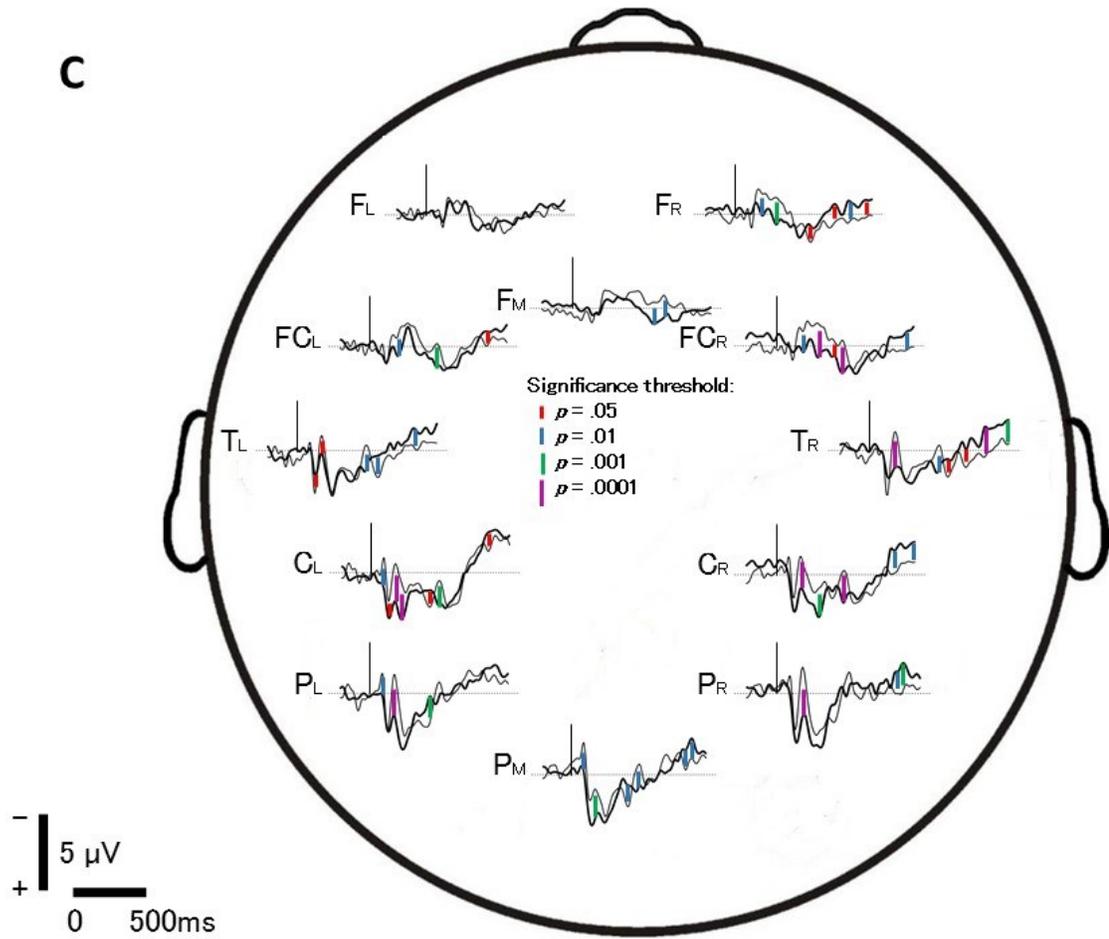
A



B



C



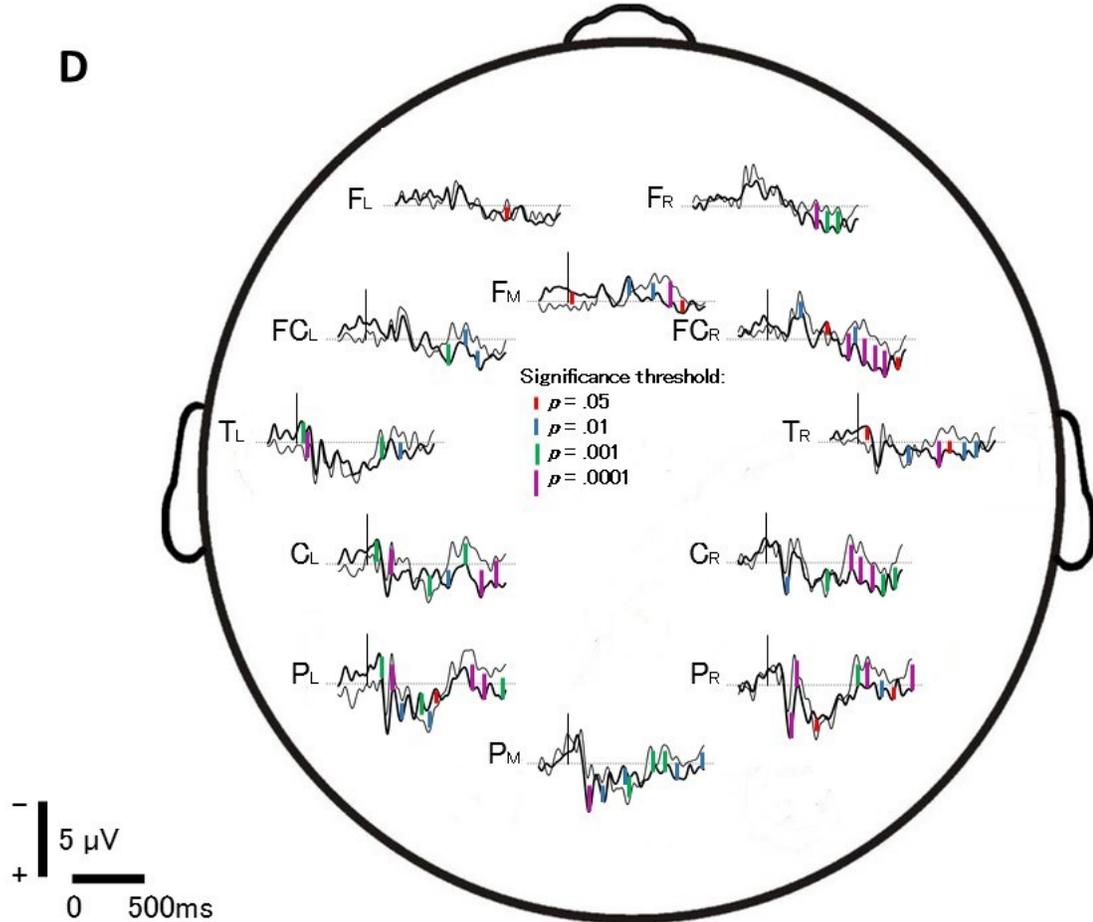


Figure 2. Top view of the head showing averaged tone-locked ERPs for the auditory Go/No-Go task from selected scalp sites using a 32-channel EEG cap with the International 10-20 electrode placement system. Grand averaged ERPs are shown in different panels for the following stimuli: (a) Go tone at 1100Hz; (b) No-Go tone at 1100Hz; (c) Go tone at 2000Hz; and (d) No-Go tone at 2000Hz for OrKidstra (thicker ERP line) and for the comparison group (thinner ERP line). ERP data from single electrodes were subdivided by averaging in twelve EEG Source Imaging (ESI) sets, relabelled and [computed]. The electrode positions with their nomenclature, which appears on the right-hand side of each equation, are as follows: *Frontal Left* (FL = [F3 +

F7]/2), *Frontal Right* (FR = $[(F4 + F8)/2]$), *Prefrontal Left* (FCL = $[(FC1 + FC5)/2]$), *Prefrontal Right* (FCR = $[(FC2 + FC6)/2]$), *Temporal Left* (TL = $[(T7 + FT9 + TP9)/3]$), *Temporal Right* (TR = $[(T8 + FT10 + TP10)/3]$), *Central Left* (CL = $[(C3 + CP1 + CP5)/3]$) and *Central Right* $[(C4 + CP2 + CP6)/3]$, *Parietal Left* (PL = $[(P3 + P7)/2]$), *Parietal Right* (PR = $[(P4 + P8)/2]$), *Frontal Midline* (FM = Fz), and *Parietal Midline* (PM = Pz). Effect size thresholds for ERP amplitude differences are shown using different coloured distance-bars (drawn to scale in relation to $5 \mu V$). The thin vertical black line indicates when the stimulus was presented (i.e., 0ms for the epoch).

3.2.1 Early potentials differences (pre-P300).

Early amplitude differences (EPs) were observed bilaterally in the prefrontal and right centroparietal electrodes for the 1100Hz Go condition (see Figure 2a) between children in the OrKidstra and comparison groups. In terms of polarity, the OrKidstra children showed delayed deflections with positive polarity and smaller deflections with negative polarity in the centroparietal electrodes relative to the comparison children. In contrast, EPs were observed between groups for all the left electrodes of interest, except the left central electrodes, and in the right prefrontal and centroparietal electrodes for the 1100Hz No-Go condition (see Figure 2b). The OrKidstra children displayed smaller EPs bilaterally in the frontal electrodes, smaller P100 and larger P200 peaks bilaterally in temporal electrodes, and smaller P100 and N200 peaks in the left parietal electrodes, relative to their counterparts.

EPs were also found for all electrodes except the left frontal electrodes between groups for the 2000Hz Go condition. In this condition, the largest effects were observed in the left parietal, right central, and temporoparietal electrodes (see Figure 2c), where the

OrKidstra children showed larger P200 and P200-like and N200 and N200-like deflections. For the 2000Hz No-Go condition, EPs between groups were observed bilaterally for all posterior electrodes, but not the prefrontal and frontal electrodes, and the largest differences were found in the left central and temporoparietal and right parietal electrodes (see Figure 2d). The N200/P200 peaks were smaller on the left side but larger on the right side for the OrKidstra children compared to their counterparts.

3.2.2 P300 differences.

Significant amplitude differences were found in the P300 window between groups for three of the conditions in the anterior electrodes (bilaterally for 1100Hz Go, [see Figure 2a]; bilateral frontal and left prefrontal electrodes for 1100Hz No-Go [see Figure 2b]; right frontal and prefrontal electrodes for 2000Hz Go condition [see Figure 2c]).

However, a clear P300 morphology was displayed only in OrKidstra children.

Additionally, in these conditions, parietal, temporal, and central electrodes showed clear P300 differences between groups. The general pattern was that OrKidstra children displayed earlier larger or delayed smaller P300 components typically in the temporal and parietal electrodes of either side.

P300 differences were observed in the left centroparietal and right parietal electrodes for the 2000Hz No-Go condition (see Figure 2d). In this condition, the OrKidstra children did not display a clear P300 signature in the right central electrodes during the P300 time window, but the comparison children did. The OrKidstra children, relative to the comparison children, displayed smaller P300 components with similar latencies in the left central electrodes and smaller earlier P300 components in the left and right parietal electrodes.

3.2.3 Differences in late potentials (post-P300).

Significant late potential amplitude differences (LP) were found between groups in the left central electrodes for the 1100Hz Go condition (see Figure 2a). OrKidstra children tended to display LPs with an earlier latency, relative to the comparison children. LPs were displayed bilaterally for the 1100Hz No-Go condition, in all but the left parietal and right prefrontal electrodes (see Figure 2b). Delayed LPs were present in the frontocentral electrodes and earlier LPs in the temporal electrodes for the OrKidstra children, relative to the comparison children. There were no clear LP patterns observed for the right hemisphere. In this hemisphere, the OrKidstra children had varied LPs with latency shifts in the temporal electrodes (delayed) and in the central electrodes (early).

In the 2000Hz Go condition (see Figure 2c) and No-Go conditions (see Figure 2d), LPs were observed bilaterally for all electrodes, except for the left frontal electrodes in the Go condition. Relative to their counterparts, the OrKidstra children generally had larger but delayed amplitudes in the more anterior electrodes and smaller earlier amplitudes in the more posterior electrodes. This pattern was observed fairly consistently in both hemispheres.

3.2.4 Topographic ERP patterns.

Figure 3 presents a visual summary of the ERP results in terms of topographic patterns across the three time windows examined in the Go (panels A and C) and No-Go (panels B and D) conditions. The patterns in each headmap represent integrated (i.e., synchronized) or isolated ERP effects as overlapping or separate foci of activity (represented by circles/ovals). Considered over time windows (i.e., pre-P300, P300, post-P300) depict spread of ERP activity across the scalp. The OrKidstra children appear to

have higher levels of overlapping spread of neural activity in the pre-P300 and post-P300 time windows when compared to their counterparts.

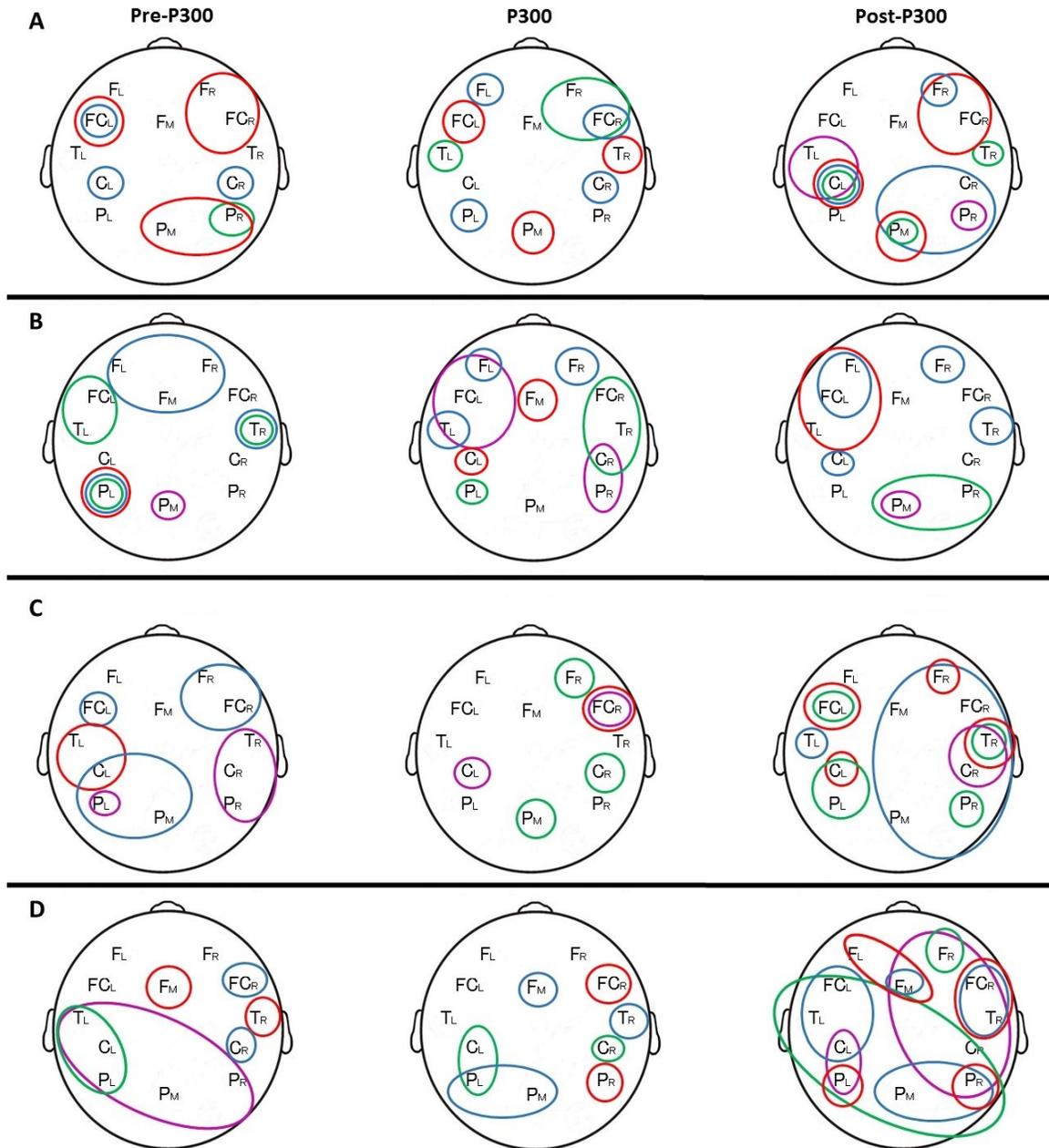


Figure 3. Top view of the head showing the spread of neural activation in terms of the effect size of ERP amplitude differences between OrKidstra and the comparison group. The different panels represent the different conditions: **(a)** Go tone at 1100Hz; **(b)** No-Go tone at 1100Hz; **(c)** Go tone at 2000Hz; and **(d)** No-Go tone at 2000Hz. ERP activity is shown for pre-P300, P300, and post-P300 latencies for each condition. Round coloured circles/ovals represent the different effect size thresholds for the ERP amplitude

differences, which correspond to $0.80\mu\text{V}$ ($p = .05$, red), $1.1\mu\text{V}$ ($p = .01$, blue), $1.4\mu\text{V}$ ($p = .001$, green), and $1.7\mu\text{V}$ ($p = .0001$, purple). The circles/ovals only involve a brain region if they cover the label for that area.

4 Chapter: Discussion

This study tested several hypotheses. First, it was predicted that OrKidstra children, relative to the comparison children, would have superior auditory discrimination on the pediatric hearing test by displaying lower auditory thresholds for tones presented between 500 to 4000Hz. The hypothesis was supported for tones at 500, 1000, and 2000Hz, but not for 4000Hz. This higher auditory sensitivity for the OrKidstra children may be attributed to a near transfer effect of music training on bottom-level sensori-perceptual functions associated with the auditory cortex (Moreno & Bidelman, 2014).

The second hypothesis was that the OrKidstra children would display shorter reaction times but similar accuracy rates for the auditory Go/No-Go task, relative to their counterparts. Shorter reaction times were predicted because the task is auditory and the result of musical production is also auditory, therefore, those with intensive musical training would be expected to perform more quickly than those with no or less intensive musical training. The accuracy rates were predicted to be similar since those without OrKidstra training may still be capable of performing accurately, but just at a slower rate. However, behaviourally, no significant differences were observed between groups in terms of reaction times and accuracy. As such, the differences observed in the ERP patterns were more likely due to underlying neural differences since they cannot be accounted for by their motor response.

The third hypothesis proposed that during the auditory Go/No-Go task the OrKidstra children, relative to the comparison group, would display smaller ERP amplitude peaks, which could be interpreted as more efficient processing, such that fewer cognitive resources need to be used; and that these children would display shorter ERP latencies, which could be interpreted as more automatic processing, where the brain needs less time to respond to a stimulus. This hypothesis was partially supported since the OrKidstra group generally had earlier but smaller pre-P300 waveforms and P300 peaks, but larger prefrontal late positive potentials (post-P300), which are waveforms associated with auditory perception, stimulus evaluation, and inhibitory/response control, respectively. Further research can help examine why the post-P300 potentials tended to be larger and if this pattern still exists in a larger sample size. The results also suggest that there is a global sharing of information when many cortical brain regions are activated in response to the auditory Go/No-Go task.

Moreover, this study examined whether participation in an El Sistema-inspired music program (i.e., OrKidstra) would be associated with changes in children's neural correlates of executive functioning during an auditory Go/No-Go task. The OrKidstra children displayed a greater spread of neural activation than the comparison children. In particular, the ERP activity of the OrKidstra group appeared more distributed and coordinated for the late potentials for the 2000Hz tones, especially for the No-Go condition. In the No-Go condition, the participants are supposed to withhold their response and the late potentials in the No-Go condition are associated with response inhibition. When these late potentials are displayed, the pattern of data suggests that the participants manifest a heightened neural activity globally across many parts of the

cortex. This is consistent with the interpretation that in this late time frame, OrKidstra children may have a heightened level of appraisal or awareness of the auditory task. This explanation is consistent with previous behavioural findings on auditory and musical imagery (Aleman, Nieuwenstein, Böcker, & de Haan, 2000) and the ability of musical experience to increase EEG coherence related to other tasks (Sarnthein et al., 1997).

The present findings connect El Sistema's approach to two important theoretical aspects. First, music plays a role at multiple levels (Hedayati & D'Angiulli, 2015). At the brain level, it affects the brain's structure and function. At the mind level, it affects cognitive processing. At the personal level, it can influence one's thoughts and emotions, as well as the regulation of well-being. At the social level, music enhances social cohesion. Thus, many systems which usually work by segregating information in specific modular neural networks can be simultaneously engaged through music making and training. Furthermore, it is plausible that the synchronized activation is associated with functional integration or broadcasting of information in the brain (for a related argument, see Dehaene, 2014). It is likely that intensive music training, such as participation in OrKidstra, could enhance the integrative functions in children.

Second, the social aspect of OrKidstra that aims to promote well-being may help develop resilience through neuroplasticity and as a result, can positively impact the lives of children living in disadvantaged environments. Moreover, five areas have been identified that characterize human flourishing and well-being: positive emotion, bonding in relationships, engagement, achievement, and meaning (Seligman, 2011). Producing music can positively influence all five areas (refer to Croom, 2012 for a review), which as demonstrated by the implementation of El Sistema in Venezuela (Majno, 2012) could

be a natural intervention method for children growing up in poverty in North America, as well.

A limitation of this study is its small sample size due mainly to recruitment issues such as a difficult commute to the university laboratory for some participants and their families; and the researchers' lack of access to a mobile EEG/ERP unit, which prevented the study from being taken directly to the participants. Although the sample size may appear small, EEG/ERP studies typically report sample sizes that do not appear too large (e.g., mode = 15, median = 20, mean = 34; Yoder et al., 2014), and oftentimes there is often enough power for significant findings.

In conclusion, the present findings show preliminary but plausible evidence for the impact of intensive ensemble music training, following an El Sistema-inspired method, in children's neurocognitive functions. Given the broader implications, the findings contribute to the emerging field of "positive" neuroscience (Kapur et al., 2012) incorporating developmental aspects of child well-being, with a prominent role for socially-based music interventions.

Future research can explore pre- and post-effects of the OrKidstra program, where participants are evaluated before they start the program and then after a year of the program to see what changes are seen within the same individuals over time. Yearly follow-ups can determine the long-term effects of participation in OrKidstra. Children who continue in the OrKidstra program for more than one year can also be compared to children who drop out to see if any differences appear between these participants and if shorter-term exposure to OrKidstra can be as beneficial as longer-term exposure.

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Canada's Capital University

INFORMED CONSENT

Experiment Title: Tone detection and self-regulation training can improve educational performance in children

Faculty Sponsor: Dr. Amedeo D'Angiulli,

Department of Neuroscience Carleton University
1313 Dunton Tower
(613) 520-2600 x 2954

The purpose of this informed consent form is to ensure that you understand both the purpose of the study and the nature of your participation. The informed consent must provide you with enough information so that you have the opportunity to determine whether you wish to participate in the study. Please ask the researcher to clarify any concerns that you may have after reading this form.

Research Personnel:

In addition to the Faculty Sponsor named above, the following people are involved in this research and may be contacted at any time should you require further information about this study:

Principal Investigator: Dr. Amedeo D'Angiulli (amedeo.dangiulli@carleton.ca)
Collaborators: Nina Hedayati (nina.hedayati@carleton.ca)

Purpose:

This study examines how stress changes in young children as they perform cognitive tasks such as those that examine selective attention and shifts of attention, executive function, self-regulation, or learning and whether this can affect a person's performance, subjective experience, brain activity and educational performance. In addition, we are gathering information on socioeconomic status (SES), to determine if there is a relationship between SES, the levels of short-term stress, and electrical brain activity. Furthermore, we would like to look at your and your child's DNA to determine if any genetic variants may have resulted due to stress. Please review the information on DNA attached.

Task:

At the start of the session, you and your child will be asked to participate in a saliva test. This will be analyzed later and used to determine the amount of cortisol in your systems. Cortisol is a naturally occurring hormone that occurs when you are under stress. This part of the experiment consists of spitting into a tube until a certain level (2 ml) is reached. A Powerpoint presentation will be shown to allow you and your child to become familiar with the procedure.

Upon completion of the initial saliva test, you will be asked to complete some questionnaires about your child while your child completes a vision and hearing test (i.e. audiogram). These tests do not have any diagnostic value and are only used for screening purposes for this experiment. If you have concerns after your child completes this part of the test, you can contact your health care professional for follow-up testing. If

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your child's scores show that he/she is not a candidate to participate, you and your child will be excused from the rest of the experiment. The hearing test will screen six pure tone frequencies (250, 500, 1000, 2000, 4000, and 8000 Hz) to determine your child's threshold at each of these frequencies. These tests are child-friendly and are meant to make it an enjoyable experience for your child. Participants must achieve certain scores on these tasks to continue. If your child's scores show that he/she is not a candidate to participate, you and your child will be excused from the rest of the experiment. We will provide you with a letter for your doctor and the results of the test if you wish to get further testing performed. You will still receive your compensation for the number of hours in which you participated.

Although highly unlikely, should the experimenter note any unusual readings during the course of the experiment the study will be stopped immediately. The experimenter is not a physician and cannot make a medical diagnosis. You will be asked to contact your family physician. The researcher will contact your physician in writing explaining why the experiment was stopped. You may not return to the study or undertake any further experiments without the written consent of your physician.

The brain activity recordings that we take are similar to those of routine clinical electroencephalography (EEG) and will be take place in a separate room from the music area. If you wish, you can accompany your child into the testing area. To record the brain responses, electrodes are placed on the scalp and around the eyes. The electrodes on the scalp are kept in place with an elastic cap that fits over the head like a bathing cap. The electrodes around the eyes will be kept in place with double-sided washers and, if necessary, some medical tape. The skin beneath the electrodes is rubbed slightly with a prep pad or Nu-Prep, which contain alcohol and pumice, to remove any dirt or oil before the electrodes are connected to the skin with a double-sided washer. When the electrodes are taken off, any residue can be removed with water. The skin under the electrodes may be slightly red for a little while after the recording but this soon returns to normal. This may require your assistance or the assistance of another researcher so that your child does not become frightened and unwilling to complete the experiment.

Prior to starting the experimental task, the child will repeat the saliva collection procedure as described previously. This will be followed directly by the brain wave recording sessions that will last approximately one hour; however, the length of time varies depending on the tasks that your child will complete and your child's performance. The assignment of each child to an experimental task is random. All children will complete the Peabody Picture Vocabulary Task IV (PPVT-IV) Form B while the brain waves are recorded. After the PPVT, your child will complete one of the auditory experiments which will require your child to either respond to musical instrument tones or watch a silent subtitled movie while musical instrument tones are played in his/her ears.

The recording session have several short blocks, separated by rest periods. Before the blocks begin, a resting EEG will be recorded. Your child will not have to do anything during this time except to remain still. We will record five 1-minute blocks so your child does not have to remain still for a long time. Once this is completed we will begin the experimental blocks. During each block we will measure brain activity and eye movements while your child performs the task presented on insert earphones for the music experiments and on a computer screen for the visual experiment (i.e. PPVT). After the task is completed, your child will repeat the resting state recordings. About 20 minutes

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after completing the task, your child will be asked to repeat the saliva collection as described above.

While your child is completing the experimental portions, you will be asked to answer some simple computerized questionnaires. The socioeconomic questionnaires are designed to measure wealth, housing, education, and occupation. You are not required to answer any questions with which you are uncomfortable; however, answering all the questions provides us with a better understanding of your life situation and better information for analysis. You will also be asked to complete some or all of the following questionnaires on behalf of your child (most of which are fairly short and will only take about 5-10 minutes):

- General Questionnaire
- Edinburgh Handedness Inventory
- Hollingshead Socioeconomic Status Inventory
- Perceived Stress Questionnaire
- Ruminative Responses Scale
- Depression Anxiety Stress Scale (DASS)-21
- Common Language Version of the California Child Q-Set (CCQ)
- Music Experience Questionnaire
- Musician Questionnaire
- Strengths and Difficulties Questionnaire (child only)

When your child has completed the experiment blocks, you will receive more detailed information about the experiment in which your child participated and you and your child will be given the opportunity to ask any questions and provide feedback to the researcher. You and your child will be provided a rest time after the experiment. Prior to leaving we will ask that you and your child provide one more saliva collection.

Duration & Locale:

The experiment will take place at the Leading Note Foundation centres and the NICER lab at Carleton University in Ottawa. You will only need to answer the questionnaires on the first occasion at the Bronson Centre. If your child is part of the pilot project, you will only need to come to Carleton University on one occasion. If your child is part of the main project, your child will repeat the experiment three times over the course of the year. The whole session should take about 2-3 hours.

Remuneration:

You will be given \$15 flat rate for your participation plus costs for your transportation to and from the Bronson Centre to Carleton University.

Potential Risks/Discomfort:

There are no known risks with the procedure. The electrodes for the EEG recordings can be mildly uncomfortable (the skin is rubbed slightly with pumice to remove any dirt or oils that can interfere with the measurements) and the experiment may seem a bit dull because of the repetitive measurements. If, however, your child should feel uncomfortable at any time and wish to end his/her participation in the

experiment, the child or you may notify the researcher and the session will be discontinued.

Anonymity/Confidentiality:

Your and your child's name appears only on this consent form. All other records are identified by an arbitrary identification number, making them anonymous. The consent forms are kept in a locked file cabinet at Carleton University and only accessible to project personnel. After all the data have been collected, the consent forms will be destroyed in accordance with the policies set by Library and Archives Canada. Any personal information collected about you or your child during this study will be kept anonymous, stored in a locked file cabinet at Carleton University for seven (7) years, kept strictly confidential, and will only be used for the purposes of this research. In any publications or presentations that derive from this research, you and your child will not be referred to in any way that will allow your or your child's identification. Furthermore, all data gathered from this experiment will only be made accessible to the researchers involved with this study and to duly authorized authorities at Carleton.

By initialing in the space provided, you consent to the researchers re-contacting you for future research in relation to this project _____ (Initial here please).

If we can contact you through the Leading Note Foundation in regard to future studies, please initial here _____.

Right to Withdraw:

Your and your child's participation in this experiment is completely voluntary. You and your child can withdraw consent and stop participation in this experimental study at any time and for any reason. Such withdrawal from the study will not prejudice in any way your or your child's treatment at Carleton University. If you are receiving compensation for your and your child's participation, withdrawal will not constitute any financial penalty and you will still attain the partial compensation for participation in this study. If there is anything with which you are uncomfortable providing information, you have the right to omit these items without affecting your or your child's participation in the study.

The results of these experiments will not provide any direct benefit to you or your child. However, these results may help us in developing guidelines for learning and development.

Approval:

This study has been approved by and received clearance from the Carleton University Research Ethics Committee (reference #12-0736) and the Biohazards Safety Committee (reference #BC-12-13).

For additional information, please contact:
Dr. Amedeo D'Angiulli at (613) 520-2600 x.2954.

Should you have any ethical concerns regarding this study then please contact:

Dr. Louise Heslop, Chair
Dr. Andy Adler, Vice Chair

Carleton University Research Ethics Board-A
Carleton University Research Ethics and Compliance Office
511 Tory, Carleton University
1125 Colonel By Drive
Ottawa, Ontario, Canada
K1S 5B6
Phone: (613) 520-2600 ext. 2517
Email address of Contact Persons: ethics@carleton.ca

Should you have any other concerns about this study then please contact:

Dr. John Stead
Chair, Department of Neuroscience
331 LSRB
613 520-2600 x8774

Genetic testing: Common questions and concerns

What is DNA?

DNA is a large molecule that contains information necessary for our bodies to build all the components needed for our development, growth and survival. This information is commonly referred to as the genetic code or the DNA sequence. Some rare diseases can be attributed entirely to simple errors in our DNA sequence. However, the majority of common diseases (including depression) are caused by a combination of many different genetic factors, together with environmental factors (how we grew up, life events, etc).

How will my DNA be used?

If you compare any two people, their DNA will be about 99% identical. We are interested in the 1% of DNA that is different between people. Our current plan is to investigate these differences, focusing on just a small proportion of your genes (we are targeting less than 100 of the ~30,000 genes that humans have) which we anticipate may be involved in risk of either anxiety or depression.

We are also planning future follow-up studies on your DNA, which will extend the analysis to substantially more genes – potentially all genes. These future studies will be limited to analyses of the DNA molecule and the genetic code, and will not involve any other use or manipulation of your DNA sample. However, in no case will your samples be kept for more than 3 years, at which time the samples and the sample container will be incinerated. At the end of this form, you have the option to opt-out of any such future uses of your DNA sample.

How long will my DNA be stored, and potentially used in research?

By providing a DNA sample and signing this form, you are indicating that you are willing for us to preserve and analyze your DNA sample for an extended period of time (3 years or less). During this period, use of the sample is guaranteed to be limited to studies that read the DNA molecule.

Will I be told the results of my own genetic analysis?

No. Your DNA sample and genetic information will be identified by a code number, and not your name. This preserves confidentiality of this information. Returning your personal genetic information to you would require that confidentiality to be compromised so will be avoided. Furthermore, as described above, genetic data collected in this study will not allow accurate prediction of whether or not you will develop any disease. It would therefore be irresponsible of the researchers to inform participants that they had a slight increase in susceptibility to disease (as this could cause undue stress to both participants and their families), or that they had increased protection against disease.

What if something unexpected and potentially dangerous is discovered in my DNA?

None of the DNA sites that we plan to analyze are currently known to be predictive of disease with any real accuracy. However, future advances in genetic research could allow disease predictions to be possible based on information from these, or other genetic sites. In exceptional circumstances, if genetic research reveals information about a serious or life-threatening condition that can be prevented or treated through intervention, then we have an obligation to inform you of this information, and potentially also inform your biological relatives who may share similar risk of disease. This would therefore represent a potential breach of confidentiality. In this instance, only information directly relating to disease diagnosis, and participant identity, would be shared.

Can my DNA ever be used to identify me?

This is a complicated question to answer. Unless you have an identical twin (whose DNA will be identical to yours), your DNA is absolutely unique to you. It is this unique nature of genetic material that allows individuals to be identified based entirely on their DNA, through techniques such as DNA fingerprinting. It is therefore theoretically possible that in the future, your identity could be determined from simply analyzing your DNA sample.

It is extremely unlikely, however, that you could be identified based on your DNA sample. In order to identify you based purely on your DNA sample, it would be necessary to compare your DNA sample that you provide today, with another DNA sample from you in a DNA database, which is linked to your identity. DNA databases do exist in countries including Canada, Australia, USA and UK, but are limited to samples from criminal offenders. Access to these databases is strictly limited to law enforcement agencies thus cannot be accessed by researchers. Access to DNA samples taken for this study will similarly be limited to the researchers, and will not be provided to any law enforcement agency unless we become legally obliged to do so (to our knowledge, this has never happened to any research group). Furthermore, these government DNA databases typically contain information about only 13 regions of human DNA, none of which are to be analyzed in the present study.

If you have any additional questions or concerns, please ask the researcher today, or contact any of the principal investigators at a later date.

Right to withdraw from this study

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Participation in this study is entirely voluntary. At any point during the study you have the right to not complete certain questions or to withdraw with no penalty whatsoever. Furthermore, if at a later date you wish to withdraw from the study, you can contact the principal investigators and we will destroy all of your records (questionnaire answers, responses from the interview, plus DNA sample) from this study. The only exception is where data has already been published. In this instance, unpublished data plus your DNA sample will be destroyed.

DNA will be extracted from saliva samples using individually wrapped OG-500 collection kits, purchased from DNA Genotek (Ottawa, ON), shown in the picture below. (For scale, the entire length of the tube is 12 cm.)

Simple instructions (including diagrams) are provided within each kit, printed in 14 languages. The first side of the instructions (7 languages) is shown below, with a larger version of instructions in English underneath.



Declaration of Consent:

I have been provided with a description of the experimental procedures and any possible risks or benefits that might be associated with these procedures. I have been told that confidentiality will be maintained.

I have also been given an opportunity to ask questions concerning these procedures and any questions that I have asked have been adequately answered. I shall be given a copy of this informed consent.

I have been told that I can withdraw my consent and stop my and my child's participation in this experimental study at any time and for any reason. Such withdrawal from the study will not prejudice, in any way, my or my child's treatment at Carleton University.

I understand the information that I have been provided and I voluntarily consent to participate and to have my child participate in this experimental study.

While we would ideally obtain consent to use your DNA for any future research studies that are aimed at analyzing DNA sequence (Option 1 below), please indicate below how you would like your sample to be treated in the future. There are no obligations or penalties for you associated with your selection.

- Option 1: I grant the researcher permission to use my DNA/saliva samples for any future research studies, limited to analyses of the DNA molecule.

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- Option 2: I grant the researcher permission to re-contact me to seek consent to use my DNA/saliva samples in future research studies.

- Option 3: Use of my DNA/saliva sample must be strictly limited to the analysis of <100 genes, as described in the current research plan.

Signatures

I have read the above form and understand the conditions of my participation. My participation in this study is voluntary, and I understand that if at any time I wish to leave the experiment, I may do so without having to give an explanation and with no penalty whatsoever. Furthermore, I am also aware that the data gathered in this study are confidential and anonymous with respect to my personal identity. My signature indicates that I agree to participate in the following:

- a. Questionnaires and ERP
- b. Questionnaires, ERP, and Salivary Cortisol
- c. Questionnaires, ERP, Salivary Cortisol, and DNA as indicated above

Participant's Full Name: _____

Participant's Signature: _____ Date _____

Researcher's Name: _____

Researcher's Signature: _____ Date _____



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CHILD'S ASSENT SCRIPT

Experiment Title: Tone detection and self-regulation training can improve educational performance in children

Faculty Sponsor: Dr. Amedeo D'Angiulli,
(person in charge) Department of Neuroscience Carleton University
1313 Dunton Tower
(613) 520-2600 x 2954

Research Personnel (People that are part of this activity):

In addition to the person named above, the following people are part of this research and may be contacted at any time if you want more information about we are doing:

Principal Investigator: Dr. Amedeo D'Angiulli (amedeo.dangiulli@carleton.ca)
Collaborators: Nina Hedayati (nina.hedayati@carleton.ca)

The reason for what we are doing here is to make sure that you understand why we want to do this and what we are asking you to do if you want to participate. We want to give you enough information so that you have the chance to say whether you want to participate in the study. Please ask me to answer any questions that you may have after or while I tell you about what we want you to do.

We are asking you to be part of this activity. This is not something you usually do like in daycare or with mom and it is not like going out to play or going to the doctor. This is a bit different than any of those. You do not have to be part of this activity if you don't want to.

First, we are going to ask you to spit into a tube. I will show you some pictures so you get to see how it is done. We will ask you to do this several times during your time with us. Your spit will tell us things about what is happening inside your body but I won't be able to tell you because a scientist needs to look at it. This will only take a few minutes each time.

Next, we would like to put this cap on your head. It fits just like a bathing cap (show child the cap and let him/her touch it, hold it, etc.). We are going to put extra of these little circles around your eyes and behind your ears as well (show which ones these are on the cap). These will feel a little bit heavy at first but you will get used to it after you start the activity. Each of these little circles will tell us about your brain but I won't be able to tell you very much because we have to look at it later. I can tell you what your eye blinks look like and what happens when you move around or grit your teeth. Please remember that you do not have to do this and you may stop whenever you want. No one will be upset or angry with you if you want to stop. When the cap is on your head we have to put this stuff inside each little hole (show child the gel/solution) and it will make your hair a bit wet but this will dry up after the cap is taken off. Someone will help me do this so it won't take a long time. Once we have finished, we are going to ask you to look at the monitor and just rest for about 5 minutes. We will stop every minute so that you can move around if you want but we would like you to stay very still for 1 minute and we do this 5 times.

Once this is done, you will play a computer-type game or listen to some sounds. This part will take about 20 minutes. We would like you to try your best and don't worry if you get something wrong. We would like you to try to stay as still as possible when you are doing this part of the task as well. We will tell you what to do at each part so you don't forget. We will then repeat the part where you rest with the cap on your head for 5 minutes.

Now, in order to make these little circles tell us about your brain, we have to make sure they are placed on your head very well. For the little circles on your face, I will have to use this stuff (show child prep pad and let him/her touch it). It cleans the skin really well and takes off anything extra on the skin like oil (can show child how a fingerprint shows up on a glass). Sometimes this pad will make your skin a little bit red but it will not stay that way.

We are getting a lot of children to do this activity so that we can put all the scores together to see what your age group looks like when we look at other age groups. We hope it will tell us about your body and your brain.

We will not tell anyone about your help with this and we won't give the scores to anyone. It is just between us. For example, when you are in a classroom, your answers are not 'anonymous' because there are a lot of other children around you. These scores will be anonymous because no one will know but us.

If you want to stop at any time, all the information about you will be destroyed (i.e. thrown out). If, at any time, something new happens and I did not tell you, you can stop as well.

We are not going to use your name on anything. Instead we will use a number to say who you are. That way no one will know that this is you, except us. We will only use this number on anything where we would normally use a name.

This type of activity has been done lots of times with lots of children and it works very well. Also, you should know that this activity will not be able to give you anything.

If you have any questions, you can call these people and ask questions:

Amedeo D'Angiulli
Nina Hedayati

I have given you their phone numbers and email addresses just in case you have more questions later.

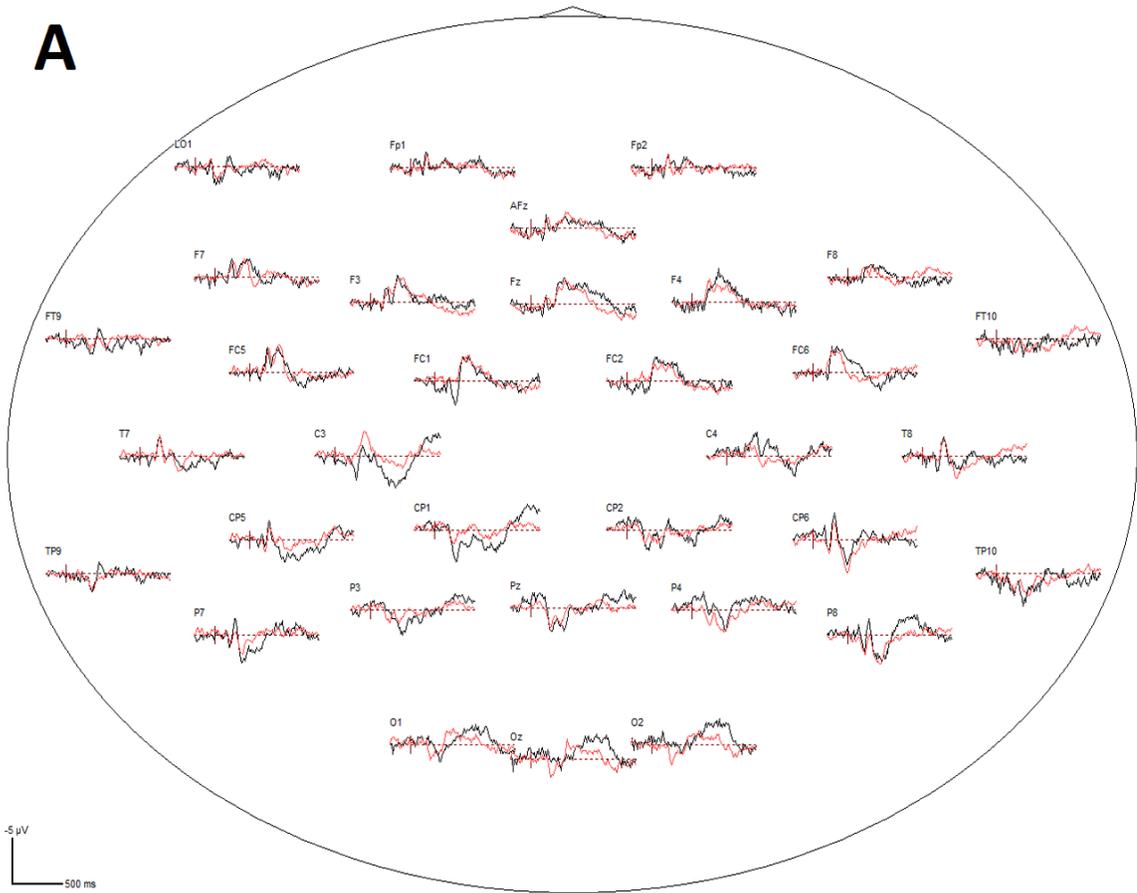
I'm going to give you a copy of this so that you have the phone numbers and the information about what we did today.

Now, I have to ask you some very important questions:
Do you remember everything we have talked about?
Do you need me to explain anything to you again?
Do you want to participate in this activity?

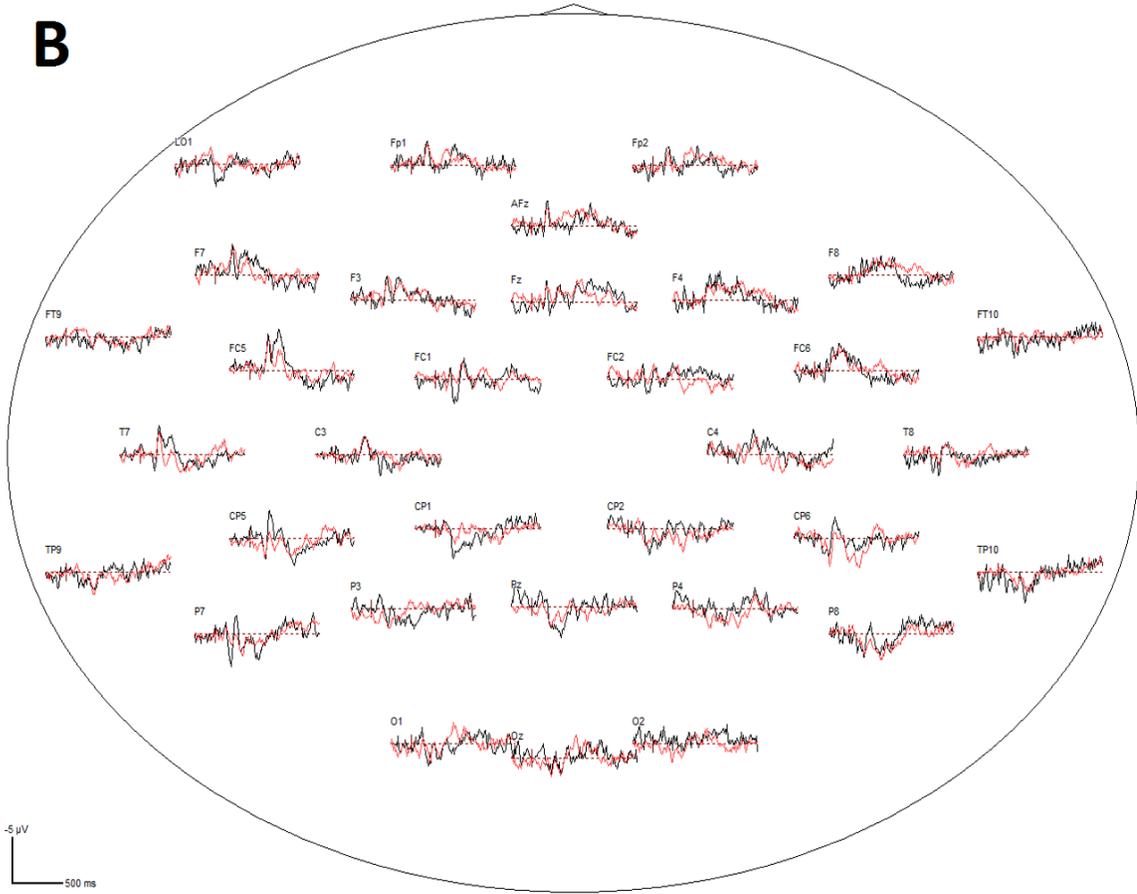
Like how your mom takes care of you, I have a group of people that take care of me and make sure that I don't make mistakes. They have a big name, the Carleton

University Research Ethics Board, and they make sure that I tell you everything and then they say whether or not I can do these activities with children and they have told me it is okay.

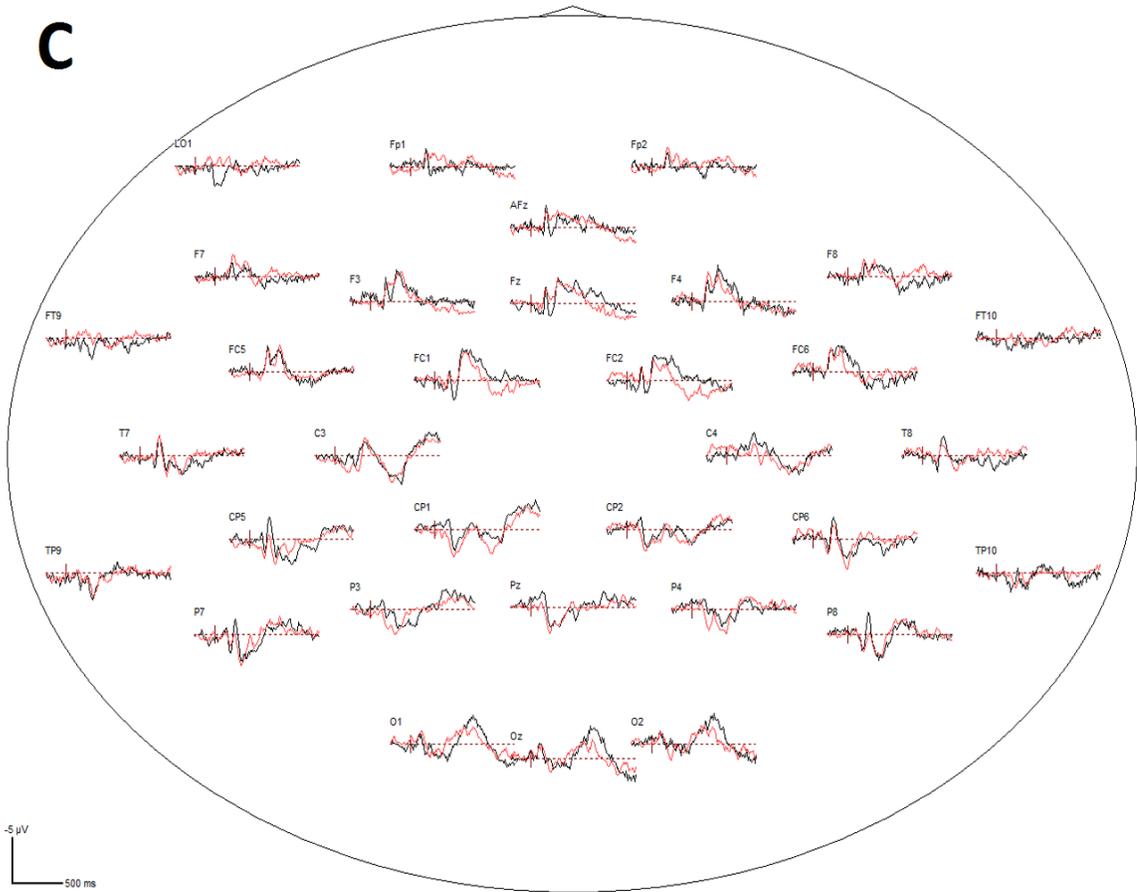
Appendix B: Raw BESA Headmaps



B



C



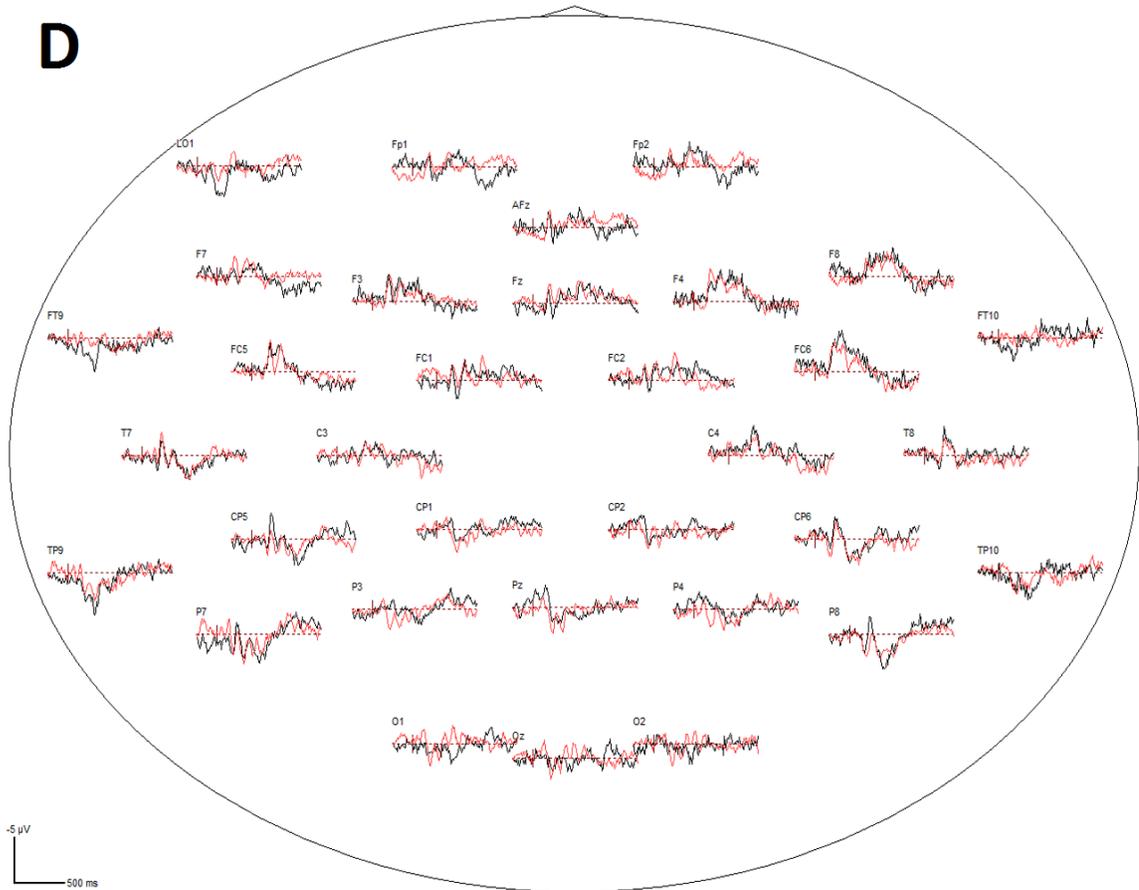


Figure S1. Top view of the head in a single plane projection showing raw grand averaged tone-locked Event-Related Potentials (ERPs) for all recorded sites during the auditory Go/No-Go task in OrKidstra and comparison children. The different panels represent the following stimuli: (a) Go tone at 1100Hz; (b) No-Go tone at 1100Hz; (c) Go tone at 2000Hz; and (d) No-Go tone at 2000Hz. ERP waves are shown in red (OrKidstra) and black (comparison group). The nomenclature of the electrodes follows the International 10-20 system: Frontal pole (Fp), Frontal (F), Frontocentral (FC), Central (C), Parietal (P), Centroparietal (CP), Temporal (T), Parietal (P), Temporoparietal (TP), and Occipital (O). Even and odd numbers following these labels represent homologous electrodes placed over the right and left hemisphere, respectively, but midline electrodes are followed by the letter z instead, which stands for zero. Electrodes were attached to an EEG cap placed

on the participants' heads, except LO1 which was placed on the outer canthus of the eye.

AF_z acts as a ground and F_z, P_z, and O_z are reference electrodes.