CA²JU: An Alternative Communication System Developed in Brazil for Children with Disabilities

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ABSTRACT
Education is a fundamental right of all, guaranteed in the Brazilian constitution and in the legislation of several countries in the world. In Brazil, Special Education targets people with disabilities and global developmental disorders. A disabled person needs certain supports, the demands for which are varied. One such demand relates to people with disabilities who have complex communication needs. The **CA²JU** software, an augmentative and alternative communication tool that helps children with complex communication needs, was developed to tackle this problem. Its sophisticated computerised devices can form phrases and sentences for its users and are made available in two access modes: Illustrated and Pro-Expanded. This work aimed to investigate the effectiveness of the **CA²JU** system in terms of implementing alternative communication among children with disabilities. The research analysed the software test with 39 participants between 5 and 12 years of age. The software test showed an average efficiency of 38% in grammatical expansion and ease of access. In both access modes, greater efficiency and grammatical expansion were used in the software than in the communication boards. The lack of ways to communicate will negatively impact students' educational experiences. Thus, the **CA²JU** software is a daily communication alternative for people with disabilities that can not only realise but also accommodate the most varied demands and social contexts, thereby contributing to the development of inclusive schools.

Keywords: software validation, school inclusion, augmentative and alternative communication, disabled children

INTRODUCTION
School inclusion/special education policies have been implemented in a heterogeneous manner in Brazil and across the world. It is well known that when students with disabilities enter school, specific problems, such as issues of accessibility, emerge. In such cases, services and resources that eliminate barriers must be offered so that students with disabilities can access learning. When inclusive public policies are adopted, assistive technology (AT) is used to guarantee the accessibility of people with some motor disabilities and/or dysfunction. AT fits within this framework, bringing innovative instruments and ways that guarantee the inclusion of disabled persons in various spaces (Bailey & Baker, 2020). AT is used to identify any item, resource, and/or service that helps the user increase, maintain, or improve his/her functional capabilities such as communication, mobility, and control of his/her environment (Brunner, Hemsley, Togher, & Palmer, 2017). Therefore, AT could enhance the functional abilities of people with disabilities and favour their inclusion in various social contexts (Boster & McCarthy, 2018).

AT comprises augmentative and alternative communication (AAC) that combines resources and/or services of advanced and basic technologies. Because motor disabilities can hinder speech, it is necessary to use advanced technological features (Mngomezulu, Tönsing, Dada, & Bokaba, 2019) that can act as mediators between the user and the alternative communication system. Examples of such features are mice (hardware), which function as triggers since they fire signals that are interpreted by the software installed on the computer (O'Neill, & Wilkinson, 2020) and can select certain meaningful symbols and pictograms. Based on the selection of these pictograms, the user constructs his/her message and communicates with the interlocutors (Hervás, Bautista, Méndez et al., 2020).

AAC systems also provide individuals with access to a variety of linguistic concepts, while also facilitating the everyday use, which is important for the development of intrinsic communication skills (Aydin & Diken, 2020). When AAC users are proficient in a predominantly oralised environment but must use an expressive language system in another modality, certain aspects of language structure may be particularly difficult both receptively in spoken language and expressively in the aided communication. In addition to expanding the lexical system and determining the relationships between the meanings of the spoken language, users need to identify how the words in their lexicon relate to the external symbols provided to them. As they improve their understanding of the content of spoken language, AAC users are expected to become familiar with what their pictographic symbols represent, what they are, and, subsequently, how the syntactic relations between these symbols work (Bloom, Critten, Johnson, & Wood, 2020a).

Therefore, when discussing the implementation of AAC systems, one must consider the linguistic levels of comprehension and production through which children undergo the process of linguistic construction (Von Tetzchner, Launonen, Batorowicz et al., 2018). This work developed a computer software called CA²JU for implementing AAC considering the different linguistic proficiencies of patients who need advanced technology for communication.

The development of this AAC software aimed to provide more effective communicative possibilities through pictographic symbols at a low resource cost, allowing access from conventional computers to smartphones and expanding the range of environments and social contexts (Von Tetzchner et al., 2018).

In short, this article aimed to investigate the effectiveness of the CA²JU (Macedo, Chella, Givigi et al., 2015) system in terms of implementing alternative communication among people with disabilities. In view of mentioned panorama, this study aimed to present the results of the tests about the effectiveness of the created system, CA²JU, regarding the implementation of AAC for people with disabilities. The driven reason of this study is the developmental of a software characterized by enhanced of grammar expansion of people that need Assistive Technology to communicate. During this study, we analysed types of sentence organizations and symbols that promotes potential to lead to endure linguistically the patients needs.

METHODS

This study employed a qualitative-quantitative crossover clinical strategy that consists of methods, techniques, and procedures that seek to describe and interpret the phenomena through meanings attributed to the lives of the subjects or any other person who shares the therapeutic setting (Campos, Alves, & Turato, 2015).

The precepts of the Ethics and Research Committee, involving human beings of the Federal University of Sergipe, Brazil, were respected throughout the study. The subjects were included in the respective study groups after the signing informed consent forms. The project was approved by the Research Ethics Committee of the Federal University of Sergipe under CAAE: 15822613.7.0000.5546.

Participants

Initially, participants were selected from the Clinic School of the Speech Pathology Therapy College Program of the Federal University of Sergipe and three state schools located in the same city to undergo the software tests. The selection was based on (1) the analysis of children's charts wherein their medical diagnoses were described, (2) the children's communication profile and general speech-language evaluation, and (3) a screening in which the aspects considered were the presence or absence of cognitive impairment and linguistics difficulties.

The inclusion criterion for this research were: subjects had to be aged between 5 and 12 years and had to have a diagnosis and communication profile that fit groups 1, 2, 3 or 4. In total, 39 children participated in the groups, as described in Table 1:

Table 1. Groups for the testing.

Group	Profile	Number of participants
1	Participants without orality and without intellectual disability	5
2	Participants without orality and intellectual disability	12
3	Participants with orality and without intellectual disability	14
4	Participants with orality and intellectual disability	8

Note: Description of the four test groups with number of participants per group

Group one (G1) comprised 5- and 12-year-old children who presented an absence of speech or significant speech changes and did not have a diagnosis of intellectual disability. Considering that the software was developed with the purpose of facilitating communication among people without orality, these subjects constituted the target audience for the integral use of this program in its two modalities and, consequently, for the tests carried out.
Group two (G2) comprised 5- and 12-year-old children who had absence of speech or significant speech changes. Thus, children who did not develop oral language and did not make use of it for communication, besides those presenting clinical diagnoses of intellectual disability, were included. G2 children with mild to moderate cognitive and/or intellectual disorders constituted this group. This group represents the public that can use CA²JU as a tool that enables communication, despite cognitive deficiency, due to the flexibility of the software regarding the linguistic level of the user.

Group three (G3) included subjects aged between 5 and 12 years without any type of alteration of oral and cognitive language; they were the control group of this study. On the other hand, group four (G4), which comprised subjects between 5 and 12 years with orality and intellectual disability, represented those who would not use the software because it requires oral language usage and is used for mild-to-moderate cognitive impairment.

Software: CA²JU Illustrated and CA²JU PRO-Expanded
The CA²JU software is an assistive tool that aims to facilitate communication among people with deficient oral language. Its basic functioning consists of the automatic conversion of natural text into digitalised pictographic symbols that are semantically related. This software was registered at the National Institute of Industrial Property (INPI) under the registration number BR 5120150010557.

All the pictograms used by the software were derived from the portal ARASAAC (Portal Aragonés de la Comunicación Aumentativa y Alternativa, 2020), whose project was financed by the Department for Education, Culture and Sport of the Government of Aragon and coordinated by the Directorate General of Innovation, Equality and Participation of this department. The pictograms are from to the work of Sergio Palao for CATEDU (http://catedu.es/arasaac/) under Creative Commons license.

In view of the different linguistic conditions of each user, the CA²JU was developed in two modes of equal execution but different possible applications. The first modality was named CA²JU Illustrated, and the second CA²JU Pro-Expanded.

When one types a complete sentence in CA²JU Illustrated, it is translated into a sentence composed only of pictograms of the keywords. In other words, it transforms words of semantic-lexical nature into pictographic symbols. Each pictogram is added to a sequence that will later be converted into a sentence. For this task, the software works with several techniques such as Stemming and Entity and Name Recognition, which makes it possible to erase and add pictograms based on their semantic relations (Santos, Medonça Júnior, Macedo et al., 2015; Pereira, Macedo, Chella, & Givigi, 2017). The CA²JU Illustrated should be introduced at an early stage for those who have never used any CAA system. The following figure (Figure 1) exemplifies the conversion of sentence 3.2. of the execution protocol typed in the text box into a pictographic phrase:

Figure 1. Conversion of sentence typed in the text box and converted into a pictographic frase. CA2JU Illustrated: Software.

The other mode of operation was called CA²JU Pro-Expanded. Unlike the CA²JU Illustrated the CA²JU Pro-Expanded mode allows the text to be transformed into pictograms with all elements represented in symbols, including semantic-grammatical elements. Figure 2 below exemplifies the result of the conversion of sentence 3.2. of the protocol of execution to a pictographic phrase.

Figure 2. Conversion of sentence with more elements typed in the text box and converted into a pictographic frase. CA²JU Pro-Expanded: Software.

Procedures

First, a study was carried out among the pilot group comprising six subjects in the age range of 5 to 12 years to determine parameters such as duration of the test, level of difficulty of interpretation of pictograms, and response options. Subsequently two study groups were established: CA²JU Illustrated and CA²JU Pro-Expanded. In the CA²JU Illustrated, the effectiveness of the software in the communicative function of the patient group was investigated through pictograms that were presented following the order of sentences recommended in the execution protocol. By typing a sentence in the CA²JU Illustrated mode, only words of a semantic-lexical nature were transformed into pictographic symbols. In the Pro-Expanded CA²JU study group, the possibility of grammatical expansion was investigated, following the order of presentation of the phrases of the execution protocol. In this modality, the children were expected to change the structure of the sentence of the protocol of execution, besides using articles, prepositions, and adverbs, among others, which increased the level of complexity of the test.

The tests were conducted in two phases: one testing phase used the software CA²JU Illustrated and CA²JU Pro-Expanded, while the other used paper craft boards (AAC boards) made with the pictograms available on the ARASAAC software. These boards contained the same sentences used for testing the software.

After dividing the patients into the study groups, each group was divided in half in a non-randomised manner to determine which patients, the linguistic profile determined the groups, would start with the AAC board and which ones would start with the software. After the application of the test, starting with one of these instruments, the reverse was performed; in other words, the subjects who started with the software would respond to the AAC board, and the subjects who started with AAC boards underwent software evaluation. .

The non-validated execution protocol used in the tests comprised three sentence levels for morphosyntactic analysis (Appendix.A). All sentences were structured through a morphosyntactic study of the linguistic construction of the subject, relating age and context of the communicative functions. The first, second, and third levels contained common sentences to children aged between 5 and 8 years, 8 and 10 years, and 10 and 12 years, respectively. Thus, all subjects would start at level 1, whether or not they advanced to higher levels subsequently. Each level consisted of five sentences.

With regard to the evaluation, it was considered correct when the subject pointed out the image that corresponded to the meaning of the sentence from among the pictograms presented in the software and the AAC board. The subject passed to the next level if he/she had three or more correct answers.

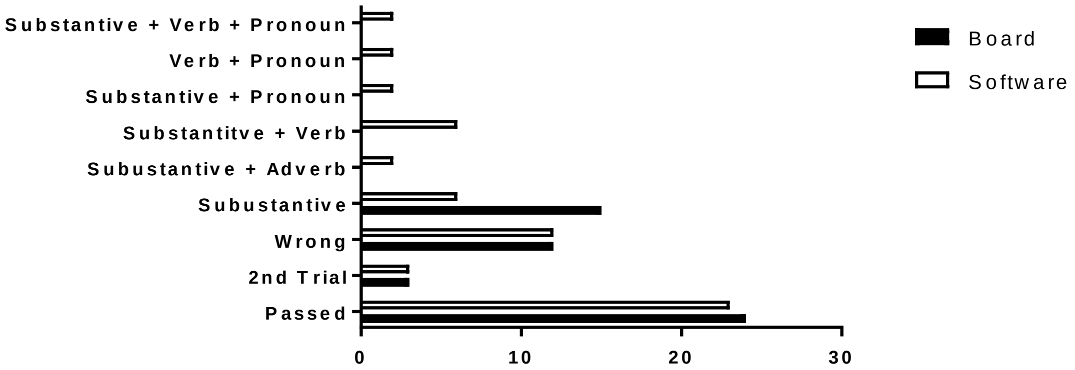
We established the following standard procedure for all tests: the subject assigned from among the group of children would start with the AAC board and then proceed through the software, beginning with the first level of the CA²JU Illustrated mode, which comprises the simplest functionality of the software. If the subject accomplished all requirements, he/she would be tested using the CA²JU Pro-Expanded mode.

All subjects were obliged to participate in the tests of the CA²JU Illustrated mode (board and software), but only those who fulfilled the requirements would continue to the CA²JU Pro-Expanded mode.

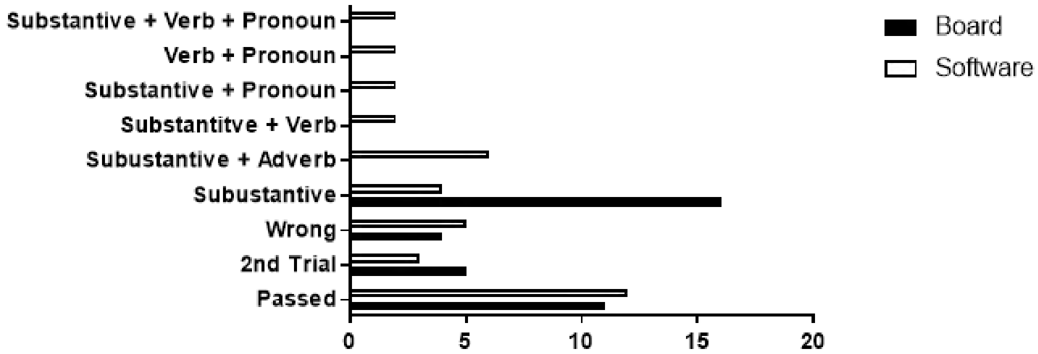
Statistical analysis
Collected data were entered into the Excel for Windows 2013 program data sheet and in the SPSS program, version 16.0. The Kappa coefficient was used to analyse reliability among rates and confidence intervals.

RESULTS
In total, 39 subjects participated in the test, and 38% progressed from the Illustrated mode to the Pro-Expanded mode. This data confirms the hypothesis that the subjects have to use the AAC for some time to be able to use the Pro-Expanded mode, which requires greater linguistic complexity than the former.

The units of pictograms for comprehension were more effective in the Illustrated mode than in the ACC. Regarding the grammatical expansion of the CA²JU Pro mode, a great variety of possible semantic combinations were found in the application, which is not possible with the paperboards, because they only consider the printed pictograms, while the software allows working with several grammatical classes using pictograms . It is noteworthy that in the Pro mode software testing stage, children are expected to change the structure of the sentence in the execution protocol in order to investigate the level of grammatical expansion of the program. Comparatively, in the testing phase of the boards, children are expected to modify the meaning of the sentence using only the options of answers in the boards, in order to compare the efficiency of the software in relation to the paper boards. This comparison showed the flexibility of the linguistic construction of the system in relation to grammatical complexity, a characteristic that is limited in the AAC boards. This result can be verified in the following graphs 1 and 2:

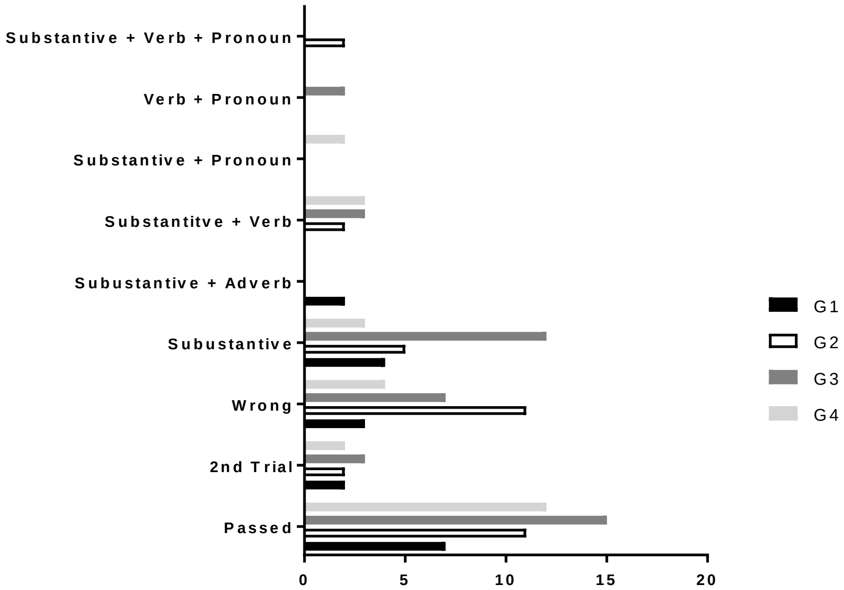


Graph 1. Graph showing the grammatical expansion between board mode and software, at the initial level of testing.

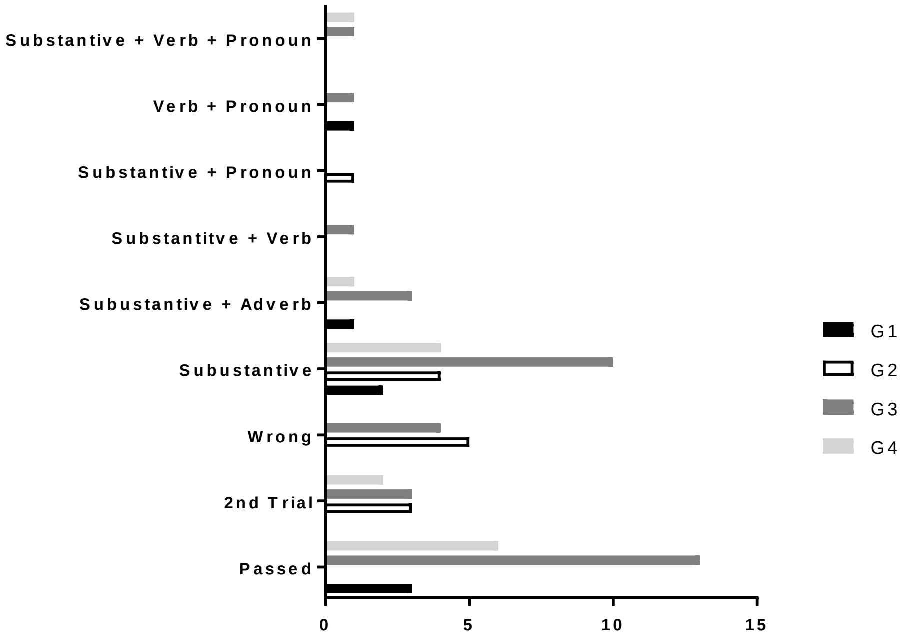


Graph 2. Graph showing the grammatical expansion between board and software mode, in the last sentence of the second level of testing.

Regarding the study groups outlined, it was observed that regardless of the origin of the subject – G1, G2, G3, or G4 – it was possible to perform grammatical expansion. Following are graphical analyses of grammatical amplification, regardless of mode (Illustrated or Pro-Expanded):



Graph 3. Grammatical expansion by groups, level 1.1.



Graph 4. Grammatical expansion by groups, level 3.5.

DISCUSSION

Although technological communication advancements are made worldwide, it is difficult to report the efficiency of the equipment and the consequent high cost. In 2013, a communication device was developed for people with disabilities based on advanced learning of cognitive, language, and user-learning skills (Yook, Oh, Lee, Go, & Bae, 2013). In addition, with regard to the interaction between man and computer, we can rely on ocular tracking devices to enhance the communication of disabled users with speech disorders or absence of speech, as the software was specially developed to meet such demands (Bekteshi, Konings, Vanmechelen, et al., 2020; Holmqvist, Thunberg, & Dahlstrand, 2017; Vessoyan, Steckle, Easton et al., 2018).

Currently, scholars have been working on the development of interface assessments of electrical signals on the scalp (electroencephalography EEG), or by means of electrodes implanted on the cortical surface in a surgical procedure, or through intracerebral electrodes (peaks of neuronal action). An important study verified the recognition of specific oscillatory patterns in multichannel electroencephalograms (EEGs). The ability to separate segments of real and imaginary movements during the EEG was verified (Pavlov, Grishina, Runnova, et al., 2019). Despite the advances, there are many outdated ones, such as cheap technology and physical enhancements in the performance of devices that use brain computer interface (BCI) (Uktveris & Jusas, 2018).

One of the major obstacles to the development of computer programs that offer AAC resources is the high cost and variety of aspects that must be addressed when it comes to language learning (Elsahar, Hu, Bouazza-Marouf, Kerr, & Mansor, 2019).

In British Columbia, Canada, a study investigated the sociodemographic characteristics of students with various special needs and disabilities. It revealed that, although profiles were heterogeneous, more than a quarter of those surveyed had one or more special needs. It was also noteworthy that within the same disability category, there was considerable diversity in its sociodemographic attributes (Lloyd, Zou, & Baumbusch, 2020).

In view of the obstacles described, it is important to consider the profile of users of alternative communication and their preferences in relation to the interlocutors who are involved in their conversations. Therefore, it is necessary that the alternative communication system is flexible to be most efficient (Boster & McCarthy, 2018). The CA^{2}JU software was built based on the linguistic levels through which children undergo the process of language construction. Thus, it was necessary for the tests to respect this relationship between the children's age and their linguistic level to guarantee the validity of the software validation as a communication tool for those with little or no orality.

Previous studies have verified the need for alternative communication resources that are flexible in language and syntactic strategies (Deliberato, Jennische, Oxley et al., 2018; Bonora, Dalai, De Rosa et al., 2019). At the end of the tests, the results showed that the CA^{2}JU satisfies the topic of syntactic-semantic flexibility because it allows the construction of sentences as the user selects a new item. The phrase that will be constructed can reflect what the user wanted to communicate because of the possibility of changing the pictograms; thus; it also allows the user to change the meaning of the whole sentence. This option was easily and quickly accessible to all groups, and all groups were able to perform this grammatical expansion, regardless of their diagnosis.

CONCLUSION

To be effective in school, individuals with complex communication needs require AAC resources. These resources enable interaction between peers and the students' participation in the learning process. Many studies have investigated the support provided to students with disabilities, reporting the importance of a variety of materials and modifications (Clark, Adams, Roberts, & Westerveld, 2020; Rose & Shevlin, 2020).

The development of CA^{2}JU software for CAA through the use of digitised pictographic symbols enables users with significant speech impairment to communicate with greater autonomy by sharing their wishes and desires.

Based on the 112 tests conducted, it is possible to consider the use of Illustrated and Pro-Expanded modes as a resource for everyday communication, since the software is not only online, allowing it to be accessed from conventional computers, smartphones, and tablets, but also effective in terms of the flexibility and semantic variability of pictograms, adapting to the demand of each subject. In addition to its everyday applicability, the software is an alternative, much like a therapeutic resource in the context of AAC implementation, facilitating the therapist's intervention with the subject who has similar communicative demands to those addressed in this study. However, the use of CA^{2}JU is not restricted to the therapeutic and domicile environment. The application of this tool as a means of communication in the school community opens a range of pedagogical possibilities aiming at the inclusion of the user in the activities that demand dialogues or even in the interactions among classmates, teachers, and other professionals of the school network. In inclusive education, when teachers are poorly supported, they are more likely to be unsuccessful. Of the various supports that are cited as important for the inclusion of the student in regular school are the communication resources (Saloviita, 2020).

This work is the result of a partnership with the Computer Sciences department. From their articulation of knowledge, it was possible to create a low-cost product that adapts to the subjects' communicative demands and have open standards for the purpose of enabling the interconnection with current software and hardware technologies. This mainly points to the possibility of people with disabilities to communicate and develop effective learning strategies.

Other research on using appropriate software or hardware systems and assistive technologies has shown that they contribute to learning and facilitate the interaction of students with disabilities. With the development of communication skills, such students can work in a team, solve problems, and participate in school activities (Bakken, Varidireddy, Uskov, & 2019; Drigas, Dede, & Dedes, 2020).

We argue that more work is needed to facilitate the communication of children and young people not only with disabilities but also with complex communication needs (Bloom, Critten, Johnson, & Wood, 2020b). In particular, we propose that other parameters be considered in the process of including children and young people with disabilities in schools.

There are many challenges for the development of communication tools for children with complex communication needs (Bloom et al., 2020b). However, there is a social and educational need to contribute to the construction of inclusive learning environments. Without communication, students will feel the negative impacts on their educational experiences.

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CONFLICT OF INTEREST

There are no conflicts of interest to declare.

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Appendix A

CA2JU ILLUSTRATED and PRO-EXPANDED TEST PROTOCOL

LEVEL 1

1. LET'S HAVE SOME ICE CREAM.

☐ Correct Answer ☐ Correct Answer on the Second Attempt ☐ Incorrect Answer

2. THE GIRL WENT TO THE MARKET, BUT SHE DIDN'T HAVE ANY MONEY.

☐ Correct Answer ☐ Correct Answer on the Second Attempt ☐ Incorrect Answer

3. GIVE ME SOME BLUE AND YELLOW PAINT TO COLOR THE FLAG.

☐ Correct Answer ☐ Correct Answer on the Second Attempt ☐ Incorrect Answer

4. SIT CLOSE TO ME BECAUSE I WANT TO TALK TO YOU.

☐ Correct Answer ☐ Correct Answer on the Second Attempt ☐ Incorrect Answer

5. DON'T FIGHT WITH THE BOY BECAUSE HE IS SAD.

☐ Correct Answer ☐ Correct Answer on the Second Attempt ☐ Incorrect Answer

	CORRECT ANSWER	CORRECT ANSWER ON THE SECOND ATTEMPT	INCORRECT ANSWER
TOTAL POINTS			

LEVEL 2

1. I HAVE A BAD HEADACHE; I CAN'T STUDY.

☐ Correct Answer ☐ Correct Answer on the Second Attempt ☐ Incorrect Answer

2. IT IS VERY COLD IN THIS CITY, SO THE MAN PUT ON TWO COATS TO AVOID GETTING SICK.

☐ Correct Answer ☐ Correct Answer on the Second Attempt ☐ Incorrect Answer

3. YESTERDAY I DREAMED THAT A PRINCESS AND PRINCE FELL FROM THE TOP OF THE CASTLE.

☐ Correct Answer ☐ Correct Answer on the Second Attempt ☐ Incorrect Answer

4. THE PARTY WAS TODAY. IF IT HADN'T RAINED, I WOULD HAVE RECEIVED MANY GIFTS BECAUSE I INVITED A LOT OF FRIENDS.

☐ Correct Answer ☐ Correct Answer on the Second Attempt ☐ Incorrect Answer

5. WHY ARE THERE BIG PEOPLE AND SMALL PEOPLE? WHEN HE GROWS UP, HE WANTS TO BE BIG LIKE HIS FATHER.

☐ Correct Answer ☐ Correct Answer on the Second Attempt ☐ Incorrect Answer

	CORRECT ANSWER	CORRECT ANSWER ON THE SECOND ATTEMPT	INCORRECT ANSWER
TOTAL POINTS			

LEVEL 3

1. IT IS GOING TO RAIN, SO DON'T FORGET TO CLOSE THE WINDOWS WHEN YOU LEAVE HOME TO MAKE SURE THAT THE FURNITURE DOES NOT GET WET.

☐ Correct Answer ☐ Correct Answer on the Second Attempt ☐ Incorrect Answer

2. THE GIRL WOKE UP SO EARLY THAT SHE GOT TO CLASS BEFORE EVERYBODY ELSE AND HAD TO WAIT FOR THE TEACHER.

☐ Correct Answer ☐ Correct Answer on the Second Attempt ☐ Incorrect Answer

3. LAST WEEKEND, I WENT TO GRANDMA'S FARM. I RODE A HORSE, SWAM IN THE RIVER, ATE MANGOES, DRANK MILK FROM THE COW, AND PLAYED WITH MY FRIENDS WHO LIVE THERE.

☐ Correct Answer ☐ Correct Answer on the Second Attempt ☐ Incorrect Answer

4. WHEN SHE WAS A LITTLE GIRL, HER MOTHER TOOK HER TO SING IN THE CHURCH CHOIR, BUT SHE DIDN'T LIKE IT BECAUSE SHE FELT EMBARRASSED.

☐ Correct Answer ☐ Correct Answer on the Second Attempt ☐ Incorrect Answer

5. HEARING THE BIRDS SINGING ON SUNNY DAYS CAUSED THE CHILDREN TO WAKE UP HAPPIER ABOUT GOING TO SCHOOL AND PERFORMING THEIR TASKS.

☐ Correct Answer ☐ Correct Answer on the Second Attempt ☐ Incorrect Answer

	CORRECT ANSWER	CORRECT ANSWER ON THE SECOND ATTEMPT	INCORRECT ANSWER
TOTAL POINTS			