Tablet-Based Activity Schedule in Mainstream Environment for Children with Autism and Children with ID

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Including children with Autism Spectrum Disorders (ASD) in mainstreamed environments creates a need for new interventions whose efficacy must be assessed in situ. This paper presents a tablet-based application for activity schedules that has been designed following a participatory design approach involving mainstream teachers, special-education teachers and school aides. This applications addresses two domains of activities: classroom routines and verbal communications.

We assessed the efficiency of our application with two overlapping user-studies in mainstream inclusion, sharing a group of children with ASD. The first experiment involved 10 children with ASD, where 5 children were equipped with our tabled-based application and 5 were not equipped. We show that (1) the use of the application is rapidly self-initiated (after two months for almost all the participants) and that (2) the tablet-supported routines are better performed after three months of intervention. The second experiment involved 10 children equipped with our application; it shared the data collected for the 5 children with ASD and compared them with data collected for 5 children with Intellectual Disabilities – ID.

We show that (1) children with ID are not autonomous in the use of the application at the end of the intervention; (2) both groups exhibited the same benefits on classroom routines; and, (3) children with ID improve significantly less their performance on verbal communication routines. These results are discussed in relation with our design principles. Importantly, the inclusion of a group with another neurodevelopmental condition provided insights about the applicability of these principles beyond the target population of children with ASD.

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1. INTRODUCTION

Children with Autism Spectrum Disorders (ASD) are characterized by restricted and repetitive behavior patterns, as well as impairments in communication and social interaction [APA 2000]. Symptom severity and intellectual ability vary considerably, but

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in all cases, the capacity to cope effectively with the demands of daily life is negatively affected. Children with ASD, for example, experience difficulties in organizing time, planning, and completing tasks [Gagné 2010].

Despite these challenges, there is growing evidence that educational inclusion produces a positive effect on children with Autism Spectrum Disorders (ASD) [Hunt and McDonnell 2007]. However, inclusive education of these students is often hampered by the misgivings of school staff that presumes negative outcomes on classroom functioning if the student is not autonomous enough to perform a range of tasks [Harrower and Dunlap 2001]. Specifically, children with ASD may need help to manage daily routines, make transitions between activities and engage in social interactions [Cramer et al. 2011]. If these special needs are not addressed, they can result in interruptions during class that decrease learning opportunities, not only for the student with ASD, but also for all the students [McCurdy and Cole 2013].

Activity schedules are an efficient method to enable children with ASD to be more autonomous [Koyama and Wang 2011; Lequia et al. 2012; McClannahan and Krantz 1999]. An activity schedule is based on picture and/or text sequences decomposing tasks or activities into successive steps [McClannahan and Krantz 1999]. By following such schedules, users can achieve tasks, using paper-based supports [Koyama and Wang 2011] and multitouch tablets [Cihak et al. 2010; Hirano et al. 2010]. Such compensation technologies have been studied for a long time (for a comprehensive review, see Frank Lopresti *et al.* [Lopresti Frank et al. 2004]). Hence, activity schedule is a promising assistive method, especially when it is realized on a tablet, because of the documented preference of ASD children for this device [Sampath et al. 2012; Tentori and Hayes 2010].

Surprisingly, the use of computer-based activity schedules in school settings is only proposed for special classrooms, not in mainstreamed classrooms. This situation may stem from the complexity of specifying tasks that need support in general classroom, compared to special classroom. For instance, contrary to special education settings, inclusive education in a secondary school entails frequent changes in terms of classrooms, teachers, and classmates. Furthermore, in mainstreamed environments, the expectations of teacher may not be as personalized as in a special classroom. For instance, a pedagogical focus on a single task or a limited set of tasks is possible in a protected class, whereas a wide panel of tasks is implicitly expected as being correctly performed in mainstreamed setting.

This paper presents the design of a tablet-based application, named *Classroom Schedule+ (CS+)*, that supports activity schedules for both classroom and verbal communication routines. This design has been carried out with a participatory design approach, including the stakeholders of educational inclusion. Students with ASD used this application in mainstream classes. An experimental study compared the performance of equipped students with ASD to non-equipped students with ASD.

In practice, students with ASD spend their time in a special-education classroom, when they are not in an inclusive class. This special-education classroom often gathers students with other conditions than ASD; they are mostly students with non-specific Intellectual Disabilities (ID) [Duncan et al. 2014]. For obvious ethical reasons, we decided to equip with our tablet all the students of the special-education classrooms, whether or not with ASD. Besides the satisfaction of being inclusive in our approach, this situation could create an opportunity, if all students participated in our study. Specifically, we would then be able to measure the effects of our application on participants, exhibiting similar functional limitations, but having a different condition. In doing so, we would know whether the design of our application was specific to the children with ASD, and whether it produced different benefits depending on the students' condition.

In this paper, our contributions are as follows.

The creation of a tablet-based application that supports activity schedules. This application has been designed following a participatory design approach involving mainstream teachers, special-education teachers and schools aids. In doing so, we identified activities that must be supported in general classrooms for students with ASD, and we collected the requirements needed for a computer-based activity-schedule system. *CS+* supports two domains of classroom activities for which mainstream teachers have given priority: classroom routines and verbal communication.

Our application was used in mainstream classes. Ten students in special-education classes of secondary schools were equipped with our tablet-based application. Their age ranged from 13 to 17. Their conditions included ASD and ID. Our intervention lasted for 3 months and involved including these children for the first time in mainstream classes (one hour per week accompanied by a school aide).

We demonstrated the efficiency of our application to support mainstream inclusion. Specifically, five students with moderate ASD were equipped with CS+ (ASD experimental group), while five others students with moderate ASD were not equipped (ASD control group). Equipped students showed significant improvements for classroom and verbal communication routines, over non-equipped ones, in the mainstream classroom.

By recruiting five children with ID, we determined the perimeter within which our design principles apply to both populations (with and without ASD). We measured similar improvements for classroom routines in both groups, suggesting that our design applies equally well to both cases. However, we observed significant differences in favor of children with ASD when considering verbal communication routines. This result suggests that for these activities our design is better suited for children with ASD.

This article is an expanded version of a conference paper presented in the ACM ASSETS 2014 Conference on Computing and Accessibility in Rochester (US) [Fage et al. 2014]. We present results from an additional experimental group with another condition and discuss the relationships between our initial design principles and the variations in the efficiency of our application on both populations (ASD and ID).

2. RELATED WORK

Assistive technologies in the school context. Several computer-based intervention tools have been developed to support inclusion in mainstreamed environments. For example, Escobedo *et al.* provided a smartphone-based tool for assisting social skills during breaks in a public school, using an augmented reality approach [Escobedo et al. 2012]. It helped 3 students with ASD increasing their communication and social interactions, enabling their integration with 9 neurotypical students. Huong *et al.* investigated the relevance of online crowdsourcing to provide individuals with ASD with "social support from out-group workers in order to cope with everyday issues and frustrations" [Hong et al. 2015]. For another example, a task manager, hosted by a smartphone, has been used by young adults with ASD studying at the university [Gentry et al. 2010].

Activity schedules in the school context. Recently, principles of activity schedules have been explored as underpinnings of the design of assistive technology for ASD children. Specifically, paper-based activity schedules are mostly used by special education teachers with children with ASD; these schedules usually consist of line drawings or photographs with Velcro© on the back [Lequia et al. 2012]. They have been used in educational programs dedicated to individuals with ASD and represent a key component of the structured teaching model in the TEACCH program (Treatment and Education of Autistic and Related Communication Handicapped Children) for many years [Mesibov et al. 2004]. However, they include limitations for school aides or teachers, such as time to create them and difficulties to record data for tracking student progress [Hirano et al. 2010]. Consequently, activity schedules can be considerably improved when they are based on a multitouch tablet [Cihak et al. 2010; Hirano et al. 2010]. Hirano *et al.* developed vSked, an interactive activity scheduling for use in special education classroom [Hirano et al. 2010]. The vSked system was designed to include the benefits of traditional activity schedules (*e.g.,* transitioning between activities, independently engaging in classroom tasks) as well as new functionalities, such as dynamic task creation and real-time usage tracking. Cihak *et al.* supported students with ASD to initiate a general classroom task (*e.g.,* writing, reading or listening), not to follow a sequence of activities [Cihak et al. 2010]. The authors use photos showed to the student, self-modelling task engagement to support the initiation of a classroom task. These photos were inserted into a PowerPoint© presentation on a handheld computer.

Therefore, to the best of our knowledge, there is no study assessing the use of activity schedules to support inclusion of children with ASD in general classrooms. Although their effectiveness has been demonstrated in special education classrooms.

Introducing an assistive technology in special-education classrooms: inclusion of children with ID. As mentioned earlier, for ethical reasons, we included both children with ASD and children with ID in our study. These two populations exhibit similar functional limitations of daily living activities, involving the autonomy skills, and communication skills [Liss et al. 2001; Mouga et al. 2014]. Specifically, these two populations exhibit a similar level of difficulties in communication skills, while children with ID perform slightly better in daily living activities related to autonomy skills [Liss et al. 2001; Mouga et al. 2014].

Consequently, activity schedules have been extensively used to assist both populations to improve their autonomy and reduce their dependence to caregivers [Anderson et al. 1997; Copeland and Hughes 2000; Carson et al. 2008; Mechling 2007]. Specifically, Irvine *et al.* [1992] addressed the school context by using paper-based activity schedules in a special-education classroom with four students with severe intellectual disabilities. Thanks to their paper-based activity schedules, participants managed to self-initiate each step of a previously established routine when arriving in the classroom in the morning. However, authors did not assess the performance on prompted tasks, but rather emphasized on their self-initiation. Spriggs *et al.* [2007] provided four students with ID with activity schedules books in a special-education classroom. All four participants performed more step independently when using these activity schedules books. Effectiveness of activity schedules to assist people with ID has been reported when implemented on technological supports, such as PDA, smartphone and touch-screen tablet [Davies et al. 2002; Lancioni et al. 2000]. The authors observed an enhanced autonomy of the participants.

From a methodological standpoint, including two different populations in the validation of an intervention enriches the results of a study. Such experimental design is called Cross-Syndrome design [Sigman and Ruskin 1999]. It is suited to demonstrate specific intervention effects in a target population, while matching participants on their individual factors, namely the age, the intellectual functioning, and the educational environment. According to Sigman and Ruskin, if syndrome group A and contrast group B are matched on chronological age and intellectual functioning, but the mean of group A on an intervention effect is significantly higher than the mean of group B, then group A is considered to exhibit a specific benefit on the intervention. A benefit (or pattern of benefit) is considered unique to syndrome A if it is evidenced only by individuals who have this syndrome.

Even though we included children with ID in our study, our work focused on designing and validating a tablet-based activity schedule to support mainstream inclusion of children with ASD. Therefore we considered general principles to develop interactive technologies for children with ASD and adopted a participatory design approach to develop such an assistive tool.

General principles to develop interactive technologies for children with ASD. Individuals with ASD have a preference for computers and video games to assist them with social communication and academic activities [Putnam and Chong 2008]. Prevalently, the research on the design of interactive technologies for children with ASD recommends simplicity, predictability, and clear mappings between actions [Hayes et al. 2010; Hourcade et al. 2013]. Because individuals with ASD tend to process visual information more effectively than auditory information, existing intervention approaches use visual supports [Hayes et al. 2010; Hirano et al. 2010; Hourcade et al. 2013]. Since Autism is considered as a spectrum, the severity of the difficulties encountered is extremely variable among children. Assistive technologies must be flexible enough to support and adapt to each child uniquely, as (s)he develops [Hayes et al. 2010]. Distractive stimuli should be avoided. More precisely, they should be mistake-free to reduce frustration (*e.g.,* no error messages, no wrong answers) [Hourcade et al. 2013]. These well-known general principles ensure the usefulness and usability of the interactive technologies for children [Hayes et al. 2010; Hirano et al. 2010; Hourcade et al. 2013]. However, these principles are not enough to ensure that the technology matched the constraints of mainstreamed environments.

Participatory design approach. A participatory design method creates a great interest in the area of assistive technologies [Druin 2002] because it relies on the active involvement of end-users and stakeholders to identify needs and constraints. It has been extensively used in the design of technologies for children with ASD [Benton et al. 2012; Frauenberger et al. 2011], notably in the vSked system to identify needs and constraints of special education classrooms [Hirano et al. 2010]. To the best of our knowledge, such approach has not conducted to analyze the needs of students with ASD in the context of their first inclusion in mainstream classrooms. Yet, a participatory approach could help identifying which activities need support for children with ASD when first included in mainstreamed classrooms.

Aim of this paper. We have conducted a participatory design approach to developing an application that provides activity schedules to support children with ASD during their inclusion in mainstreamed classrooms. We have assessed the application's effectiveness with children with ASD at secondary school. Additionally, we enriched the results by including children with another condition in our study, namely intellectual disabilities.

3. DESIGNING ACTIVITY SCHEDULES

Let us now introduce the design principles that make our application for activity schedules amenable to general education classrooms. These principles result from interviews we conducted with a panel of school staff members. The interviewers from our team consisted of psychologists and cognitive scientists. Interviewees from the school staff included 3 special education teachers and 5 school aides; all of them had at least 5 years of experience with children with autism. We also interacted with a dozen of teachers who had previously taught children with disabilities. Interviews were conducted with small groups (4/5 people in each session) at school. During the first session, school staff members presented some examples of visual supports they were using in their classrooms (*e.g.,* pictures and words (to be paired) printed on small-sized paper sheets). The following sessions were dedicated to making classroom functioning explicit and exploring how technological support could fit in the mainstream environment: usage duration, role of the school aide, *etc.*. Then, we proposed ideas of assistive support, and discussed with the school staff to determine the ones they thought were the best suited for their needs. This participatory design resulted in five main principles to be taken into account in the design of our tablet-based activity schedule application.

3.1. Design Principles

Requirements related to the implicit and explicit rules of general classroom functioning have been given by the school staff. Not only do these principles come from stakeholders in the field, but most of them also conform to the litterature [Charbonneau et al. 2013; Cihak et al. 2010; McClannahan and Krantz 1999]. Let us examine these principles.

Activity schedules must promote reading skills. Reading skills is a pervasive need in the school setting. Consequently, supporting this skill in any activity at school fits the school learning objectives. To support this, visual double-coding (*i.e.,* pictorial and textual) has been applied for each step in the sequence of our activity schedules application. Text and visual information are coupled to give children who cannot read the opportunity to associate words to pictures.

Sequences must be short. Classroom instructional flow is critical for some children, especially with ASD. School staff were unanimous on the fact that the intervention had to be as short as possible, to prevent the child from losing track of what is going on in the classroom. Thus, to support inclusion of students with ASD, an activity schedule must be as short as possible (*i.e.,* decomposed into few steps). This principle is consistent with general requirements to create activity schedules [McClannahan and Krantz 1999].

Pictures and sentences must be concrete and idiosyncratic. Each step in the sequence of our activity schedule includes a picture and a sentence. School staff was unanimous on the fact that pictures and sentences must be idiosyncratic (*i.e.,* specific to a person). Furthermore, because of the complexity of multiple concurrent behavioral requirements in an academic setting (*e.g.,* waiting at the door with classmates, waiting for an approval of the teacher, *etc.*), the use of self-modeled pictures, similar to those proposed by Cihak *et al.*. [Cihak et al. 2010], is recommended. For instance, to support a classroom behavior (*e.g.,* to raise hand), students self-modeled pictures should be use (see Figure 1).

Progress status. To help students better manage their time, it is important to give them an indication of their progress in activity schedules. Furthermore, the use of visual timers leads to reducing anxiety - particularly present in mainstreamed classrooms. In doing so, the reduction of maladaptive behaviors may be achieved.

Activity schedules must not use the auditory channel. The intervention inside the classroom must exclude audio materials. First, they would require the use of head-

Fig. 1: Self-modeled pictures of the same action.

phones that would cause a sensory exclusion, precluding the child from participating to the class. Second, headphones would stigmatize the child in front of others students because the use of technology for inclusion must be as unobtrusive as possible.

3.2. Identification of classroom activities

Given these principles, we worked with all stakeholders to list activities of interest in inclusive education classrooms. This step was then followed by a selection of the critical activities that required assistive support.

General listing. We first listed general classroom activities involved in inclusion education with a participatory approach. These activities do not concern academic activities but classroom functioning involving students. Indeed, our technological support is not a pedagogical tool to improve student learning performance, but to guarantee typical classroom functioning. Mainstream teachers, special-education teachers and schools aides have participated to propose general classroom activities to list. For instance, few general classroom activities proposed are : Going into classroom; Answering to classmate; Following explanations or complex directives; Answering questions about a text which comes from it being read *etc.*. A total of 27 general classroom activities have been proposed by these stakeholders.

Priority selection. The second step was to select critical activities to be supported in this large selection. Such activities were required not to bring the student with ASD to disturb classroom functioning. Indeed, some activities create critical disruptions, and the school staff is frequently forced to suspend the inclusion of the student with ASD and to re-place him in special education classrooms for the end of the class [Harrower and Dunlap 2001]. Furthermore, to create activity schedules properly, we also selected activities with a clear beginning and end [McClannahan and Krantz 1999]. These criti-

Table I: The two domains of classroom activities

Classroom Routines	**Verbal Communciation**
Listening and taking notes	Answering the teacher
Going to classroom	Answering a classmate
Leaving the classroom	Talking to teacher
Taking out school supplies	Talking to classmate
Using calendar	

Table II: Example of the “talking to teacher” activity

Ask to repeat
Raise your finger
Wait for the teacher to interrogate you
Say: ”Could you repeat please ?”
Finished!

cal activities can be respectively regrouped in two general domains: classroom routines and verbal communication (see Table 1).

3.3. Sequencing

Each activity of the two domains has been decomposed into sequences thanks to methods described in McClannahan and Krantz (1999) [McClannahan and Krantz 1999]. Furthermore, authors specified some requirements to follow to create an activity schedule: it must be easy to manipulate, includes at least one social initiation when possible, finishes with reinforcement (*e.g.,* “Finished!”) *etc.* [McClannahan and Krantz 1999].

Each classroom activity involves a sequence of steps. We have developed one activity in each domain to show examples. For all verbal communication activities, several choices are possible. For example, in the activity “talking to teacher”, 3 choices are proposed: make a comment; ask for an explanation or ask to repeat. These tasks are meant to bring children with ASD to be aware of the goal of their communication. Here is an example of one of them (see Table 2).

4. APPLICATION DESCRIPTION

Our activity-schedule system runs on a touchscreen tablet. This platform enables rich visual supports and allows the application to be used in any environment. Furthermore, tablets do not carry any stigma as they are increasingly used as portable gaming platforms. Their effectiveness to support intervention has already been demonstrated with children with ASD [Escobedo et al. 2012; Hirano et al. 2010; Hourcade et al. 2013].

Although each student is responsible for her tablet, the school aide can initiate its use. Specifically, she monitors the child and the class flow of activities to determine whether an activity schedule becomes pertinent. When such a situation occurs, she launches the appropriate activity schedule or invites the child to do so thanks to a list of activity schedules is proposed on the top left corner of the screen. Each activity schedule is represented by a text (title) and a little picture (thumbnail). After a while, the school aide only makes sure that the child initiates the use of tablet and the selection of the appropriate activity schedule.

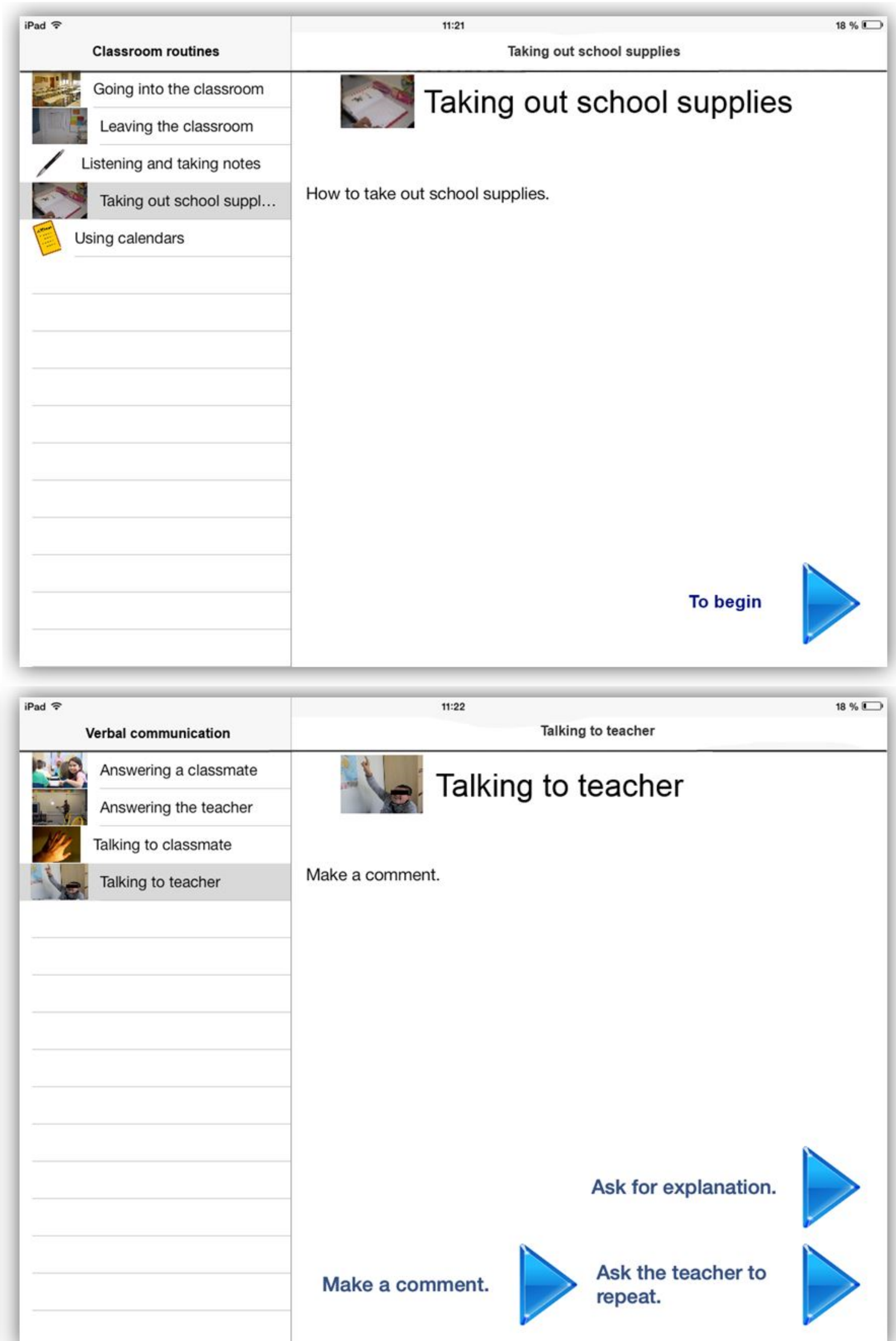

Fig. 2: The selection of an activity schedule.

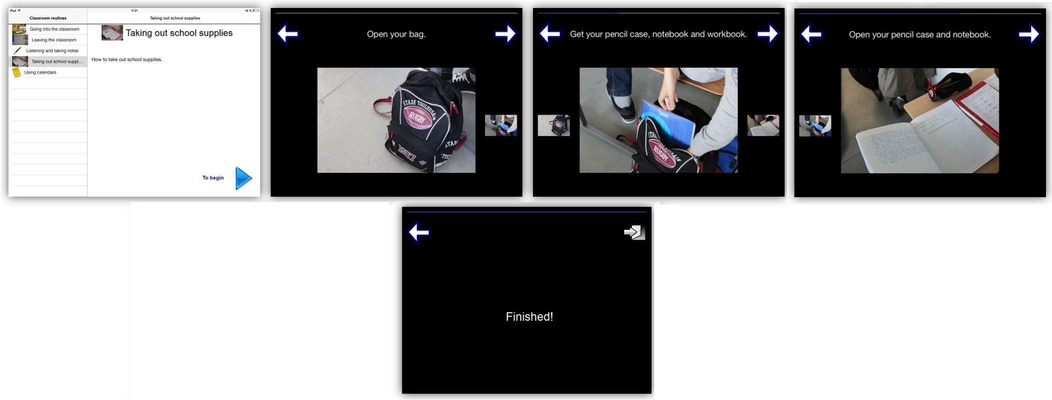

Fig. 3: Each steps of the "Taking out school supplies" activity.

The selection of an activity schedule consists of three stages: (1) the domain of activities, (2) the activity, and (3) the task to be accomplished. These stages are intended to structure the way the child should proceed with the execution of an activity, given that planning (*i.e.,* the activity steps) has been externalized with the tablet. Let us examine in detail each stage. In the first stage, the user chooses between two activity domains: classroom routines and verbal communications (see Figure 2). In the second stage, a list of activities is displayed (top left part of the screen). Notice that in case of verbal communications, these activities are split into two categories: answering and talking. The third stage proposes one of more tasks that address situations within the activity.

Once the activity schedule is in use by the child, the school aide solely supervises the process. The child is guided through each step of the activity via pictures annotated with instructions. This guiding process is idiosyncratic in that it consists of pictures of the child performing the required steps. We asked participants to perform each target task, step by step, to allow an appropriate self-modeled picture to be taken. Even though this process was time consuming, it allowed us to respect the specificity of each child, especially the order in which they usually complete the task. An arrow on each side of the screen allows the child to navigate through the steps. Furthermore, a progression bar enables the child to visualize where she is in the activity steps.

5. EVALUATION

CS+ has been deployed in school settings and used by children with different conditions in general inclusive classrooms. First, we present comparisons between two groups of children with ASD with and without *CS+*. Then, additional results comparing two groups equipped with *CS* (children with ASD and children with ID) are examined.

5.1. Evaluation of CS+ for children with ASD

Participants. Our study took place in special education classrooms in secondary schools. A total of 10 students between the ages of 13 and 17 were included in our study. Five of them were children with ASD equipped with *CS+* (five boys), five others were non-equipped children with ASD (four boys and one girl). The two groups were matched by chronological age ($m_{Equipped} = 15.00$; SD=1.22; $m_{Non-equipped} = 14.60$; SD=1.14; $p > .700$) and intellectual functioning (according to the IQs estimated from abbreviated WISC-IV [Grégoire 2000]; $m_{Equipped} = 74.00$; SD=29.83; $m_{Non-equipped} = 66.50$; SD=26.72; $p > .600$). The group comparisons were tested using a non-parametric test (Mann-Whitney U). Neuropediatricians examined all the children, and the ASD diagnosis was performed according to the criteria of the DSM-IV [APA 2000] and with respect to the "Autism Diagnostic Interview-Revised" scale [Lord et al. 1994]. To assess the severity of social impairment in the school setting, the teacher of each special education classroom initially completed the French version of the Social Responsiveness Scale (SRS) [Constantino et al. 2003]. Concretely, the SRS provides a quantitative score for social impairment in a natural setting. The two groups of children with ASD had similar school-related social impairment (*i.e.,* $m_{Equipped} = 79.80$; SD=37.42; $m_{Non-equipped} = 86.80$; SD=30.51;$p > .700$). At this level of functioning, children are verbal, even if their speech is often inappropriate. They usually need help in conducting and transitioning between basic activities, such as handling their school accessories or taking notes, especially in new environments. As recommended by the Helsinki convention, both parental informed consent and children's assent were obtained before participation. Also, the ethics committee of our university approved the experimental protocol, prior to recruiting participants.

Materials and instruments. Besides supporting the inclusion of children with ASD in general classrooms, our application collects data regarding its usage: number of uses in the mainstream class indexed by a task within the domains of activities (*i.e.,* classroom routines and verbal communications). These data are complemented by a behavioral measurement addressing efficacy and usage of *CS+* (see Figure 4).

Classroom Schedule+ efficacy: We have developed a specific questionnaire to measure how each task of the two activity domains is performed. Each step of a given task is assessed by the school aide as follows: the behavior is "not observed / not performed", "performed when requested, with help or poorly" or "performed autonomously". The scoring is made as follows: "not observed / not performed" are scored 0; "performed when requested, with help or poorly" is scored 1; "performed autonomously" is scored 2. Then, we sum the scores of all the steps of an activity. The overall score for an activity is a percentage representing the ratio of the sum of scores to the sum of the maximum scores. For example, if all the steps of an activity are performed autonomously, the overall score is 100%. Next, we want to compute an overall score for each domain of activities. To do so, we consider activity percentages (previously computed) as values and compute their mean. In doing so, we obtained an overall score for each domain and for each child.

Classroom Schedule+ usage: This part of the assessment included school aide observations of the use of *CS+* by each child, and log data extracted from our application.

— Autonomous usage. At the end of each month of the intervention, the school aide was asked to indicate whether the child used the application autonomously and in an adequate manner (scored 1) or whether (s)he had needed help to use it (scored 0).
— Number of routines activated. From the log data, the number of routines activated during the classroom inclusion is collected (*i.e.,* for each classroom inclusion during one month period).

Procedure. Prior to our intervention, we held a meeting with the inclusion teachers, the special education teacher, the school aides, the parents, and the children. The goal was to give them an overview of our procedure (see Figure 4), to explain the importance of using our application on a regular basis, and to answer all their questions. We also gave a demonstration of our tool, explaining its functioning. At the baseline assessment session, the special education teacher of the children with ASD completed a demographic information form and the SRS scale. The children completed the abbreviated WISC-IV. The participants were then observed during their inclusion in the

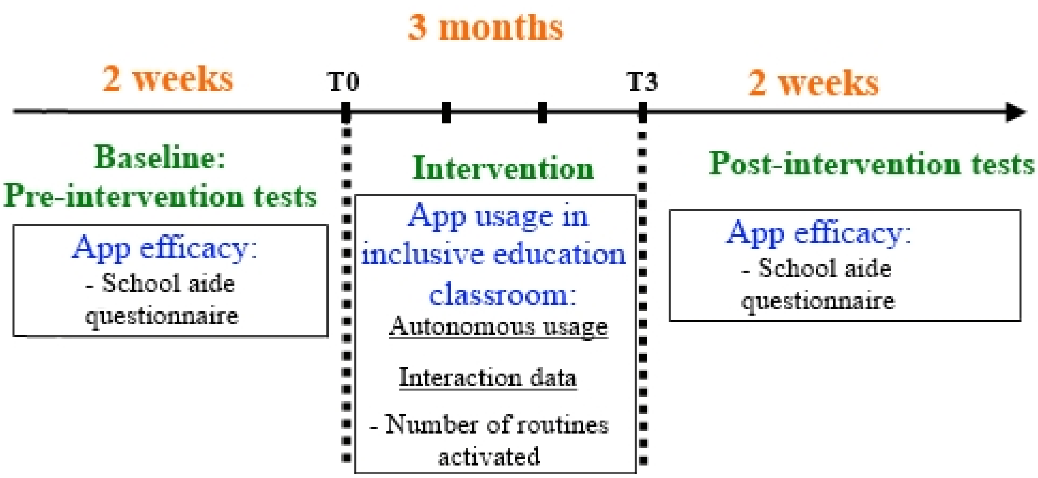

Fig. 4: An overview of our procedures.

classroom (French, mathematics, history, geography, or biology) for two weeks. In the context of our intervention, each participant attended a new class where new situations could occur. It was a one-hour class that occurred once a week during a period of three months. A school aide accompanied each child during inclusion. Each school aide was trained to support students with ASD. In addition, they were explained how to use *CS+* to play the role of social support during inclusion. During each inclusion class, the school aide completed a specific questionnaire to collect the activity observations for each child (that are equipped). All post-intervention measures were completed within two weeks after the end of the three-month intervention. All interviews were conducted at school or at home.

Design and statistical treatments. For efficacy measure, a mixed factorial design was implemented with two within factors and one between factor. The within factors were activity domain, which had two levels (Classroom vs. Communication) and Time, which had two levels (pre- and post-intervention). The between factor was Group, and it had two levels (Equipped and Non-equipped). For the autonomous use measure, the Friedman test was used with the Time factor (after one month, two months, and after three months of intervention) as the independent variable. For the log data from *CS+*, the factorial design included only within factors with: activity domain, which had two levels (Classroom vs. Verbal communication) and Time, which had two levels (after one month and after three months of intervention). Despite the small-size samples that probably generate non-parametric data, an ANOVA analysis have been carried out to assess the intervention effect as a function of the Group factor, as well as Activity Domain factor. Indeed, statistically capturing the intervention effect requires to analyze the two-way interaction effect, including the Time and the Group factors. Only an ANOVA analysis provides information on two-way or three-way interaction by taken into account the total variance across all the factor conditions. To be statistically rigorous, all significant effects from the ANOVA analysis are completed by partial eta-square value (measuring the effect size) and by non-parametric pair-wise comparisons. Such statistical procedures are commonly performed in psychological studies with small-size samples [Cohen 1988; Guéguen 2009]. According to Gueguen (2009), we considered effect sizes as small for $\eta^2 < .06$, medium for $.06 \leq \eta^2 < .14$, and marked for $\eta^2 \geq .14$. All the dependent measures were numeric. All the pairwise comparisons were carried out with non-parametric procedures, as recommended for small-size samples with non-normal distributions, notably the Mann-Whitney U (between-factor) or the Wilcoxon (within-factor) test (with alpha-value = .05). We used the SPSS-19 tool to perform our statistical analysis.

Results. Let us now present the results of our study, comparing ASD children with and without *CS*+. For the sake of conciseness, we only report and discuss the significant results in this section and defer the presentation of the entire statistical results in the appendix. Overall, the results support the efficacy of *CS*+ in showing that both classroom and verbal communication routines performed in general education classrooms were significantly more enhanced for the equipped ASD children compared to the non-equipped ones. Note that the pre-post progress was higher in classroom routine domain than in the verbal communication domain for all the children. In addition, the observations from the school aide indicated that the children reached an autonomous usage of *CS*+ during the second month of use. Finally, log data indicated that the use of *CS*+ was high and unchanged across time for activity schedules within the verbal communication domain. By contrast, within the classroom routines domain, the use of *CS*+ was high only during the first month of classroom inclusion and considerably decreased during the third month of use.

Classroom Schedule+ Efficacy (see Figure 5)
Hypothesis: Equipped children improve their performance, compared with non-equipped children.

The ANOVA revealed significant effects for Activity domain [$p < .001$] and Time factor [$p < .001$] on the routines correctly performed in the classroom. The interaction effect, including Time and Activity domains, was also significant [$p < .01$] and showed that the performance increase with time was higher on verbal communication than on the classroom routine domain, for both conditions of ASD children. Importantly, the interaction between Group and Time factors stated that the performance increase with time was significant for children with *CS*+ ($p < .01$), whereas this is not obtained for non-equipped children ($p > .100$).

Classroom Schedule+ usage in inclusive education classroom
Hypothesis 1: Children who were equipped will use *CS*+ autonomously before the end of the intervention.

The following two hypotheses rely on the same measure: the number of activated routines. Note that these two hypotheses are mutually exclusive; one of them will be validated by our measurements.
Hypothesis 2: Activations remain constant across time due to the persistence of the needs of children (Hypothesis of compensation function of *CS*+).
Hypothesis 3: Activations decrease with time due to a learning effect on children (Hypothesis of remediation function of *CS*+).

Let us now examine each result.

— Autonomous usage measure.
The time factor effect was significant [$\chi^2 = 6.50; p < 04$]: a mostly autonomous usage of our application reached by the children after two months ($M_{after\ one\ month} = 0.20$; SD=0.44; $M_{after\ two\ months} = 0.80$; SD=0.44; $M_{after\ three\ months} = 1.00$; SD=0.00).
— Number of routines activated.
The ANOVA revealed a main effect of the time factor [$p < .05$], indicating that the number of activated routines decreases with time. Also, although the interaction effect (Time * Activity domain) did not reach the significance ($p > .05$), the post-hoc

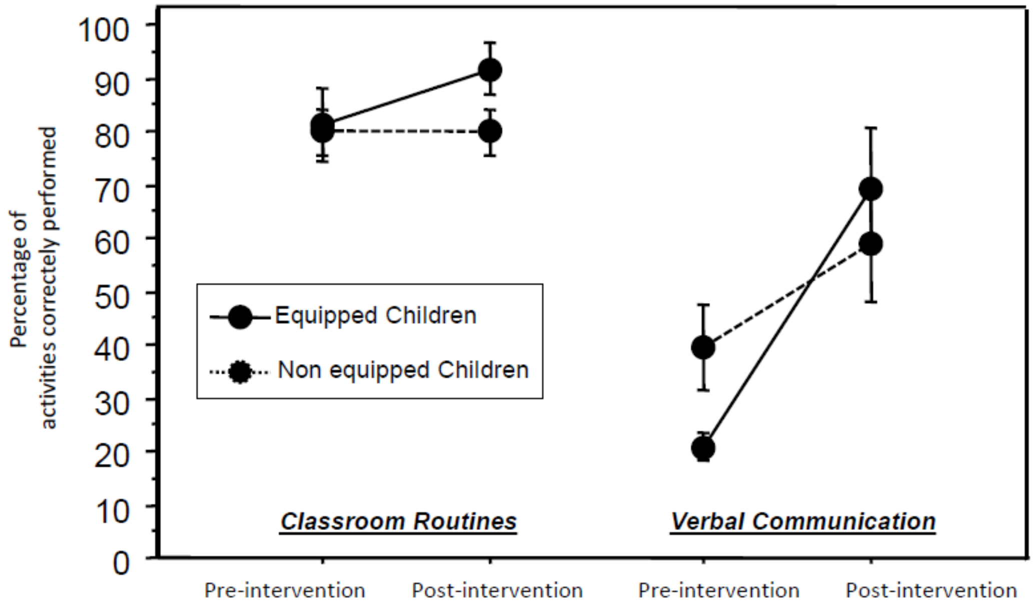

Fig. 5: Percentage of activities correctly performed on classroom according to activity domain and group condition.

comparisons indicated that the use of *CS*+ did differ significantly for classroom routines across time ($p < .05$). By contrast, the use of *CS*+ did not differ significantly across time for verbal communication condition ($p > .05$) (see Figure 6).

5.2. Evaluation of CS+ for children with ID

Participants. Children with ID were recruited in the special education classrooms where we enrolled children with ASD. Five students with ID between the ages of 13 and 17 were equipped with *CS*+ (one boy and four girls). Children with ID were matched with equipped children with ASD by chronological age ($m_{EquippedASD} = 15.00$; SD=1.22; $m_{EquippedID} = 14.14$; SD=1.12;$p > .400$), intellectual functioning (according to the IQs estimated from abbreviated WISC-IV [Grégoire 2000]; $m_{EquippedASD} = 74.00$; SD=29.83; $m_{EquippedID} = 44.60$; SD=13.28; $p > .200$) and for school-related social impairment ($m_{EquippedASD} = 79.80$; SD=37.42; $m_{EquippedID} = 69.4$; SD=29.10;$p > .600$). The group comparisons were tested using a non-parametric test (Mann-Whitney U). Two children with ID had Down Syndrome, while the three others were children with non-specific ID. All children with ID exhibited learning disabilities. As recommended by the Helsinki convention, both parental informed consent and children's assent were obtained before participation. Also, the ethics committee of our university approved the experimental protocol, prior to recruiting participants.

Children with ID equipped with *CS*+ followed the exact same procedure as the one for children with ASD (described in Section 5.1), using our tablet based application in the general education classrooms for 3 months.

Design and statistical treatments. For efficacy measure, a mixed factorial design was implemented with two within factors and one between factor. The within factors were

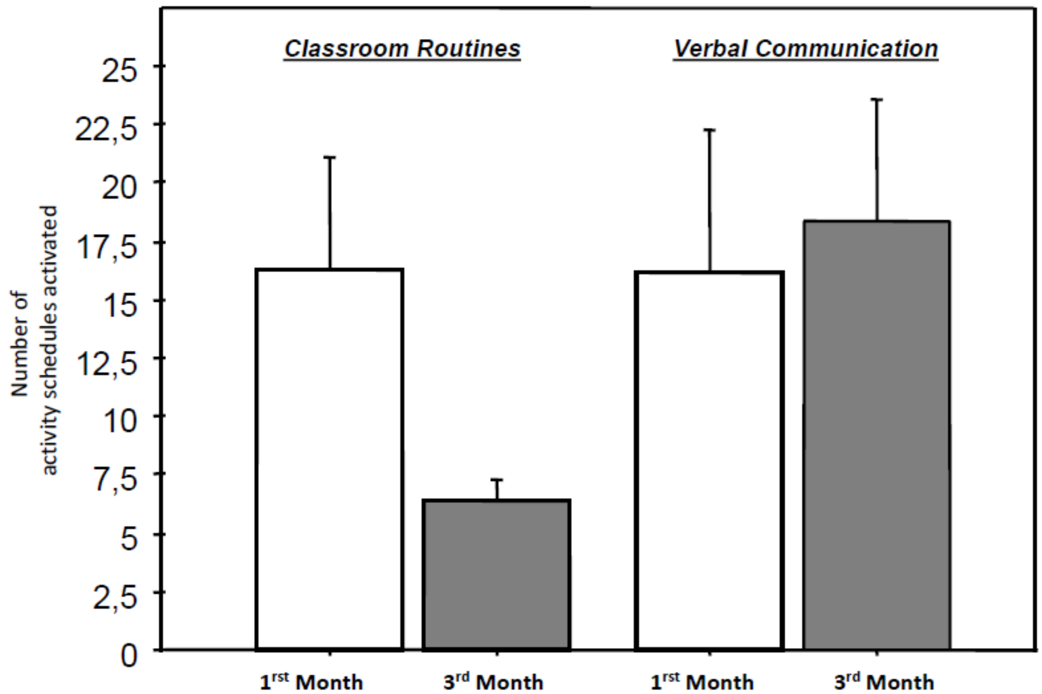

Fig. 6: Number of routines activated as a function of activity domains and intervention duration.

activity domain, which had two levels (Classroom and Communication) and Time, which had two levels (pre- and post-intervention). The between factor was Group, and it had two levels (EquippedASD and EquippedID). For the autonomous use measure, a mixed factorial design was implemented with two within factors and one between factor. The within factors were Group, which had two levels (ASD and ID) and Time, which had three levels (after one month, two months, and after three months of intervention). For the log data from *CS*+, the mixed factorial design included one between factor and two within factors with: activity domain, which had two levels (Classroom vs. Verbal communication) and Time, which had two levels (after one month and after three months of intervention). The between factor was Group, and it had two levels (EquippedASD and EquippedID).

All the dependent measures were numeric. All the pairwise comparisons were carried out with non-parametric procedures as recommended for small-size samples with non-normal distributions, notably the Mann-Whitney U (between-factor) or the Wilcoxon (within-factor) test. We used SPSS 19.

Results. Let us now present the results of our study, comparing equipped children with ASD and ID. As before, for the sake of conciseness, we only report and discuss the significant results in this section and defer the presentation of the entire statistical results in the appendix.

Overall, the results support the specific pattern of benefit of *CS*+ for children with ASD compared to children with ID. Classroom routines have been similarly enhanced for the two equipped groups, whereas verbal communication routines performed in general education classrooms were significantly more enhanced for the equipped children with ASD compared to those with ID. In addition, the observation from the school aide indicated that children with ID reached a limited autonomous *CS+* usage after 3 months of intervention, compared to children with ASD. Finally, log data indicated that the use of *CS+* by children with ID was considerably decreased in the third month of use for both activity domains, while it was high and unchanged across time for activity schedules within the verbal communication domain for children with ASD.

Classroom Schedule+ Efficacy (see Figure 7)

Hypothesis: Children with ASD will improve their performance greater than children with ID.

The ANOVA revealed significant effects for Activity domain [$p < .000$] and Time factor [$p < .002$] on the routines correctly performed in classroom. The interaction effect including Time and Activity domains was also significant [$F(1,8) = 5.24; p = .05; \eta^2 = .025; \eta^2 = .16067$] and showed that the performance increase with time was higher on verbal communication than on the classroom routine domain for both children with ASD and ID. Importantly, the Group and Time factors interaction [$p = .05$] stated that the performance increase with time was significant for children with ASD ($p < .05$), whereas this is not obtained for children with ID ($p > .170$).

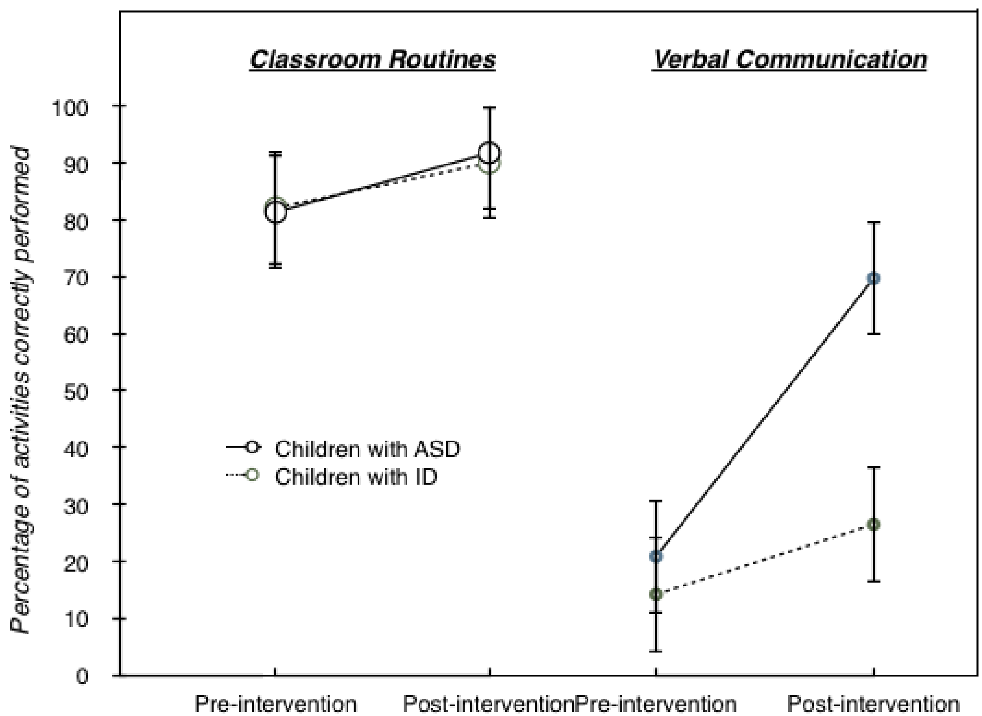

Fig. 7: Percentage of activities correctly performed on classroom, according to activity domain and group condition.

Classroom Schedule+ usage in inclusive education classroom

Hypothesis 1: Children with ASD reach an autonomous usage of *CS+* sooner than children with ID.

Hypothesis 2: Activations reveal different *CS+* usages between children with ASD and children with ID.

The results are as follow.

— Autonomous usage measure.
The time factor effect was significant [$F = 9.87; p < .005$] and the group factor was significant [$F = 6.00; p < .05$]. Results show a most autonomous usage of our application reached by the children with ASD after two months ($M_{after\ one\ month} = 0.20$; SD=0.44; $M_{after\ two\ months} = 0.80$; SD=0.44; $M_{after\ three\ months} = 1.00$; SD=0.00), whereas children with ID reached only partial autonomous usage of our application ($M_{after\ one\ month} = 0.00$; SD=0.00; $M_{after\ one\ month} = 0.20$; SD=0.44; $M_{after\ one\ month} = 0.60$; SD=0.44).
— For the number of routines activated.
The ANOVA revealed a tendency of time factor effect [$p = .06$], suggesting that the number of activated routines decreases with time. Also, despite of the interaction effect (Time * Activity domain * Group) not reaching the significance ($p > .05$), the post-hoc comparisons indicated that the use of *CS+* did not differ significantly for classroom routines and verbal communication condition during the first month for both groups (children with ASD: $p > .900$; children with ID: $p > .700$), while its use for classroom routine domain was lower than for verbal communication domain during the third month period for children with ASD ($p < .05$) but not for children with ID ($p > .260$) (see Figure 8).

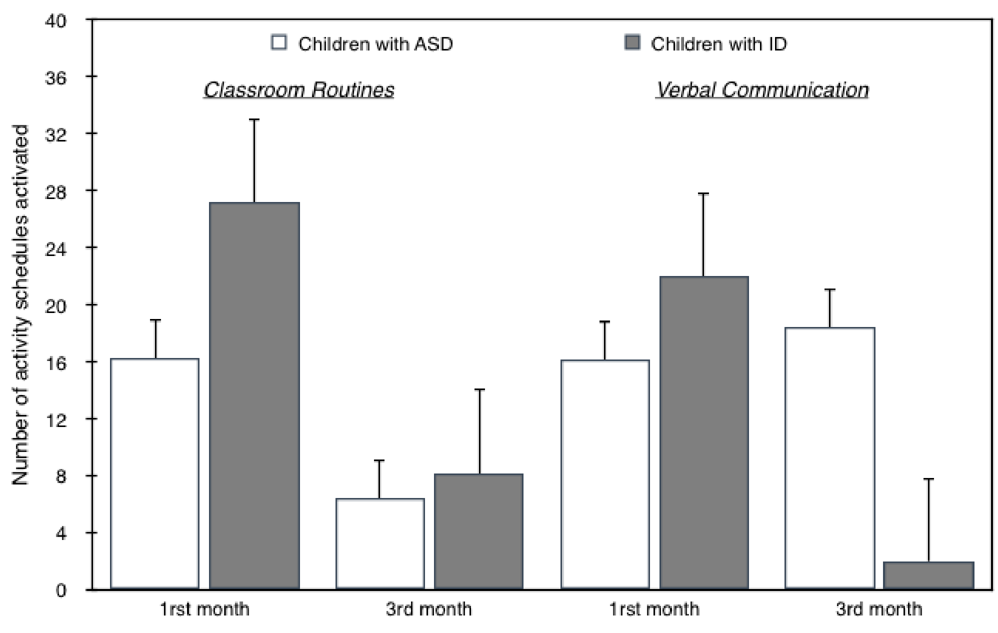

Fig. 8: Number of routines activated as a function of activity domains and intervention duration.

6. DISCUSSION

To the best of our knowledge, there is no study assessing a technology-based system for activity schedules to support children with ASD in mainstreamed school environments. Additionally, we found no study addressing the activity schedules with idiosyncratic contents to provide assistive support for first-time inclusion of ASD children in general education classrooms. The results presented here provide insights on these issues. Including children with another neurodevelopmental condition (*e.g.,* Intellectual Disabilities) enriched our results by suggesting which of our proposed design principles might be specific to children with ASD and which ones could apply to both populations.

6.1. CS+ for children with ASD

Efficient and autonomous use in mainstreamed environments. Our empirical results demonstrate that *CS+* provides children with ASD with a relevant task-management support in mainstreamed environments, such as a classroom. Importantly, the socio-adaptive routines in class were greatly enhanced for equipped children with ASD, despite the short intervention time (*i.e.,* only three months). We also observe high usability of our application (*i.e.,* independent use after the second month). The limited number of interaction steps within one activity schedule and the two navigation options (forward and backward) allow children to quickly and easily follow the critical steps of each routine. Experimental results suggest that interface organization, interaction duration, and idiosyncratic contents have played a key role in the adoption of our tool, while ensuring the child's effective presence in the classroom.

Relevance of flexible visual supports for activity schedules in school settings. Interestingly, for all the children (whether or equipped), the pre-post progress was higher in the classroom routine domain (with nearly perfect execution) than in the verbal communication domain ($\approx 70\%$ correctly performed). A related result comes from the log data: we reported a decreased use of *CS+* over time for classroom routines contrasting with a high and constant use of *CS+* for verbal communication domain. This usage discrepancy is probably due to differences in socio-cognitive demands of the target tasks into the two domains. Specifically, the more a child becomes proficient in an activity domain, the more (s)he performs the domain-related tasks autonomously, and the less (s)he uses the corresponding contents of *CS+*. This means that the child is able to select the contents of *CS+* appropriately with respect to her own progress and needs: probably, classroom routines meet a child's needs related to the early stages of classroom inclusion, while verbal communication routines are persistent needs for the classroom life of children with ASD. Note that *CS+* is built as a learning and assistive device with flexible contents. As a result, when a routine is acquired by the child, stakeholders can create new adapted ones. This is possible thanks to the decoupling between the interface and the contents in *CS+*. Indeed, routines (texts, pictures and step numbers) can be changed while the interface skin remains the same, which is desirable for children with ASD [Hayes et al. 2010; Hourcade et al. 2013].

Relevance of idiosyncratic and concrete contents for activity schedule in school settings. Both efficacy and autonomous usage of *CS+* may result from the superiority of idiosyncratic visual supports over general-purpose ones [Park et al. 2012]. In light of the diversity and complexity of tasks having to be resolved in a school setting (*e.g.,* waiting at the door with classmates, waiting for an approval of the teacher, *etc.*), the use of self-modeled pictures provides illustrations of the particular child in the context of interest. This approach is in favor of imitative behaviors [Cihak et al. 2010]. Additionally, because this experiment includes children with IQs around 70, idiosyncratic visual supports probably contribute to matching their concrete reasoning abilities.

Collaborative evaluation induces technology acceptance. The collaborative nature of our intervention allowed our tool to be pervasively accepted by all stakeholders of the child's mainstreamed environment. Teachers, especially, played a major role in facilitating the application usage inside their classroom. For instance, they encouraged children to use our application with sentences like "you should have a look at your tablet".

6.2. CS+ for children with ID

A contrasted efficiency. Results indicate that the use of *CS+* by children with ID enhanced their autonomy on performing classroom routines in general inclusive classrooms. Children with ID exhibited the same benefits than children with ASD on this domain of activities. However, even if their autonomous use increased with time, the short intervention time did not allowed them to use our tool autonomously (60%). At the end of our study, two participants still relied on the school aide to initiate *CS+* usage. This result suggests that the cognitive cost of handling *CS+* is still higher after three months for children with ID, while it quickly decreases for children with ASD. This observation could be explained by differences between children with ASD [Morrison et al. 2002] and children with ID [Bevill et al. 2001] in terms of learning time. Consequently, children with ID may need a longer intervention (superior of three months) to reach an autonomous use.

Assisting classroom routines: same benefits for both populations. We reported the same pattern of results for both populations when considering classroom routines. At the end of the intervention, participants performed nearly perfectly these routines, while decreasing their use of *CS+* over time. This result suggests that some of our design principles is suitable for both populations when assisting non-verbal routines in mainstream classrooms. Specifically, concrete and idiosyncratic pictures seem particularly appropriate, as they have been extensively and successfully used by children with ID to improve their autonomy [Anderson et al. 1997; Copeland and Hughes 2000; Carson et al. 2008; Mechling 2007; Spriggs et al. 2007]. This also supports findings by which the schedule principles are relevant for both ASD and ID children [Koyama and Wang 2011].

Assisting verbal communication routines: limited relevance of CS+ for children with ID. Children with ID exhibited limited benefits on verbal communication routines, compared with children with ASD. Additionally, log data indicated a dramatic decrease of use at the end of the intervention. Children with ID can be discouraged by the limited enhancement of their performance, given the remained high-cognitive cost of handling *CS+* (still not autonomous with the tool after 3 months of use). Moreover, verbal communication tasks require cognitive flexibility, which has been reported more impaired for children with ID, compared with children with ASD [Didden et al. 2008; Peters-Scheffer et al. 2013]. These verbal functioning differences could explain the lesser benefits in children with ID compared with children with ASD. This observation challenges effectiveness of our design principles to assist verbal communication routines of children with ID in mainstream classrooms. Notably, excluding auditory or tactile prompts can be unfortunate design options for this population. Indeed, while multi-modal intervention (*i.e.,* visual, auditory or haptic feedbacks) is to be avoided for children with ASD [Mottron et al. 2006], it has been demonstrated to be successful for prompting children with ID [Mechling 2007]. Numerous studies implemented vocal instructions rather than written sentences, given the poor reading skills observed in this population. We did not considered auditory prompts to avoid stigmatization of using headphones inside the classroom and to promote reading skills. Our results suggest future studies should investigate alternative ways to provide more prompt modalities than only the visual ones, when supporting children with ID on verbal communication tasks.

Deploying an assistive technology in mainstream environments: lessons learned. There are numerous constraints when addressing mainstream environments such as a school. In our case, it took some time to find an agreement with participating schools between their ground constraints and our scientific requirements. School staff wanted our intervention to be as short as possible because of their time constraints, potentially limiting our results, especially for children with ID. They also asked for the inclusion of all children of their special-education classroom in our inclusion process. Responding to this requirement brought us to adopt a design study (*i.e.,* Cross-Syndrome design) that could be of great value for researchers in the domain of accessible computing. Additionally, some teachers had some negative beliefs about tablets and gaming platforms for children education [Ertmer 2005], and more particularly for children with ASD (*e.g.,* a tablet socially isolates the child). Finally, let us note that our experimental study had an overall positive outcome in the participating school with regard to inclusion: our intervention allowed some of the children previously identified as “not being able to be included in a mainstream classrooms” by the school staff showed spectacular improvements in their behavior and autonomy. This situation resulted in the increase of their time mainstream classrooms, as well as their inclusion in additional classes, for some of our participants.

6.3. Insights from single-case analysis

In this section, we provide qualitative analysis of single-cases to enrich our results. Specifically, we examine the children who exhibited the highest and the lowest improvements over the time of the intervention; they are noted *Hi* and *Li* in the indices used below to refer to our single-cases. This work is done on each activity domain: Classroom Routine activities (Figure 9) and Verbal Communication activities (Figure 10). Overall, data from the performance of potentially 12 children is analyzed (3 child conditions $\times$ 2 activity domains $\times$ 2 improvement patterns). Practically, for each group of children with ASD (*e.g.,* equipped or non-equipped), the child who exhibited the highest benefits on an activity domain also exhibited the highest benefits on the other activity domain, and conversely for the child with the lowest benefits (4 children). As for the children with ID, the same child exhibited the lowest benefits on both activity domains, but a different child exhibited the highest benefits for each activity domain (3 children). This method allows us to capture inter-individual variability within each group condition, as well as intra-individual variability within each activity domain.

Globally, as seen in Figure 9, examining the cases of the two children with ASD, not equipped with *CS+* (noted *NeASD*), reveals that the child $B_{NeASD_{Hi}}$ presents similar non-observable improvements on classroom routine activities compared to $B_{NeASD_{Li}}$. In contrast, on the verbal communication domain, the child $B'_{NeASD_{Hi}}$ exhibits high improvements compared to $B'_{NeASD_{Li}}$ (see Figure 10). Such results stress the inter-individual variability in the dynamic of developmental trajectory within the spectrum of ASD. Indeed, it is well-known that the developmental dynamic in the spectrum of autism is extremely heterogeneous. Specifically, the magnitude of developmental progress is non-linear with leaps and bounds for some children, especially those in the middle/low range of the spectrum. This profile corresponds to the children recruited for our study; they contrast with higher-functioning children described in the pediatric literature [Stichter et al. 2012].

Regarding the four single-cases of equipped children with ASD (noted *eASD*), the child $A_{eASD_{Hi}}$ strongly enhances his performance on classroom routine activities compared to the child $A_{eASD_{Li}}$ (see Figure 9). In other words, the slope of improvements is different across children. For the verbal communication activities, great improvements are observed for both the child $A'_{eASD_{Hi}}$, and the child $A'_{eASD_{Li}}$. However, the slope of improvements is dramatically different between these two children (see Figure 10). The child $A'_{eASD_{Hi}}$ dramatically increased performance in both activity domains at the end of the intervention.

Finally, compared with non-equipped children with ASD, the inter-individual variability is observed among equipped children with ASD for the two activity domains. In other words, this observation means that *CS*+ intervention exacerbates the inter-individual variability. This situation aligns itself with some studies that advocate the flexibility and evolutivity of assistive devices to meet the developmental changes of children with ASD [Hayes et al. 2010; Mechling 2007].

Regarding equipped children with ID, the four children exhibit different improvement slopes on classroom routines activities while they are homogeneous for verbal communication. Indeed, these improvements are moderate for lowest improvements on classroom routine activities, while the child with ID exhibiting highest improvements dramatically increase his performance (see Figure 9). On the opposite, improvements are homogeneous and greater for verbal communication activities (see Figure 10).

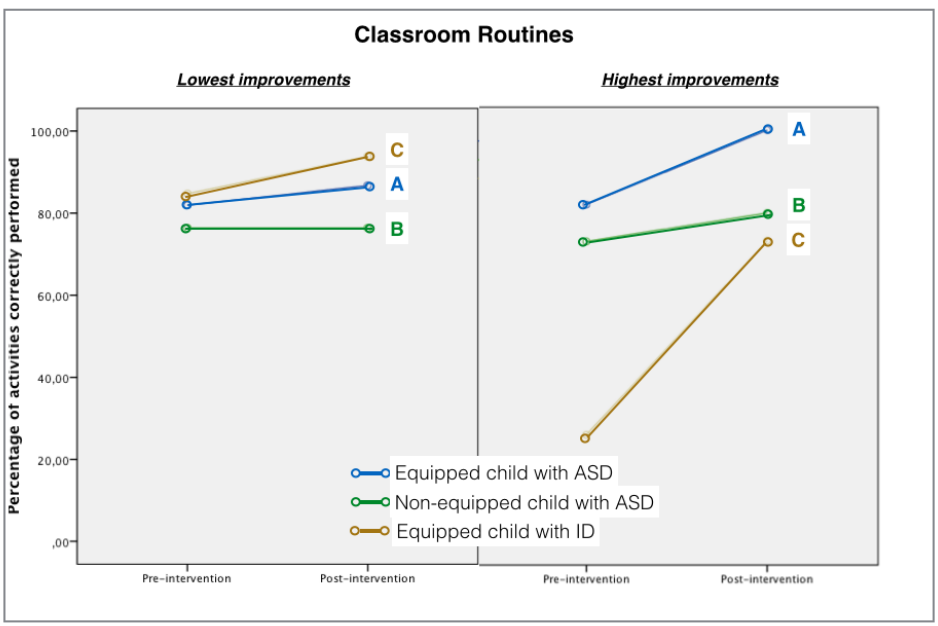

Fig. 9: Percentage of activities correctly performed in the classroom by the child of each group exhibiting the lowest and highest improvements on the Classroom Routine domain.

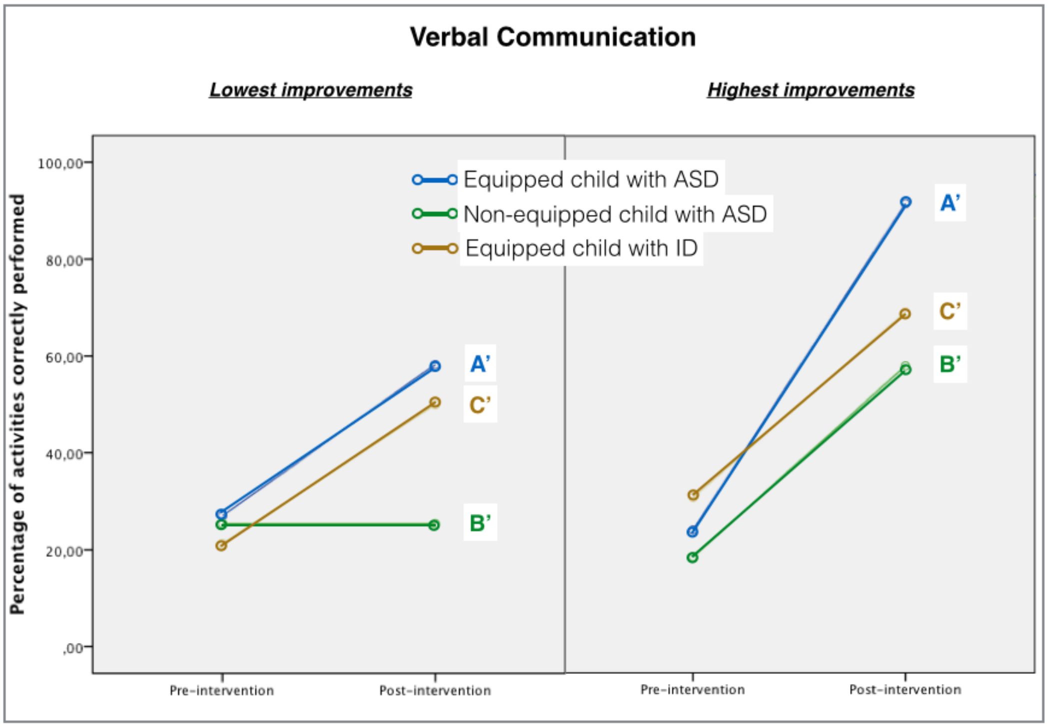

Fig. 10: Percentage of activities correctly performed on classroom for the child of each group exhibiting the lowest and highest improvements on the Verbal Communication domain.

Analyzing the cognitive profiles of these 7 children give insights to better understand their different needs in terms of assistive technologies in mainstream classrooms (See Table 3). First, children with ASD seem to have homogeneous profiles across activity domains (same child exhibits the lowest – or the highest – benefits on both activity domains), whereas children with ID present more intra-individual variability (different children exhibit lowest or highest benefits, depending on a given activity domain). Second, we can observe two main results with the three studied variables: 1) Age variable does not seem to have any influence on benefits from using *CS+*, regardless of the benefits profile (*i.e.,* lowest or highest benefits); 2) the two children with ASD – whether or not equipped – exhibiting the highest improvements have relatively low SRS scores, compared with children with ASD exhibiting the lowest improvements; 3) for children with ID, presenting relatively low IQs, the highest benefits are obtained by children with higher SRS score. These results support different recommandations of *CS+* for mainstream inclusion of these two populations: children with ASD with relatively low SRS scores (*i.e.,* children with better social response) and children with ID with relatively high SRS scores (*i.e.,* with the poorest social response). However, we only measured social response through SRS questionnaire to assess sociocognitive profile of the participants. Obviously, an enrichment of child's profile with more clinical and psychometric measures would give more insights on our single-case analysis.

Overall these single-case analyses stress the inter-individual variability within ASD, and between ASD and ID. This situation should prompt the research community to be cautious when generalizing the efficacy of a given assistive technology. This concern

	Lowest Benefits		Highest Benefits	
	Classroom Routines	Verbal Communication	Classroom Routines	Verbal Communication
Equipped ASD	*Age:* 15.42 *IQ:* 109 *SRS:* 64	*Age:* 15.42 *IQ:* 109 *SRS:* 64	*Age:* 13.92 *IQ:* 106 *SRS:* 54	*Age:* 13.90 *IQ:* 106 *SRS:* 54
Non-Equipped ASD	*Age:* 13.17 *IQ:* 40 *SRS:* 101	*Age:* 13.17 *IQ:* 40 *SRS:* 101	*Age:* 11.5 *IQ:* 89 *SRS:* 84	*Age:* 11.5 *IQ:* 89 *SRS:* 84
Equipped ID	*Age:* 15 *IQ:* 38 *SRS:* 66	*Age:* 15 *IQ:* 38 *SRS:* 66	*Age:* 13.5 *IQ:* 35 *SRS:* 88	*Age:* 15.67 *IQ:* 66 *SRS:* 74

Table III: Cognitive profiles of children from single-case analysis.

is addressed by clinical studies that promote longitudinal analyses within single-case design to better capture the developmental trajectory specific to each child [Ganz et al. 2012; Wang et al. 2013]. In other words, the high inter-individual variability within ASD seems to call for a longitudinal assessment of technology-based interventions within several single-cases. Obviously, such experimental design is time-consuming but would provide strong insights concerning the therapeutic impact of technologies in the context of children in the ASD.

Limitations and Future Work. Regarding the participating children, their number did not reach a sufficient sample size for statistically conclusive results, even though the use of non-parametric statistical tests has been respected and single-case analyses were reported. Also, the participating children did not cover the spectrum of intellectual functioning. Consequently, it remains to be shown that our results carry over to children with ASD that are on the higher end of the spectrum of intellectual functioning.

Moreover, all school aides participating to this field-study received precise instructions regarding the way they supported children when they used *CS+*: when they have to trigger it, how they let children autonomously choose and use appropriate routines, being less intrusive across intervention time, *etc.*. We believe results we report in this paper would have been less encouraging without applying these instructions rigorously, despite the short intervention time. This observation should be considered for further studies in mainstream environments.

To further explore our research avenue, an interesting direction would be to add new routines to cover as many aspects of task-management as possible, broadening the support of children (with ASD or ID) in mainstreamed school settings. For instance, applications designed to manage tasks may be helpful for self-initiating adaptive behaviors in other school settings (such as school cafeteria, school playground, school bus, *etc.*). Additionally, future work for children with ID should consider implementing multi-modal solutions for assisting verbal communication in mainstream classrooms.

7. CONCLUSION

This paper presents a tablet-based application (*Classroom Schedule+*) supporting task-management skills of children with ASD in mainstreamed environments. This application has been used by five children with ASD from special-education classrooms during their inclusion in secondary school classes. To be inclusive in our experimental study, we enrolled the other children of the special-education classrooms, namely, five children with ID; they also used our application and were included in mainstream classes.

All children with ASD successfully adopted our application, whereas children with ID did not reach an autonomous use. The two groups (with ASD and ID) exhibited different patterns of benefits. Children with ASD largely increased their socio-adaptive behaviors on both classroom and verbal communication domains, while children with ID improved only on non-verbal classroom routines. With a participatory design approach, we identified activities that needed support for the inclusion of children with ASD, and we defined design principles that allowed *Classroom Schedule+* to be infused in a mainstreamed environment. Including children with ID in our study gave us insights on the applicability of our design principles for activity schedules. We plan to expand this work by introducing applications that address a wider spectrum of the needs of children (with ASD and ID) for their inclusion in mainstreamed settings.

8. APPENDIX

	Time	Activity domain	Time x Group	Activity domain x Group	Time x Activity Activity domain	Time x Activity domain x Group
Percentage of activities correctly performed	F(1,8)=32.49 p<.001 η^2=.802	F(1,8)=62.75 p<.001 η^2=.887	F(1,8)=8.30 p=.021 η^2=.509	F(1,8)=1.41 p>.200 η^2=.150	F(1,8)=14.47 p<.005 η^2=.644	F(1,8)=1.53 p>.200 η^2=.161
Number of routines activated	F(1,4)=12.26 p=.025 η^2=.754	F(1,4)=.28 p>.600 η^2=.066			F(1,4)=3.37 p>.100 η^2=.457	

Table IV: Three-way mixed ANOVA [2(Time) * 4(Activations) * 2(Group)] analysis for Emotions and Levels activations: Equipped ASD vs. Non-equipped ASD.

	Time	Activity domain	Time x Group	Activity domain x Group	Time x Activity Activity domain	Time x Activity domain x Group
Percentage of activities correctly performed	F(1,8)=20.13 p<.002 η^2=.716	F(1,8)=89.19 p<.001 η^2=.918	F(1,8)=4.87 p=.058 η^2=.379	F(1,8)=4.55 p=.066 η^2=.362	F(1,8)=5.24 p=.051 η^2=.396	F(1,8)=3.34 p>.100 η^2=.294
Number of routines activated	F(1,8)=4.45 p=.068 η^2=.357	F(1,8)=.001 p>.900 η^2<.001	F(1,8)=2.01 p>.100 η^2=.201	F(1,8)=1.75 p>.900 η^2=.179	F(1,8)=.71 p>.400 η^2=.082	F(1,8)=.99 p>.300 η^2=.111

Table V: Three-way mixed ANOVA [2(Time) * 4(Activations) * 2(Group)] analysis for Emotions and Levels activations: Equipped ASD vs. Equipped ID.

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