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Emotional Abilities in Preadolescents and Adolescents with Long-term Cochlear Implant Use

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Corresponding Author:	Hilal Dincer D'Alessandro, PhD Istanbul University-Cerrahpasa Ankara, TURKEY
First Author:	Maria Nicastrì
Order of Authors:	Maria Nicastrì Hilal Dincer D'Alessandro, PhD Ilaria Giallini Antonella D'Amico Alessandro Geraci Bianca Maria Serena Inguscio Letizia Guerzoni Domenico Cuda Annarita Vestri Danilo Alunni Fegatelli Patrizia Mancini
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	they grow up and become preadolescents/adolescents. EA assessment in CI users may not only support monitorization of EA trajectory, but also early identification of any EA disorders, so that subjects with low EA profiles could be timely and properly intervened.
Suggested Reviewers:	Teija Waaramaa Tampere University teija.waaramaa@uta.fi teija.waaramaa@uta.fi.
	Andrea D Warner-Czyz warnerczyz@utdallas.edu

Dear Editor,

We are pleased to submit an original research article for consideration for publication in your journal, entitled “Emotional Abilities in Preadolescents and Adolescents with Long-term Cochlear Implant Use”.

We believe that the present findings should be of interest to your readers since the present study is the first attempt to a holistic emotional abilities approach, considering simultaneously various emotional aspects such as perception, cognitive facilitation, comprehension, and management. Moreover, the number of currently available publications on emotional abilities is very limited for long-term preadolescent and adolescent cochlear implant users.

We declare that this manuscript is original, has not been published and is not under consideration for publication elsewhere.

We wish to confirm that there are no conflicts of interest associated with this publication and there has been no financial support for this work that could have influenced its outcome. The manuscript has been read and approved by all named authors.

We hope you find our paper suitable for publication and look forward to hearing from you at your convenience.

Sincerely,

The Authors

Emotional Abilities in Preadolescents and Adolescents with Long-term Cochlear Implant Use

Maria Nicastrì¹, Hilal Dincer D'Alessandro², Ilaria Giallini¹, Antonella D'Amico^{3,4},
Alessandro Geraci^{3,4}, Bianca Maria Serena Inguscio^{5,6}, Letizia Guerzoni⁷, Domenico Cuda⁷,
Annarita Vestri⁸, Danilo Alunni Fegatelli⁸, Patrizia Mancini¹

1. Department of Sense Organs, Sapienza University of Rome, Rome, Italy
2. Department of Audiology, Faculty of Health Sciences, Istanbul University-Cerrahpasa, Istanbul, Turkey
3. Department of Psychology, Educational Science and Human Movement, University of Palermo, Palermo, Italy
4. WeSearch Lab - Laboratory of Behavioral Observation and Research on Human Development, University of Palermo, Palermo, Italy
5. Department of Molecular Medicine, Sapienza University of Rome, Rome, Italy
6. BrainSigns Srl, Rome, Italy
7. Department of Otorhinolaryngology, "Guglielmo da Saliceto" Hospital, Piacenza, Italy
8. Department of Public Health and Infectious Diseases, Sapienza University of Rome, Rome, Italy

All correspondence should be addressed to:

Hilal Dincer D'Alessandro, Istanbul University-Cerrahpasa, Faculty of Health Sciences,
Department of Audiology, Istanbul, Turkey

E-mail: dincer.hilal@gmail.com

ORCID: <http://orcid.org/0000-0001-7320-6577>

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The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Emotional Abilities in Preadolescents and Adolescents with Long-term Cochlear Implant Use

Abstract

Objectives: Emotional abilities (EAs) are particularly important during preadolescence/ adolescence, two challenging periods characterized by significant biological, physical, and cognitive changes. The present study attempted to a holistic EA approach in preadolescents/adolescents with cochlear implants (CI) and typical hearing (TH), considering various aspects such as perception, cognitive facilitation, comprehension, and management of emotions. A secondary aim was to identify significant demographic and audiological factors of EA development.

Methods: CI/TH groups were matched for chronological age, nonverbal IQ, gender, economic income, and maternal level of education. Each group consisted of 43 participants (age range 10 to 18 years). EAs were evaluated by using the multi-trait/method IE-ACCME test. Auditory-linguistic assessments included participants' lexical skills and Matrix performance as well.

Results: EA performance for perception and cognitive facilitation did not show any statistically significant CI/TH group differences ($p > 0.05$). Significant CI/TH differences emerged for emotion comprehension and management: CI group performed significantly worse in understanding emotional blends ($t = 2.56$, $p = 0.014$) but better in personal emotion management ($t = -2.01$, $p = 0.048$). For the CI group, gender showed statistically significant effects on cognitive facilitation in sensations, with males performing better than females ($U = 129$, $p = 0.018$). TH preadolescents showed significantly lower scores in understanding emotional changes in comparison to TH adolescents ($U = 125.5$, $p = 0.01$). Emotional blends understanding showed a weak negative correlation with Matrix performance ($r = -0.38$, $p = 0.013$) and a moderate positive correlation with lexical skills ($r = 0.40$, $p = 0.008$). Relationships management showed various significant correlations: weak negative correlations with age at CI ($r = -0.38$, $p = 0.011$) and Matrix performance ($r = -0.36$, $p = 0.016$) as well as weak positive correlations with nonverbal-IQ ($r = 0.38$, $p = 0.013$) and positive moderate correlations with lexical skills ($r = 0.49$, $p < 0.001$).

Conclusion: Cochlear implantation seems to show significant positive effects on emotional development in children, allowing them to achieve age appropriate EAs as they grow up and become preadolescents/adolescents. EA assessment in CI users may not only support monitorization of EA trajectory, but also early identification of any EA disorders, so that subjects with low EA profiles could be timely and properly intervened.

Keywords: cochlear implants; adolescents; preadolescents; emotional abilities; long-term outcomes

1. Introduction

Thanks to the development of cochlear implants (CI), significant progresses have been achieved for treatment of pre/postlingual deafness in the last thirty years. More specifically, early identification of deafness soon after the birth and timely implantation allow the majority of deaf or hard of hearing (DHH) children to develop age-appropriate auditory-verbal communication skills [1] so that they integrate into mainstream schooling [2] and the hearing society [3,4].

Benefits of cochlear implantation have been investigated and reported also for reading comprehension [5], executive functions [6,7], self-concept, self-esteem development [8,9], and emotion comprehension [10]. Nevertheless, paediatric CI outcomes show variability that remains even for long-term follow up [2,11–13] and the domain of emotional development represents one of the areas where a large variability in CI population is still observed.

An individual's ability to perceive, understand, express, and manage emotions plays a crucial role in human life as it is significantly related to personal aspects such as self-esteem, self-concept, and self-identity [14]. Moreover, emotional abilities (EAs) in preschool and school age deeply affect the quality of prosocial behaviour with peers/adults and show significant correlations with reductions in behavioural problems [15].

Typically hearing (TH) children who comprehend and appropriately manage emotions are also more socially skilled in terms of achieving greater social integration and acceptance [16] as well as being more competent in resolving interpersonal conflicts [17]. In school settings, EAs are strongly involved in academic success, as they significantly affect a student's learning strategies and performances linked to storage, retrieval, and processing of information [18]. Children who have a better understanding of emotions in kindergarten, e.g., being better at resolving conflicts with peers, being more helpful, and cooperating more with others, are more likely to become well-adjusted adults to be employed and contribute positively to the society [19].

During human life, typical emotional competences develop as a result of complex interactions between social experiences with significant others (e.g., parents, teachers, peers), self-characteristics (e.g., temperament or emotional reactivity), and own cultural context [20]. Whilst moving from infancy to school entry, through such interactions, children follow a typical continuum of acquiring social and emotional skills [21] that forms the basis of their subsequent childhood, adolescence, and adulthood development [22].

During their first year of age, babies learn to be comforted and soothed by their caregivers, to self-sooth, to respond to their name by using body movements and facial expressions, to exchange vocalizations during social interactions, and to express a variety of emotions such as delight, sadness, fear, and anxiety [23]. During their second year of age, young children begin to recognize more people

and to interact with them, to expand their comprehension and expression of emotions such as defiance, anger, and frustration, to recognize the changing emotional states of others, and to act more assertively in social interactions such as directing the play of others [24]. Between three and five years of age, preschoolers begin to develop emotional connections in the form of friendship outside the family, to understand the difference between socially acceptable and unacceptable behaviours, to persist with challenging tasks without becoming unduly frustrated, to pay attention for increasingly longer periods of time, to avoid interrupting others and display delay-of-gratification skills around turn taking and toy sharing, to identify and articulate their own versus others' feelings, to increasingly manage their own strong emotions in socially appropriate ways, and to solve some social-emotional problems independently [24]. As children continue to develop EAs, they gain confidence and competence needed to build up relationships across settings, to solve problems, and to cope with challenges [25]. By the age of eight to nine years, children begin to understand that a single situation may elicit mixed and contradictory emotions, become more skilled in using psychological strategies (e.g., distraction, negation) to regulate their emotions, and appreciate morally base emotions and ethical dimensions of feelings [26].

During preadolescence/adolescence, thanks to improvements in cognitive abilities for processing more complex and sophisticated information [27], new skills are mastered: emotions can now be triggered by abstract ideas, anticipated future events, and recalled past events. Emotional responses to interpersonal relationships intensify and adolescents start to more frequently analyse their own and others' personalities, to join in relationships based on common personality properties, to become able to recognize complex, multiple, and multiply determined emotions in self and others [28]. Adolescents progressively learn to regulate intense emotions or to modulate rapidly vacillating emotions by self-soothing [28]. As emphasized by Saarni [29], they still learn to engage with their own emotions without being overwhelmed by them, to adopt the display rules of mature interpersonal interactions such as dissembling emotions and presenting a desired "look" that is more appropriate in a setting, to distinguish feelings from facts avoiding emotion-based reasoning, and to use symbolic thought to reframe a negative event as a less aversive one. Finally, they become progressively able to reason about nature and sources of emotions, to manage emotional arousal of empathic and sympathetic experiences as well as to manage strong emotions to successfully negotiate interpersonal relationships in the presence of contrasts with others [28].

EA studies might be particularly important during preadolescence and adolescence, two particularly challenging periods characterized by significant biological, physical, and cognitive changes as well as by the need for independence, academic/business success, and significant social relationships [30]. Such challenges are often accompanied by increased emotional reactivity that may

make adolescents less able to successfully regulate their emotions whilst putting them at greater risk of stress and anxiety related disorders that may even further increase in people with disabilities such as DHH people [31]. Indeed, the presence of deafness may negatively impact the quality of early social interactions that are fundamental to establish the basis of a secure emotional development. Limited access to verbal communication and suprasegmental vocal aspects of emotional expression may lead to significant quantitative/qualitative alterations in parent/child interactions [32]. Moreover, compromised auditory-linguistic skills and communicative difficulties may negatively affect their ability to build up social relationships and manage their own emotions [33,34]. Such EA difficulties in DHH subjects may lead to social isolation and feelings of loneliness [35] as well as to psychological problems such as depression, aggressiveness, and conduct disorders [36].

Over the last decade, EA performance in DHH populations received an ever-increasing attention with several studies showing variable results depending on sample characteristics and EA tasks. Fortunately, two recent systematic reviews conducted by Stevenson et al. [37] and Long et al. [38] provide an overview of EA results from existing studies in DHH people. The former one consists of a meta-analysis reflecting that DHH children/adolescents up to 21 years of age have scores on emotional and behavioural difficulties measures about a quarter to a third of a standard deviation higher than TH peers. Effect size values from the meta-analysis range from small (0.23) to medium (0.46). However, the review concerns DHH subjects without any references to their hearing technology. Conversely, the latter review takes the hearing technology into consideration and concludes that the existing CI data at the time of the review show an almost equal distribution of performance, with no evidence of prominent differences between CI and TH children. The authors report that some studies show equivalent skills in empathy, visual emotion recognition, processing/production, and emotion theory of mind, whereas some others result in lower performance of auditory emotion identification, verbal emotion labelling, and emotion regulation strategies. Likewise, variable results are observed for social-emotional wellbeing, prosocial motivation, level of anxiety, and depression (see Long et al. for more details).

A lack of knowledge becomes evident when preadolescents/adolescents are considered, with a limited number of studies focusing EAs achieved in CI subjects in comparison to their TH peers. Most of the published studies report data from validated self-assessment scales or parent/teacher questionnaires on depressive emotions [39], psychological health [40], social-emotional adjustments [41], and empathy [42]. So far, direct EA assessment in CI adolescents seems to be investigated only by Waaramaa et al. [43], Warner-Czyz et al. [44], and Evans [45]. Waaramaa et al. study [43] conducted in preadolescent/adolescent CI users shows 57% accuracy for identifying vocal emotions in comparison to 75% of TH peers. On the contrary, studies conducted by Warner-Czyz et al. [44]

and Evans [45] in CI/TH adolescents report similar group performances for the accuracy and response time of visual emotion recognition as well as for the interpretation of emotional expressions to static photographs. Moreover, Evans study [45] investigating CI/TH performances with dynamic videoclips and varying emotion intensity levels in the stimuli indicates that regardless of stimulus motion, both groups interpret full-intensity emotions similarly and achieve better emotion recognition skills for dynamic video clips than those for static photographs. Likewise, all CI/TH adolescents perform similarly well in identifying 100% intensity emotion expression and show comparable difficulties in recognizing 60% intensity. However, significant group differences emerge for the 80% emotion intensity. In this last condition, TH adolescents seem to glean an adequate amount of information about emotions from facial movements expressed with 80% and improve their performance as compared to 60% intensity, whereas CI adolescents result not to be able to perform significantly better when an intensity increase from 60 to 80% in emotion recognition is provided. The author concludes that this misinterpretation of subtle facial expressions by CI adolescents may complicate social communication with others and serve as an underlying contributor to social difficulties by CI children and adolescents.

All the previous studies demonstrate a growing interest in investigating social-emotional development in CI adolescents, but so far, no currently available studies attempt to a more holistic approach to EA by considering its various domains. Hence, the main aim of the present study was to assess various EA aspects in CI preadolescents/adolescents and to compare their performances with those of a matched group of TH peers. EA comparisons of interest regarded the followings: emotion perception, facilitation of emotions in cognitive processes, emotion comprehension, and emotion management.

A further aim was to identify potential predictors of EA performance (demographic and audiological factors). It was expected that improved auditory-linguistic skills after long-term CI use might lead to similar EA performances between CI preadolescents/adolescents and their TH peers, not only in the domain of emotion perception, but also in emotion comprehension and its use to facilitate thinking and managing personal/interpersonal relationships. Early intervention and better auditory-linguistic skills as well as non-verbal intelligence and SES indicators such as maternal level of education or economic income might be significant EA predictors.

2. Material and Methods

This study was carried out in accordance with the ethical requirements of the 1964 Declaration of Helsinki, its later amendments, and the existing legislation in Italy. The present protocol was approved by the local ethics committee (Protocol no: 259/2020). For all the study participants, informed consent was obtained by the parents.

2.1. Participants

The CI group consisted of 43 CI preadolescents and adolescents (25 females, 18 males). Their ages ranged from 10.9 to 18 years ($M = 14.4$ years; $SD = 2.42$ years). Diagnosis of hearing loss for all CI participants occurred within the first three years of age ($M=13.3$ months; $SD=9.6$ months, range 3-36). The mean age at first implantation was 22.6 months ($SD = 11.02$ months, range 7–48 months). Duration of CI experience ranged from 7 to 15.75 years ($M=12.51$, $SD = 2.42$). More than half of CI recipients employed a bilateral device configuration, either bilateral (21 subjects) or bimodal CI (2 subjects). Details of demographic information and audiological data are reported in Table 1 and 2.

All CI subjects had complete electrode arrays insertion and absence of any anatomical or functional alterations in the cochlea and/or acoustic nerve as well as a normal non-verbal IQ, measured through the Raven Progressive Matrices [46], with a score $>25^{\circ}$ percentile ($M=73.09$ percentile, $SD=17.48$). The duration of CI use ranged from 7 to 15.75 years ($M=12.51$ years, $SD=2.25$). All subjects had a congenital profound hearing loss (range 90-130 dB HL) and achieved a mean Sound Field CI threshold of 25.61 dB HL ($SD= 4.23$, range 19-34 dB HL). Speech perception scores, measured as the 50% speech reception threshold in the presence of noise by using the Matrix Sentence Test [47] were variable, ranging from -6.01 to 6.2 dB ($M=-2.01$ dB, $SD=2.41$). Lexical competence, used as a measure of language skills through the verbal denomination tasks from the Batteria di Valutazione Neuropsicologica per l'età evolutiva (BVN) 5-11 [48] and Batteria di Valutazione Neuropsicologica per l'adolescenza (BVN) 12-18 [49], showed a mean z-score of -0.45 ($SD=1.24$) and a range from -4.7 to 1.2, with 13 CI subjects (30.2% of the sample) performing below the normal standard distribution.

A matched group of TH preadolescents and adolescents was used as control group. Typical hearing was defined as PTA ≤ 10 dB HL ($M= 3.79$ dB, $SD= 3.24$, range 0-10 dB). Matching was performed for chronological age, nonverbal IQ, gender, economic income, and maternal level of education. Table 1 shows TH group characteristics in detail.

2.2. EA assessment

The participants' EAs were measured using the multi-trait/method IE-ACCME test (Intelligenza Emotiva: Abilità, Credenze e Concetto di Sè Meta-Emotivo) [50], an Italian tool specifically developed for preadolescents/adolescents. It is based on the Mayer and Salovey's [51] four-branch theoretical model that allows to measure four EA aspects: emotion perception, facilitation of emotions in cognitive processes, emotion comprehension, and emotion management.

2.2.1. Emotion perception task

Emotion perception abilities were assessed by an identification task. The subjects are shown six faces (EA-FP) and six pictures (EA-PP), with different intensity of emotion expression in the face

or directness of link between the image and evoked emotion (photos of landscapes vs abstract images). The task is to express the degree of intensity for the 6 Ekman's base emotions (happiness, sadness, fear, surprise, anger, and disgust). The intensity is scored by using a Likert scale from 1 (little) to 5 (a lot). All the six emotions should be scored for each face/picture.

2.2.2. *Tasks for facilitation of emotions in cognitive processes*

Use (EA-UF): The aim is to measure the value that a subject gives to the usefulness of a positive or negative emotion in influencing a given situation. The task is composed of 10 items: five items refer to events regarding an external character (e.g., which of the following positive or negative could have facilitated an important scientist in the formulation of a revolutionary scientific theory?), whilst the remaining five refer to events that are typical in everyday life of adolescents and could be considered as personal experiences (e.g., which of the following positive or negative could have facilitated you in solving a really difficult school task?). After each question, the subject should indicate at least one of the six emotions (happiness, sadness, fear, surprise, anger, and disgust) plus two more emotions represented by "excitation" and "waiting".

Sensations (synaesthesia) (EA-SF): The aim is to measure if the subject is able to link sensorial experiences to those that belong to the sphere of feelings. The subjects are presented with a list of 15 concepts expressing 15 sensations. The task is to indicate for each of them one or more emotions that they evoke in them. They are asked to choose the emotions as in the precedent task (i.e., Here are reported some concepts that indicate sensations we can perceive through our senses. Indicate which emotion/s you could associate to each of them: e.g., the concept of cold evokes to you a) anger b) disgust c) fear d) sadness e) waiting f) excitation).

2.2.3. *Emotion comprehension tasks*

Blends (EA-BU): The subjects are presented with a list of 10 complex emotions and a list of six simpler emotions. The task is to indicate any simple emotions that compose every single complex emotion (e.g., anxiety is a mix of a) anger b) fear c) happiness d) sadness e) waiting f) excitation). They can choose more than one emotion.

Changes (EA-CU): The subjects are presented with five everyday situations, each composed of a starting episode plus one to two sequels where the beginning situation changes in a positive or negative way. The subjects are requested to indicate their emotions for both the starting situation and the sequel/s.

2.2.4. *Emotion management tasks*

Personal Management (EA-PM): The aim is to measure the ability to manage and self-regulate emotions to solve situations directly related to the action or the internal mood of the subject. The

subjects are presented with four typical situations and a series of alternatives (e.g., today you feel really in perfect state, and you want to spend a splendid daytime, what do you usually do?).

Relationships Management (EA-RM): The aim is to assess the ability to manage and self-regulate emotions to solve situations in interpersonal relationships. Again, the subjects are presented with four typical situations and a series of alternatives (e.g., Your parents prevent you from attending a party, about which you care so much. You know that they are right, but you are really angry. They need to understand that they cannot limit your freedom.).

For both personal and interpersonal situations, the subjects are expected to express the degree of accordance in putting in act that behaviour, using a Likert scale ranging from 1 (not true at all) to 5 (almost always true). They are requested to answer according to two different point of view: in respect to the declarative knowledge about what it will be right to do (i.e., What would it be right to do in this situation?) and what the subject really does in that situation (i.e., What do you usually do in that situation?). These two different aspects allow to measure the degree of conformism between individual knowledge and real behaviour.

2.3. Score calculation

As proposed by Mayer, Solovey, and Caruso [51], the scores were defined as “consensus score” that is the percentage of subjects selecting that answer set in a general normative sample. For example, if a subject selects an answer that was also chosen by 75% of the respondents, then that subject obtains a score of .75. The scoring is performed with a specific software, online at the site of Giunti Psychometrics ([www. https://www.giuntipsy.it](http://www.giuntipsy.it)). The consensus sample consist of 1.084 Italian adolescents: 526 males and 558 females, age range 10 to 19 years, representing Southern, Central, and Northern Italy. All scores are then expressed as standardized scores with a mean of 100 and a standard deviation of 15.

Structural validation confirmed trough explorative and confirmatory factorial analyses that all IE-ACCME scales reflect Mayer and Salovey' s [52] four-branch and eight tasks structural model. All scales present acceptable test-retest reliability: EA, $r = 0.44$, $p < .001$; EA scale split-half = 0.86 [50].

2.4. Statistical analysis

All statistical analyses were carried out with the Statistical Package for Social Sciences 25.0 (SPSS, Chicago, IL, USA). Means and standard deviations were calculated for all variables of interest. The Shapiro-Wilk test was used to study the normality of data distribution and to define the statistical paradigm (parametric vs nonparametric). For data with normal distribution, a t test was used to assess statistical differences between the CI/TH groups. For data with non-normal distribution, the nonparametric Mann-Whitney U test was used. Whenever data at Shapiro-Wilk test

had values indicating a normal distribution but the Levene test was significant for differences in variance, the one-way ANOVA with Welch-Satterthwaite correction was used to adequate the freedom degrees [53]. Pearson or Spearman correlation coefficients (r or ρ) were calculated to assess EA associations with personal/demographic characteristics and audiological variables.

3. Results

3.1. Emotion perception

Distribution of standard scores for face and picture emotion identification tasks in the CI and TH groups are shown in Figure 1. The CI/TH groups showed similar performances: mean standard scores of 98.19 (SD=10.75) versus 100.82 (SD=16.89) and mean standard scores of 98.88 (SD=11.86) versus 98.44 (SD=14.58), respectively. Group differences were not statistically significant ($t=0.864$, $p=0.391$ for faces and $t=-0.153$, $p=0.878$ for pictures).

3.2. Facilitation of emotions in cognitive processes

Distribution of standard scores for emotion use and sensations facilitation in the CI and TH groups are represented in Figure 2. The CI group obtained a mean standard score of 95.44 (SD=15.76) for scoring the usefulness of a positive or negative emotion in influencing a given situation and a mean standard score of 99.56 (SD=16.89) for sensations. Higher scores were achieved by the TH group, showing mean standard scores of 100.62 (SD=15.66) for the usefulness of a positive or negative emotions and of 103.15 (SD=14.06) for sensations. Group differences were not statistically significant ($t=1.53$, $p=0.13$ and $t=1.07$, $p=0.286$, respectively).

3.3. Emotion comprehension

Distribution of standard scores for emotional changes and blends understanding in the TH and CI groups are shown in Figure 3. The CI group showed lower mean standard scores than the TH group for emotional changes understanding, with a mean standard score of 95.14 (SD=17.72) versus 99.35 (SD=15.06), but group differences were not statistically different ($t=1.31$, $p=0.193$).

For emotional blends, the CI group's performance was significantly worse than that of TH peers ($t=2.56$, $p=0.014$): CI subjects obtained a mean standard score of 92.44 (SD=9.01), whilst their TH peers reached a mean standard score of 100.06 (SD=17.61).

3.4. Emotion management

Distribution of standard scores for personal and relationships management in the CI and TH groups are illustrated in Figure 4.

The CI group showed higher standard scores than the TH group for personal management, with a mean standard score of 105.98 (SD=10.91) versus 101.10 (SD=11.6). Group differences were statistically significant ($t=-2.01$, $p=0.048$). For relationships management, the CI group's performance (mean standardized score=102.56, SD=10.31) was slightly higher than that of the TH

group (mean standardized score=98.95, SD=11.63), but the differences did not reach any statistical significance ($t=-1.521$, $p=0.132$).

3.5. Significant factors of EA development

For the CI group, gender showed statistically significant effects only on sensations: males performed significantly better than females (mean standardized scores of 105.78/SD=19.21 and of 95.08/SD=13.7, $U=129$, $p=0.018$). Emotional blends understanding showed a weak negative correlation with Matrix performance ($r=-0.38$, $p=0.013$) and a moderate positive correlation with lexical skills ($r=0.40$, $p=0.008$). Relationships management reflected various statistically significant correlations: weak negative correlations with age at CI ($r=-0.38$, $p=0.011$) and Matrix performance ($r=-0.36$, $p=0.016$) as well as weak positive correlations with nonverbal-IQ ($r=0.38$, $p=0.013$) and positive moderate correlations with lexical skills ($r=0.49$, $p<0.001$). Preadolescence/adolescence and the listening mode did not show any statistically significant effects on EA performance ($p>0.05$).

For the TH group, gender did not show any statistically significant effects on EA performance ($p>0.05$). Significant performance differences between preadolescents and adolescents were observed only for emotional changes understanding ($U=125.5$, $p=0.01$). In comparison to TH adolescents, TH preadolescents showed significantly lower scores in understanding emotional changes: mean standardized scores of 92.12 (SD=14.25) versus 103.64 (SD=14.08).

4. Discussion

Despite the challenging emotional states that DHH subjects face during their maturational process, EAs in CI adolescents have been rarely investigated so far [37,54]. Indeed, very limited information for paediatric implantation's long-term effects on this important aspect is available, in particular with consideration to its domains. The present study was planned with the aim to assess EAs in an early implanted CI group of preadolescents/adolescents and to compare their performances with those of a matched TH group.

4.1. Emotion perception

Emotion perception abilities in the CI group, measured in terms of emotion identification in faces and pictures, were similar to those of TH peers. For face emotion identification, this finding is in line with Most and Aviner [55], Warner-Czyz et al. [44] and partially agrees with Evans [45]. These three studies did not find any statistically significant differences between preadolescent/adolescent CI and TH groups in interpreting static photographs of full-intensity emotions (i.e., 100% of an expression) whilst Evans reported similarities in processing low intensity emotion expression (60%) as well. However, Evans found lower performances in the CI group than their TH peers for photographs where 80% of emotion intensity was expressed. According to Evans [45], full-intensity (100%) facial expressions provide an adequate and redundant amount of emotion

information, that facilitates identification, whilst 60% intensity emotion expression does not provide sufficient information to illuminate subtle differences in emotion recognition between CI users and TH peers. In contrast, while TH preadolescents/adolescents were able to scrape up an adequate amount of information about emotions from facial movements expressed with 80% condition to achieve a significantly improved level of emotion recognition, CI group did not show any significant differences between the 60% and 80% intensity emotion recognition conditions, requiring incrementally more facial movement to demonstrate a significant performance improvement (i.e., 80% and 100% intensities). The IE-ACCME test from the present study uses face photographs with various emotion intensity and combined emotions (e.g., sadness and anger). Despite the complexity of the present task, no significant differences were detected between the CI and TH groups, reflecting for the first time how CIs positively influence the abilities to perceive even subtle emotions in faces. Although previous research suggests that young CI children could present poorer recognition of facial expressions than that of TH peers [56–59], the present findings together with that of Most and Aviner [55], Warner-Czyz et al. [44] and Evans [45] seem to sustain the conclusion that between-groups gap diminishes with increased chronologic age thanks to increased duration of auditory-linguistic-communicative experience so that CI users achieve outcomes similar to TH peers by adolescence. Such findings are supported also by similar performances of the two groups in picture emotion identification, where three out of six images used in the test are abstract.

So far, no existing studies investigated pictures emotion perception in CI subjects, but from studies in TH populations, it is well-known that emotion perception in abstract and non-abstract pictures is an experience-driven ability that improves with expertise, that allows subjects to associate basic bottom-up visual features such as contours, shapes, colours, depth, texture, and movement to their emotional content [60]. The ability to understand emotional meaning of pictures and drawings start to develop early in childhood and is present from the preschool years [61]. As early as three years of age, children are able to recognize emotions expressed in paintings, if they are scaffolded by an adult who adopts an aesthetic stance towards paintings [62].

The possibility to have long-term access to acoustic environment and spoken language during everyday interactions seems to help preadolescent/adolescent CI users in becoming skilled in linking perceptual cues at faces and abstract images to their emotional content as effective as their TH peers.

4.2. Facilitation of emotions in cognitive processes

For the ability of using emotions to facilitate thinking, TH preadolescents/adolescents achieved higher scores than their implanted peers, however, group differences were not statistically significant. Subjects of both groups gave stackable values in judging the usefulness of a specific positive or negative emotion in influencing given situations and were similarly able to link a sensorial

experience (deriving from taste, touch, or sight) to emotional sensation or synaesthesia. So far, no other studies assessed these two aspects in CI subjects. Nevertheless, they represent two important aspects that need to be investigated when assessing CI benefit, as they play a fundamental role in human cognitive functioning [63].

Various studies in TH populations pointed up how emotions are important not only for socio-relational aspects, but also for managing attention, memory, and learning, as well as for strengthening motivation to act when facing incoming stimuli from the environment [64,65]. In particular, emotions significantly impact human decision-making, that cannot always be explained by rational principles [66]. The context of a given situation and an individual's unconscious response biases counteract rational choices and lead to more complex decision-making processes linked to a high arousal/emotional activation (hot contexts) or low arousal/non emotional activation (cold contexts). In comparison to children and adults, adolescents are more likely to make risky decisions in emotionally 'hot' contexts, e.g., when they have to evaluate how a gambling outcome makes them feel [67]. Consequently, measuring this ability in both TH and CI populations is fundamental for early identification of subjects that are potentially at risk to select non-functional emotions when they need to act in hot situations as well as for supporting them in developing more mature behaviours. Moreover, such knowledge about the ability of early implanted DHH preadolescents/adolescents to develop EAs of decision making as good as their TH peers is promising to deepen long-term benefit of cochlear implantation in domains that are still not investigated.

Likewise, for the ability to link sensations to emotions, no other studies in CI subjects are currently available in the literature, but again this research aspect needs to receive more attention. Sensations and emotions are inextricably linked to each other. Indeed, the ability of sensations to activate brain regions suggests that emotional processing is crucial for survival, functional relationships, and social adaptation, as sensations allow humans to quickly detect information about their physical surrounding and react accordingly [68]. Thus, sensory processing in children and its relationship to self-regulation development are increasingly recognized as important research topics in developmental psychopathology [69]. In fact, 33 to 63% of children meeting criteria for sensory dysregulation also show a psychiatric disorder, whilst 37 to 67% have only a sensory dysregulation disorder, indicating that sensory regulation dysfunction may exist independently from any psychiatric disorder, but is also a significant risk factor for that [69]. Another remarkable evidence comes from studies in autistic populations, reflecting an altered connection between sensory processing and elicited emotions. Various studies [70] demonstrate that hyperresponsiveness or hyporesponsiveness to sensory stimuli is significantly related to heightened responsivity not only in primary sensory regions but also in areas related to emotion processing (i.e., amygdala and hippocampus). This altered

activation is considered one of the causes of negative responses to sensory stimuli and may significantly impact adaptive behaviours that comprise age-appropriate abilities for daily social activities [71].

The present findings suggest that auditory input delivered through CI systems allow DHH subjects to adequately develop links between sensations and emotions, necessary to well act in everyday life. For subjects with low scores in both CI and TH groups, a timely identification could be useful to plan focused programs as early as possible and help them to avoid or reduce problematic behaviours, improving social adaptation [64,65].

4.3. *Emotion comprehension*

Although the CI group showed slightly lower standard scores of emotional changes understanding than those of the TH group, group differences were not statistically significant. However, their performances in emotional blends understanding differed significantly with worse scores in CI subjects.

Currently, no other studies investigated emotion comprehension in CI preadolescents/adolescents whereas several studies have been conducted in children. Similarly, with the present study, Ziv et al. [72] did not find any significant emotion understanding differences between TH and CI children who communicate verbally in typical contexts (typical situations designed to elicit specifically one of the six basic emotions: happiness, sadness, anger, surprise, fear, and disgust). Conversely, statistically significant differences were detectable for DHH subjects using sign language to communicate. The Authors suggested that CIs may have a beneficial effect on developing emotion understanding in DHH children. However, Wiefferink et al. [73] reported that young CI children were less proficient in emotion attribution in a situational context [73]. The Authors studied preschool children, with short CI experience. Indeed, such outcome differences might have been resulted from the duration of auditory experience, being one of the significant predictors of performance in CI children [10]. On the other hand, both Ziv and Wiefferink [72,73] investigated simple direct situations. However, mixed results can be found for complex emotion understanding skills, e.g., Mancini et al. study [10]. All but two subjects of the CI sample (N=72) were within the normal range not only for understanding emotions at typical situations, but also for understanding the fact that different desires may result in different emotions. However, ~20% of the sample seemed to be at risk to show difficulties in understanding complex emotions such as mixed and moral emotions. Likewise, in the present study, CI preadolescents fall behind their TH peers in understanding emotional blends: this difficulty, detected in childhood is still present in the long-term assessment. Such findings may have significant implications in everyday life.

Rather than arising in isolation, discrete emotions (e.g., fear, anger, happiness) tend to co-occur due to person- or pattern-specific reasons [74]. Indeed, emotional blends are very frequent experiences in human life, e.g., love, anxiety, and hope being the second, third and sixth most frequent everyday life emotional experiences [75]. Hence, a key factor for social relationships might be the blended emotions comprehension ability [76], helping to deal with stressful situations [77] and positively affecting general wellbeing [78]. Everyday situations usually do not present clear-cuts. Instead, they may lead to complex appraisals and emotional responses [79] where a person may frequently experience several emotions simultaneously [80].

Emotion knowledge is a consistent correlate of multiple social and behavioural outcomes, ranging from medium to large effect size, especially in the case of adolescents [81]. In fact, poor emotion knowledge in social situations may trigger inappropriate responses and the formation of maladaptive emotion-cognition relations over time. Again, over time, children with emotion knowledge deficits may experience greater social difficulties and develop persistent negative emotion patterns, leading to anxiety, depression, or other internalizing problems [82]. Moreover, poor encoding of others' emotional cues may significantly affect a child's intent attributions, possibly leading to hostile attributional biases and reactive aggression. Poor emotion knowledge may predict the inability to manage and utilize emotions for prosocial outcomes. Particularly when cooccurring with high levels of negative emotionality, difficulties in emotion comprehension may lead to dysregulated anger, frustration, and acts of aggression in social situations [81]. Translating such considerations into the CI population, difficulties in complex emotion comprehension could be seen as one of the significant reasons of psychosocial difficulties observed in CI populations. Indeed, CI users have been found to be more likely than their TH peers to display elevations in adaptive skills, hyperactivity–impulsivity, oppositional behaviours, externalizing problems, or less efficient adaptive skills [83].

Future CI studies are needed to deepen development of complex emotions comprehension, not only in childhood but also in preadolescence/adolescence periods, so that potential areas of fragility can be identified. Such an interest may help to the development and implication of on-target educational programs in CI users. Although awareness of “mixed” emotions first emerges in middle childhood and continues to develop up to 12 years of age [84], skills in their understanding and responses to mixed social emotions such as embarrassment, guilt, and shame continue to increase from early- to post-puberty. Thus, it is reasonable to expect that they can be effectively rehabilitated in this age period [85,86].

4.4. *Emotion management*

Emotion management was investigated as the ability to manage and self-regulate emotions to solve situations directly related to the action or the internal mood of the subject (personal management) as well as to solve situations in interpersonal relationships (relationships management). CI and TH groups did not show any statistically significant differences in this last aspect, whereas CI preadolescents/adolescents obtained higher scores for personal management.

For the ability to use self-regulating emotion strategies to manage everyday situations, previous studies conducted specifically in DHH children and preadolescents, wearing different auditory prostheses (traditional hearing aids or CI), enrolling in different settings (mainstreamed or special schools), and using different communication modes (signed, oral or signed+oral language) found that DHH subjects tended to experience negative emotions more intensively and to be less effective in decreasing negative emotion arousal in themselves and others [56,87,88]. They also tended to use positive strategies such as problem-focused approach or self-distraction less frequently and effectively than their TH peers, being less able to calm down and to search for strategies to recover and become happy again [88,89].

When orally speaking CI children were considered alone, most of them showed an adequate emotion comprehension, reflecting regulation strategies in line with what was expected for their chronological age. However, ~20% of them were at risk to fail the passage from more behavioural strategies (e.g., asking for holding a caregiver's hand or increment of physical movements) to psychological strategies (e.g., self-distraction) [10]. The increment in auditory experience, communication skills, and social interactions during the maturational process from childhood to adolescence seem to provide significant benefit to emotion management in personal and interpersonal experiences. It is well-known that the ability to cope with emotional stress improves significantly during adolescence [90] and this fact seems to be valid in CI users as well. Such findings are also consistent with those from Eichengreen et al. study [91] where emotion awareness and emotion regulation skills were investigated in a group of DHH subjects (9–15 years of age) followed up over a period of 18 months. The Authors did not find any significant differences between DHH and TH groups, neither at baseline nor the developmental trajectories, with an improvement in emotion regulation strategies and feelings of worry/rumination in both groups. The importance of this finding derives from the consideration of the links between psychological health and emotion regulation/management in adolescence [92]. The ability to perceive own and others' emotions and to properly act/react to them in relation with the external context, and to select more appropriate regulation strategies significantly reduce the risk of anxiety, depression, conduct disorders, and aggressiveness [93]. The relations between emotion management skills and mental health symptoms were not investigated in the present study. However, Eichengreen et al. [91] previously showed that

lower levels of maladaptive behaviours and higher levels of positive strategies were significantly related to lower levels of depression, anxiety, and externalization symptoms in DHH subjects, as it happens in TH adolescents. Furthermore, the increased emotion management skills in the study group may lead to an increment of their subjective happiness [94], as suggested by previous studies to be at the basis of insignificant differences in self-esteem or depressive levels between CI adolescents and TH peers [8,39,91].

Regarding the personal management skills, CI groups even outperformed their TH peers. This finding could be explained by the need that CI subjects have to continuously solve challenging experiences in everyday life and/or by any possible effects of rehabilitation. The section of personal management evaluates the strategies that a subject uses in four typical situations. Here, only one situation is positive, whereas all the others are negative (e.g., What do you do to calm down or improve your mood when you have lost a present for a friend, you have a bad period, or you are not satisfied of your physical appearance?). Frequently during their development, CI users need to find solutions to re-elaborate negative valences in inner emotions resulted from communicative difficulties with other people such as siblings, teachers, and peers [44,95] or from situations such as lagging behind in school tasks or other competitions [96], having a speech processor that may weigh on their body image as well as feeling different from the others in relation to their hearing loss. So, it is possible that repeated experiences where they need to manage their personal reactions in challenging situations might have helped them to select more effective personal management strategies.

In the last fifteen years, an increasing attention has been given to emotional and social aspects at both rehabilitative centres and schools. Along with specific rehabilitative programmes to improve emotional and social skills [97], specialist/teachers' knowledge on how to support children with emotional difficulties in terms of dealing effectively with stressful everyday situations is increased [98–100]. Data on emotion trainings were not collected in the present study sample neither from study participants nor from specialists/teachers, but future studies might be conducted with a specific focus on these aspects.

4.5. *Significant factors of EA development*

The present study investigated the impacts of audiological and personal factors on emotional skills as well. Previous literature revealed that gender has significant effects on visual emotion identification, with a female advantage on facial expression processing from infancy to adolescence [101]. However, present findings from both CI and TH groups did not show any statistically significant effects on emotion identification for both faces and pictures. Such differences might have stem from the fact that previous studies were conducted in larger samples. For instance, D'Amico

and Geraci [102] investigated emotional skills in 224 boys and 295 girls, whereas the present sample consisted of 25 females and 18 males. Thus, the present sample might have been too small to detect significant gender differences. On the other hand, a recent systematic review conducted by Zupan and Eskritt [103] minimized gender differences reported previously: both males and females consistently identified happiness; fear appeared to be most difficult task for both groups, whilst some minor variations were observed only for sadness and disgust.

Except for the understanding of emotional changes in the TH group, no significant performance differences between preadolescents and adolescents were found for both CI and TH groups. Indeed, a recent systematic review by Zupan and Eskritt [103] reported similar patterns of recognition for both facial and vocal emotion expressions in early, mid-, and late adolescents [103]. This may justify the findings of emotion recognition studies that frequently focalize only around basic emotions, reported to be fully developed by 10 to 12 years of age [104]. Differences could emerge only if more complex emotions are investigated [105], as they require deeper appraisal and inferencing of available cues, involving more mature cognitive processes [106]. Finally, the Authors suggested that another reason of insignificant differences might be the consideration of response accuracy alone. Indeed, some paediatric studies have shown that significant developmental differences become apparent only if response times are considered [107]. It is possible that clearer differences in the pattern of recognition may emerge across early, mid, and late adolescents if both response accuracy and response times for complex emotions are considered.

Another observation of the present study was that there were no statistically significant effects of economic income and maternal level of education on EA performance. Although significant impacts of economic income and education level are reported in the literature [108], the lack of significant effects might be due to relative homogeneity of sociocultural situation of the participants from both groups: the majority had medium/medium high economic income and mothers with at least 13 years of education. Only four subjects (two CI/TH mothers) had a vulnerable sociocultural context.

Regarding non-verbal cognitive level, linguistic and audiological factors, few correlations were found only for emotional blends and relationships management. Emotional blends understanding positively correlated with speech perception in noise and lexical skills, with correlation values weak to moderate: CI preadolescents with better speech perception in noise and better lexical comprehension skills achieved higher standard scores in blended emotion understanding. These two factors positively contributed also to relationships management skills, together with age at CI and non-verbal IQ: CI subjects with higher non-verbal intelligence, earlier implantation as well as with better audiological and linguistic outcomes were also more skilled in managing social situations where interpersonal emotion control was requested. The significant effects of early intervention,

auditory skills, and lexical abilities on these two important EA domains have already been detected by Mancini et al. [10] and are still detectable during preadolescence/adolescence.

For the CI group, no significant differences were found for the listening mode (unilateral, bilateral, bimodal). The effects of listening mode on EA performance were not investigated in other studies in preadolescent/adolescent populations and only few mixed data are available in children. For example, some studies investigating auditory emotion perception using musical tools found that bimodal children performed better than their unilateral CI peers [109], but no significant differences were observed for bimodal versus bilateral CI users [110]. Regarding emotion comprehension in children, only Mancini et al. [10] found a trend towards significantly better performance in more complex tasks for subjects with bilateral CI in comparison to unilateral users. Future studies for bilateral/bimodal listening's impacts on EA performance would have been very interesting as well.

4.6. Limitations of the study

Although the present study consisted of fairly large study and control groups that were matched for different potential confounding factors such as cognitive level, economic level and mother level of education, some limitations could be identified. First, auditory emotion perception was not investigated. Moreover, EA assessment was performed directly on CI subjects and their TH peers, without collecting information from their parents/teachers who could provide very useful data for their emotional states in everyday social contexts. Only personal and audiological factors were considered in correlational analysis, whilst other potential EA predictors such as parents communication style, personality traits, emotion dimensions were not considered. Finally, within the CI group, subjects were not balanced for the listening mode (differences in numbers of simultaneous and sequential bilateral CI users, large variability of age at the second implant in sequential cases, auditory profile differences especially in bimodal listeners). Such factors might have overshadowed a possible bilateral/bimodal listening benefit.

5. Conclusion

Cochlear implantation seems to provide significant positive effects on emotional development in children, allowing them to achieve age appropriate EAs as they grow up and become preadolescents/adolescents. Significant differences in favor of TH peers remain only for emotional blends understanding, whilst CI subjects surprisingly outperform their TH peers in personal management in everyday life. Only some personal and audiological factors seem to significantly affect some EAs in the present sample, but larger study populations might be more indicative for these interactions. Future studies may investigate other domains such as parents' communication style, emotional profiles, and social contexts. EA assessment may not only support monitorization of

emotional development trajectory, but also early identification of any EA disorders, so that subjects with low EA profiles could be timely and properly intervened.

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FIGURE LEGENDS

Figure 1. Distribution of standard scores for face and picture identification in TH and CI subjects.

EA-FP: Face Perception; EA-PP: Picture Perception

Figure 2. Distribution of standard scores for emotion use and sensations facilitation in TH and CI subjects. EA-UF: Use Facilitation; EA-SF: Sensation Facilitation

Figure 3. Distribution of standard scores for emotional changes and blends understanding in TH and CI subjects. EA-CU: Changes Understanding; EA-BU: Blends Understanding

Figure 4. Distribution of standard scores for personal and relationships management in TH and CI subjects. EA-PM: Personal Management; EA-RM: Relationships Management

Table 1. Demographic characteristics and audiological data of the study and control groups

Categorical Variables		CI	TH	
Gender	<i>Female</i>	25	25	
	<i>Male</i>	18	18	
Economic Income	low	1	2	
	medium-low	4	3	
	medium	28	28	
	medium-high	10	10	
	high	0	0	
Continuous Variables		Mean (SD)	Mean (SD)	p-values
Age at assessment (yrs)		14.4 (2.42)	14.53 (2.39)	0.77
MEL (yrs of study)		15.16 (2.92)	15.33 (2.96)	0.76
Raven (percentile)		73.09 (17.48)	72.4 (17.39)	0.82
BVN lexicon scores (z scores)		-0.45 (1.24)		
Age at diagnosis (mths)		13.3 (9.6)	/	
Age at cochlear implant (mths)		22.67 (11.02)	/	
CI use (yrs)		12.51 (2.25)	/	
Pre CI PTA (dB HL)		104.64 (9.75)	/	
Post CI FF (dB HL)		25.61 (4.23)	/	
OLSA (SRT)		-2.01 (2.41)	/	



Table 2. Cochlear implants characteristics

CI characteristics		n
Listening Mode	Unilateral CI	20
	Bilateral CI	21
	Bimodal	2
Cochlear implants	Cochlear®	20
	AB®	17
	Med-El	6
Strategies	ACE™	20
	Hi-Res120™	17
	FS4	6

Table 3. CI and TH groups' EA-FP and EA-PP mean standard scores, standard deviations (SD) and tests for null hypothesis for gender (male, female), age stage (preadolescents, adolescents), and listening mode.

		N. of subjects	EA-FP standard score (SD)	EA-FP Mann-Whitney or Kruskal-Wallis test	EA-PP standard score (SD)	EA-PP Mann-Whitney or Kruskal-Wallis test
CI group	<i>Male</i>	18	96.06 (12.37)	U=191.5, p=0.409	97.28 (11.85)	U=205.5, p=0.631
	<i>Female</i>	25	99.72 (9.38)		100.04 (11.98)	
	<i>Adolescents</i>	21	96.76 (11.37)	U=165.5, p=0.204	99.09 (10.76)	U=169.5, p=0.242
	<i>Preadolescents</i>	22	99.54 (10.2)		98.68 (13.08)	
	<i>Unilateral</i>	20	97.30 (11.07)	H: 0.950, p=0.622	102.65 (11.60)	H=5.038, p=0.81
	<i>Bilateral</i>	21	99.67 (9.89)		96.19 (11.41)	
	<i>Bimodal</i>	2	91.50		89.5	
TH group	<i>Male</i>	18	102.39 (18.70)	U=202.5, p=0.579	98.72 (15.87)	U=223.5, p=0.971
	<i>Female</i>	25	99.69 (15.76)		98.24 (13.92)	
	<i>Adolescents</i>	21	101.39 (15.37)	U=208.5, p=0.85	99.63 (14.91)	U=182, p=0.393
	<i>Preadolescents</i>	22	100.28 (18.58)		97.31 (14.51)	

Table 4. CI and TH groups' EA-UF and EA-SF mean standard scores, standard deviations (SD) and tests for null hypothesis for gender (male, female), age stage (preadolescents, adolescents), and listening mode.

		N. of subjects	EA-UF standard score (SD)	EA-UF Mann-Whitney or Kruskal-Wallis test	EA-SF standard score (SD)	EA-SF Mann-Whitney or Kruskal-Wallis test
CI group	<i>Male</i>	18	101.17 (14.50)	U=148.5, p=0.059	105.78 (19.21)	U=129, p=0.018
	<i>Female</i>	25	91.32 (15.61)		95.08 (13.70)	
	<i>Preadolescents</i>	22	94.23 (16.09)	U=206, p=0.543	100.86 (15.26)	U=216.5, p=0.724
	<i>Adolescents</i>	21	96.71 (15.70)		98.19 (18.72)	
	<i>Unilateral</i>	20	96.80 (13.57)	H: 1.393, p=0.498	98.00 (16.49)	H=0.453, p=0.797
	<i>Bilateral</i>	21	95.19 (18.12)		100.95 (18.21)	
	<i>Bimodal</i>	2	84.50		100.5	
TH group	<i>Male</i>	18	104.14 (18.89)	U=169, p=0.168	102.09 (9.81)	U=206.5, p=0.648
	<i>Female</i>	25	98.08 (12.66)		103.92 (16.63)	
	<i>Preadolescents</i>	22	102.65 (18.78)	U=174, p=0.166	101.01 (10.95)	U=193.5, p=0.362
	<i>Adolescents</i>	21	98.49 (11.62)		105.40 (16.71)	

Table 5. CI and TH groups' EA-CU and EA-BU mean standard scores, standard deviations (SD) and tests for null hypothesis for gender (male, female), age stage (preadolescents, adolescents), and listening mode.

		N. of subjects	EA-CU standard score (SD)	EA-CU Mann-Whitney or Kruskal-Wallis test	EA-BU standard score (SD)	EA-BU Mann-Whitney or Kruskal-Wallis test
CI group	<i>Male</i>	18	97.22 (12.46)	U=190, p=0.388	93.17 (8.66)	U=205.5, p=0.631
	<i>Female</i>	25	93.64 (16.24)		91.92 (9.40)	
	<i>Preadolescents</i>	22	97.86 (14.85)	U=171, p=0.144	94.50 (8.78)	U=186, p=0.274
	<i>Adolescents</i>	21	92.28 (14.38)		90.28 (8.95)	
	<i>Unilateral</i>	20	95.50 (14.30)	H: 0.216, p=0.898	92.15 (8.58)	H=0.86, p=0.958
	<i>Bilateral</i>	21	93.90 (14.90)		92.57 (9.89)	
	<i>Bimodal</i>	2	104.00		94.00	
TH group	<i>Male</i>	18	96.04 (16.36)	U=209.5, p=0.703	104.07 (18.78)	U=171, p=0.183
	<i>Female</i>	25	101.73 (13.90)		97.18 (16.49)	
	<i>Preadolescents</i>	22	93.95 (13.46)	U=125.5, p=0.01	97.24 (19.56)	U=192, p=0.343
	<i>Adolescents</i>	21	105.02 (14.85)		103.02 (15.22)	

Table 6. CI and TH groups' EA-PM and EA-RM mean standard scores, standard deviations (SD) and tests for null hypothesis for gender (male, female), age stage (preadolescents, adolescents), and listening mode.

		N. of subjects	EA-PM standard score (SD)	EA-PM Mann-Whitney or Kruskal-Wallis test	EA-RM standard score (SD)	EA-RM Mann-Whitney or Kruskal-Wallis test
CI group	<i>Male</i>	18	106.17 (12.09)	U=183, p=0.284	100.44 (10.86)	U=198, p=0.492
	<i>Female</i>	25	105.84 (10.22)		104.08 (9.83)	
	<i>Preadolescents</i>	22	103.27 (8.01)	U=152, p=0.055	103.72 (9.87)	U=209, p=0.593
	<i>Adolescents</i>	21	108.81 (12.82)		101.33 (10.85)	
	<i>Unilateral</i>	20	105.4 (12.33)	H: 2.788, p=0.248	102.65 (8.48)	H=1.030, p=0.8597
	<i>Bilateral</i>	21	107.24 (9.83)		103 (12.04)	
	<i>Bimodal</i>	2	98.50		97.00	
TH group	<i>Male</i>	18	98.34 (12.55)	U=164.5, p=0.136	98.14 (10.73)	U=211, p=0.730
	<i>Female</i>	25	103.09 (10.68)		99.54 (12.41)	
	<i>Preadolescents</i>	22	101.50 (10.73)	U=225, p=0.894	97.47 (11.09)	U=196, p=0.395
	<i>Adolescents</i>	21	100.68 (12.70)		100.51 (11.41)	

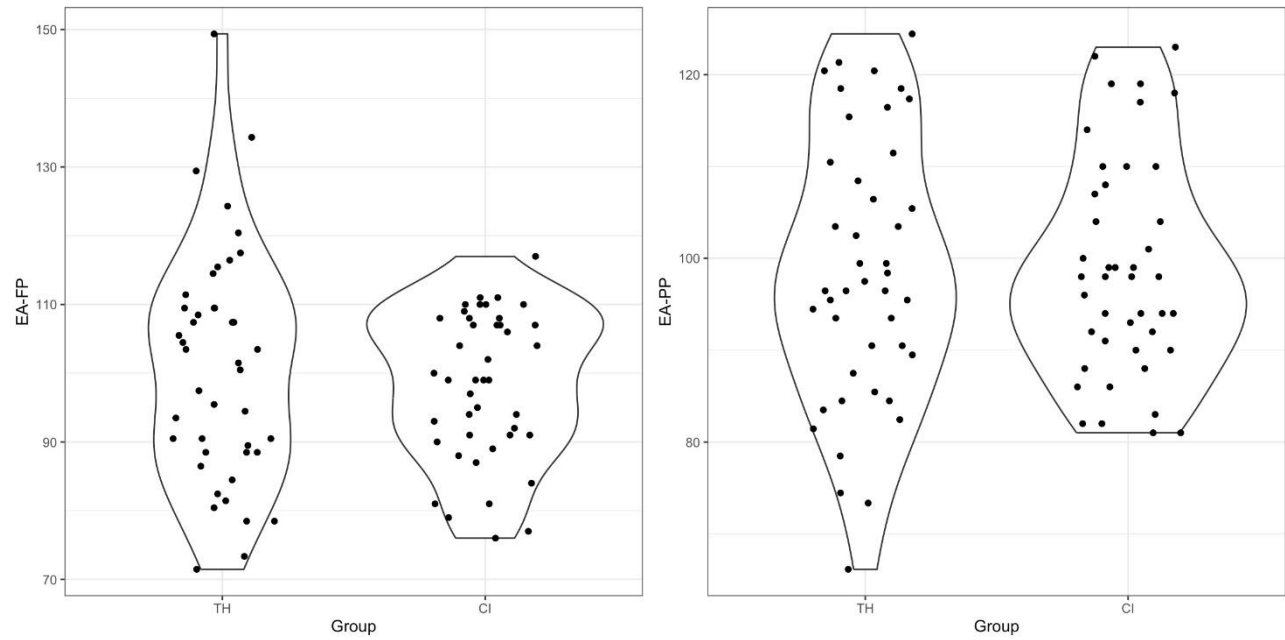


Figure 1. Distribution of standard scores for face and picture identification in TH and CI subjects. EA-FP: Face Perception; EA-PP: Picture Perception

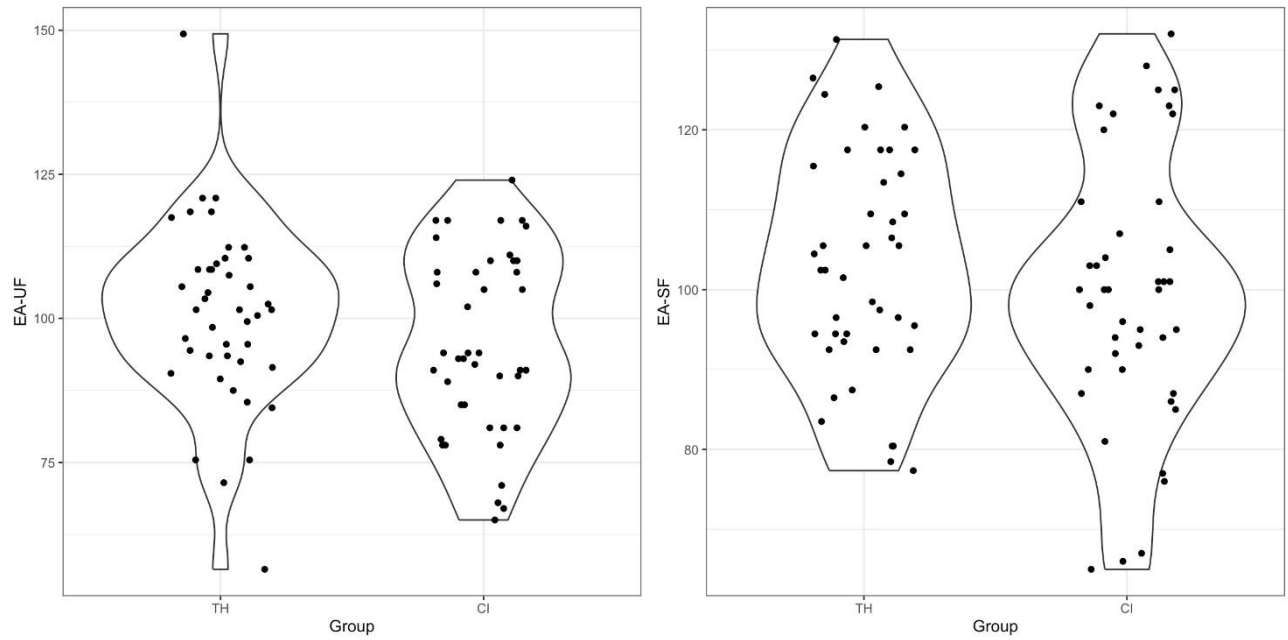


Figure 2. Distribution of standard scores for emotion use and sensations facilitation in TH and CI subjects. EA-UF: Use Facilitation; EA-SF: Sensation Facilitation

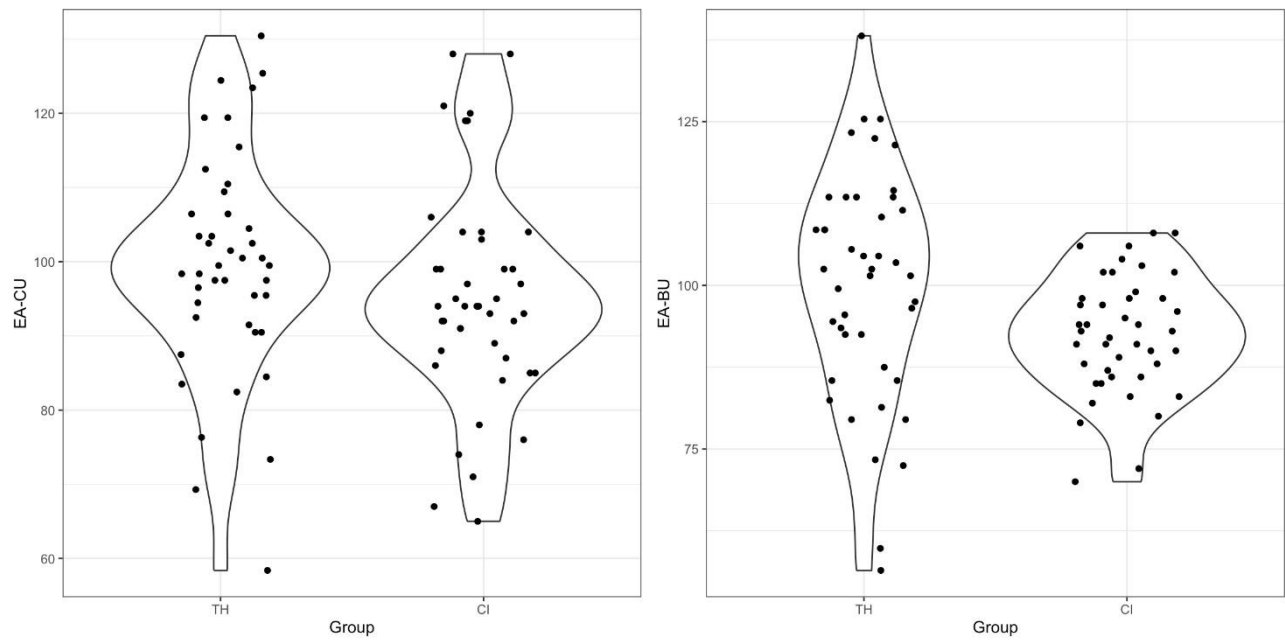


Figure 3: Distribution of standard scores for emotional changes and blends understanding in TH and CI subjects. EA-CU: Changes Understanding; EA-BU: Blends Understanding

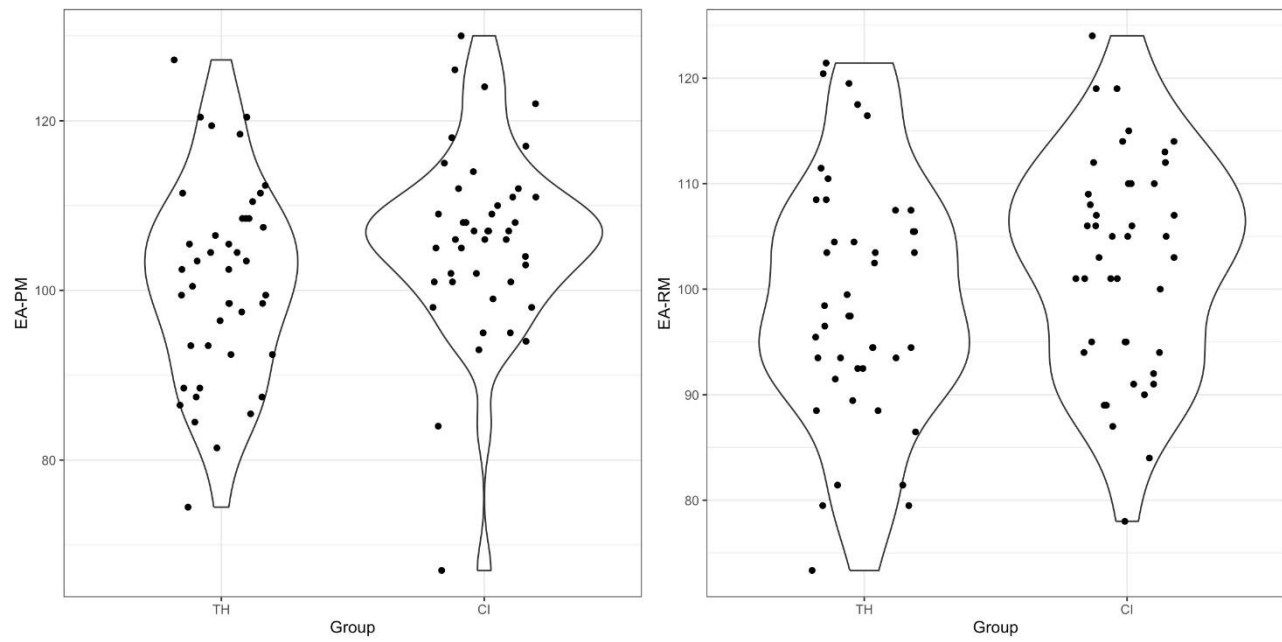


Figure 4: Distribution of standard scores for personal and relationships management in TH and CI subjects. EA-PM: Personal Management; EA-RM: Relationships Management

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The Authors