

# Measuring Cognitive Availability of Young People with Autism Using Digital Agendas

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## Research Article

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## Abstract

Children with autism have varying degrees of difficulty in their ability to find their way through time and space. This can sometimes prevent students from accessing certain kinds of learning and can therefore stop them from performing some learning tasks because the cognitive load makes it difficult for these subjects to manage themselves. The objective of this research is to understand how a digital planning tool can reduce this cognitive overload. However, it is difficult to measure cognitive overload when working with non-verbal children who have Autism Spectrum Disorder (ASD). In the study described in this article, the dependent variable measured was the cognitive availability of students during learning activities. Our hybrid methodology allowed us to combine qualitative (semi-structured interviews with professionals) and quantitative (filmed workshops with a child and an educator) analyses. Statistical analyses based on the quantitative data did not detect any significant evolution in cognitive availability over the period of the study. However, thematic analyses of qualitative data underline the value of this digital planning tool for students in developing their cognitive availability, particularly their autonomy in various different learning activities.

**Keywords:** Learning environment; New Technology; Autism; Cognitive load; Cognitive availability

**Tools:** ELAN, Tau-U, SPSS.

## Introduction

Making learning accessible to all students is a priority in France. Our work focuses on students with autism in a specialized school.

People with ASD have difficulties locating items and themselves in time and space, which prevent them from being cognitively available during a learning activity. The cognitive overload related to questions about current or future activities generates some fears. Today, it is justified and recommended to use planning tools for people with autism to facilitate their daily lives. Our study followed three non-verbal children with ASD over one year.

Accompanying education professionals offered digital support to the children as much as possible during the learning activities. We wished to investigate in what ways the digital planning tool (named çATED) promotes the cognitive availability of children with autism during learning activities.

The independent variable (cognitive availability) was analyzed through quantitative (video of activity codified) and qualitative (semi-structured interviews) data. We chose not to examine a control group in our study, focusing instead on the singularities of the selected students using the statistical tool Tau-U.

## Autism Spectrum Disorders

According to the Diagnostic and Statistical Manual of Mental Disorders criteria [1], Autism Spectrum Disorders (ASD) are defined as neurodevelopmental disorders that generally appear in early childhood. They are characterized by (1) an alteration of communication and social interactions (e.g., poor eye contact, absence of social smiling), but also by (2) the presence of stereotyped behaviors (e.g., unusual object manipulation, repetitive hand movements, etc.) and restricted interests (e.g., preoccupation with parts of objects). Each disorder has an intensity and nature that varies among individuals. Indeed, as Buron underlined in his book [2], ASD are complex because they correspond to a multifaceted disability that manifests itself differently in each individual. There are individual differences and therefore each child has his or her own difficulties.

## Difficulties in the Perception and Construction of Temporality

In a learning environment, it is essential to respect the rhythm of each learner with ASD [3]. The French public authority (*Haute Autorité de Santé* or French National Authority for Health) emphasizes that it is better for people with autism to evolve in stable or immutable environments [4]. These people do not always have the resources to carry out transitions (between different activities or different places) without fear and therefore need stable daily routines and benchmarks to feel safe [5]. According to Tardif, people with ASD generally encounter difficulties in the perception and construction of temporality. They are thus very sensitive to changes in their environment that can have an impact on their daily life [6]. Therefore, minor changes can lead to intense crises with acute symptoms of anxiety, panic, irritability, or agitation [7].

## Impact of Cognitive Load on Learning

Our research in education sciences considers the special educational needs of each person with autism in their learning activities. Anxiety that results in the development of challenging behaviors can lead to a cognitive load that hinders students with ASD in different life contexts, particularly in a learning context. As Murawski and Scott point out, cognitive load can prevent certain learning processes among learners with ASD [8]. We need to find a way to reduce that cognitive load in order to facilitate access to new learning. Moreover, there is also strong evidence that anxiety decreases working memory capacity [9]. People with ASD have difficulties to understand or maintain their daily organization in their

memory and such difficulties generate inappropriate behaviors that prevent learning. This is why using strategies to reduce cognitive load for anxious students can facilitate the availability of their working memory resources during instruction, as suggested by Chadwick, Tindall-Ford and Agostinho [10]. It is therefore necessary to reduce the cognitive load related to difficulties in the perception and construction of temporality in students with autism during learning activities.

## Paper or Digital Planning Tools

To assist people with ASD in daily life, the French National Authority for Health makes recommendations about the use of visual aids adapted to learners' levels of comprehension. Professionals and parents are used to using visual supports to help children find their way in time and space but also to increase independence among students suffering from severe disabilities in inclusive educational settings [11]. Methods of verbal communication and time management for people with autism have existed for many years because routines help to minimize cognitive load. According to Siegel & King's work [12], "visual supports have the potential to lessen cognitive load and enhance understanding and research has demonstrated reductions in challenging behaviors when visual elements are incorporated into treatment plans". Thus, the use of visual supports enables young learners with ASD to reduce the frequency of their challenging behaviors, giving them access to new learning opportunities. The çATED application aims to develop a new Augmentative and Alternative Communication (AAC) approach by offering a digital agenda adaptable to the needs of everyone [13]. People with autism are interested in new technologies [14]. The use of a digital tool with these children can help them find their bearings in time and space and reduce their anxiety. In the same way, Murawski & Scott suggest using digital tools to reduce cognitive load in the daily life of such students [8].

## Problematic

Autism spectrum disorders cause varying degrees of difficulty, including cognitive load, in students of all ages. It is in connection with the perception and construction of temporality that such difficulties can hamper or prevent learning activities. This research is focused on young children with ASD who attend a specialized school. A digital agenda seems to be a suitable tool to promote the ongoing use of planning support for children with autism in an environment conducive and helpful to new learning. "The extra cognitive load of teaching children with ASD needs to be researched, as do effective ways of managing this extra load" [15]. As these authors recommend, it is

necessary to seek effective strategies to reduce cognitive load in relation to space-time tracking and thus accompany learners with ASD in teaching situations in order to promote their cognitive availability. Therefore, the purpose of this research was to identify the effects of the use of a digital agenda on the cognitive load of young people with ASD.

It is difficult to measure the cognitive load of non-verbal children. We chose to take into account the independent variable "cognitive availability". Behavioral measures of performance during the workshops emerged as the best way to observe children's cognitive availability in a learning situation. This measure allowed us to collect and analyze our data related to the use of the digital planning tool. Thus, our problematic consisted of examining in what ways the digital planning tool çATED could promote the cognitive availability of children with autism during learning activities. We tested the hypothesis that providing continuous information about a day's agenda would allow children to be more cognitively available during learning activities.

### Population

This one-year longitudinal study was conducted with three young children with autism (ASD severity level: severe to moderate according to Holmes, Blaxill & Haley, 2003) in a specialized institution in the west of France [16]. For reasons of anonymity and ethics, we will present the data and results of each child under the names E1, E2, and E3. These children are accompanied, on a daily basis, by monitors and special education teachers.

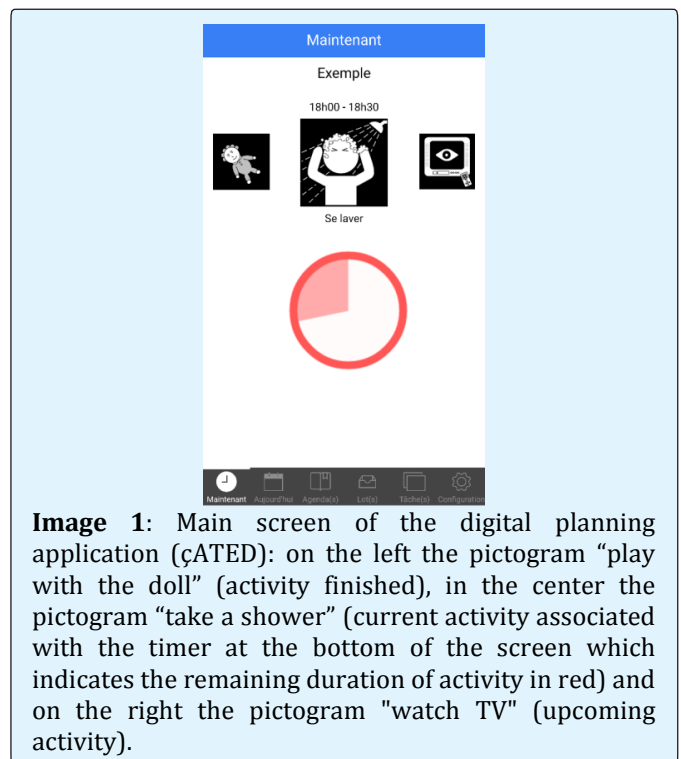
- E1 is a seven-year-old boy with a diagnosis of autism (ASD severity level: severe). He is not in regular class and is non-verbal. His parents and educators explain that he has difficulties of concentration and cognitive availability for almost all proposed educational activities. In addition, he does not remain physically at his desk for long (less than a minute), either for eating or for a learning activity.
- E2 is a nine-year-old boy with a diagnosis of autism (ASD severity level: moderate) and with moderate (right ear) and severe (left ear) deafness. He is not in regular class. He is non-verbal, but is familiar with the French Sign Language (FSL). His parents and educators agree that he has difficulties waiting during and between activities.
- E3 is a nine-year-old boy with trisomy 21 associated with autistic traits. He is not in regular class. He is non-verbal and the adults around him explain that he has difficulties handling transitions and changes in activities.

Three experienced professional educators (one woman and two men) from the specialized school

collaborated with us in this study. The first of these is a monitor-educator (12 years' experience) who has worked in the specialized school for 10 years. The second was a monitor-educator for 12 years before becoming a specialized educator (12 years' experience). He has worked in the specialized school for two years. The third is a monitor-educator (14 years' experience), who also has a sports educator certificate. He has been working in the specialized school for 18 years. Only the last of these three people said they were comfortable with digital tablets.

### Planning Tool Used

As part of the framework of "çATED-Autism" project, our multidisciplinary research team of university lecturers and researchers developed an application for digital tablets (Android and iOS devices). The çATED application (3.0; image 1) was developed with children with autism and others of identical age. The application makes it possible to build an individual mobile digital agenda for the learner according to his/her needs. Education professionals or parents enter and program the information for each child in the "administrator" function (for example, "take shower" between 6:00 am and 6:30 am and then "watch TV") with personalized photographs or pictograms, to illustrate the graphical representation related to the activity for a given duration and represented by a virtual timer.



**Image 1:** Main screen of the digital planning application (çATED): on the left the pictogram "play with the doll" (activity finished), in the center the pictogram "take a shower" (current activity associated with the timer at the bottom of the screen which indicates the remaining duration of activity in red) and on the right the pictogram "watch TV" (upcoming activity).

## Procedures

Nine sessions carried out over a year were analyzed, relating to common dates when video recordings were made of each of the three children during activity workshops.

Sessions with professionals and children of the specialized school, lasting about half an hour, were filmed. Various games workshops (Lego, puzzles, board games) were selected because the professionals had an exclusive and an individual accompaniment with the child.

In order to study evolution of the children's cognitive availability evolution, two periods are monitored, due to the experimental change caused by the use of the digital tablet. Indeed, parents needed more time to appropriate the digital tool than professionals. We trained parents for three months before offering the digital tablet at home. Our aim is to encourage the overcoming of borders in accompaniment and therefore to promote an inclusive approach:

- Phase 1 is the period from January 2015 to March 2015 (three data harvests: January, February and March). During these three months, the digital tablet is used exclusively within the specialized school;
- Phase 2 corresponds to the period from April 2015 to October 2015 (five data harvests: April, May, July, September and October). During these five months, the digital tablet was used in both the specialized school and the child's home.

The videos were coded using ELAN® software to measure the duration of each indicator (e.g. wait, install/stow the equipment, play/do the task, etc.) necessary to evaluate the evolution of the duration of the cognitive availability for each subject during the activity. This rating was carried out by the researcher in charge of the study and provides information on the total duration of the child's cognitive availability during the session. It is then possible to compare the data (n=9 workshops studied) with each other in order to observe a possible evolution of this dimension.

Data analysis was based on a unique case methodology by using the Tau-U statistical test, which makes it possible to compare batches of data for the same and unique subject [17]. Tau-U allows us to have a baseline (Phase 1; n=3) of the cognitive availability of the child with the digital tablet in interaction with the education professional, then to compare the results of

Phase 2 (n=5) of the child with respect to these same data. By providing information on a possible significant difference between Phase 1 and Phase 2 this statistical tool could highlight the effects of the use of the digital tool on the children's cognitive availability.

This quantitative analysis method was crossed with a qualitative analysis of the children's cognitive availability in situations of interaction with the educators and the digital agenda. The contribution of the data collected by the semi-structured interviews (one per month with each educator) made it possible to qualify the quantitative data obtained. The qualitative data were treated by a thematic analysis.

The following indicators of the independent variable of children's cognitive availability were measured: wait, install/stow the equipment, play/do the task, give an object, interact with the educator, point with the finger/touch/carry the digital agenda.

Three duration evaluation times were considered by the Tau-U statistical test:

- The baseline (on average) of the three durations of cognitive availability in Phase 1 (P1) is calculated.
- The average of the five durations related to the cognitive availability of Phase 2 (P2) is calculated.
- The data from Phase 1 (baseline) are compared with those from Phase 2 using the statistical test.
- The test aimed to reveal if there is a significant difference between the two evaluation times.

## Evolution of the Cognitive Availability of Children in the Workshops over the Year

Table 1 shows all the results of the descriptive analysis of the data collected for each child (E1, E2 and E3). It is an indication of the average duration in seconds, given with the data intervals (minimum and maximum values) at Phases 1 and 2 (Table 1). For example, during Phase 1, E1 is cognitively available for an average duration of 277 seconds and the interval corresponding to this Phase is [170-332].

These descriptive results highlight the wide variability in cognitive availability among the children E1, E2 and E3 with eclectic starting scores (mean duration between 277 and 467). Data could vary among the sessions within the same Phase. For example, the cognitive availability time interval for E3 in P1 was [267-475].

Child	Cognitive availability (P1)		Cognitive availability (P2)	
	Average (sec)	Range (sec)	Average (sec)	Range (sec)
E1	277	170-332	244	108-341
E2	467	413-572	452	414-521
E3	360	267-475	366	329-449

**Table 1:** Average duration and data intervals related to cognitive availability for each child.

At P2 data on E1 and E2 show a decrease in their average cognitive availability time. There was a slight increase in subject E3. Again, the data for Phase 2 varied considerably from one session to another. For example, the cognitive availability time interval for E1 in P2 was [108-341]. Semi-structured interviews later allowed us to understand this fluctuation between sessions.

Table 2 provides a summary of the data obtained from the Tau-U statistical test performed on the two datasets (P1 and P2) for each child.

Child	E1	E2	E3
Tau-U	-0.27 NS	0.20 NS	0 NS
<i>p</i>	0.55	0.65	1
90% CI	[-1.00, 4.47]	[-0.54, 0.94]	[-0.74, 0.74]

CI = Confidence Interval; \* $p \leq 0.05$ ; NS = not significant

**Table 2:** Value of the Tau-U effect tested for each child.

The results of the statistical analysis given in Table 2 (above) for E1, E2 and E3 data do not show any significant difference between Phase 1 and 2 for these children ( $p > 0.05$ ). Despite the previous descriptive analyses (Table 1), these initial results lead us to consider that cognitive availability changes a little over time for children with autism using the digital tool. Additional qualitative analyses based on semi-structured interviews with professionals will allowed these results to be refined so they could be better understood.

### Cross-Referencing Educator Interviews with the Quantitative Data

Data from the semi-structured interviews can improve our understanding of data variability within each Phase highlight the limitations of a statistical tool such as the Tau-U.

The educators statements highlight the evolution of the students' behavior in learning situations, but also his or her ability to be more cognitively available during the task proposed in the workshops.

The use of the digital agenda in learning situations made it possible to develop autonomous and anticipatory

behaviors. Indeed, during this study, E1 and E3 developed (according to the professional educators accompanying them) these types of behavior, allowing them to be actors, indicated in the following examples by the use of the pronoun "he", in the management and organization of the different tasks.

- Professional 1: "He looked and, seeing the picture of the toilet, he untied his thing (the belt of his chair when he's at his desk) and did the same thing to go to the toilet".
- Professional 3: "Once he had done that, he sat on the toilet, we changed the diaper, the tablet stayed next to him. He took it back and the next sequence was to go to get a snack. He took the tablet back and he went there (to the kitchen)".

It was the information available on the screen that enabled the children to carry out the change of activity independently. The content of the digital agenda, adapted to the child's understanding, allows him to anticipate and carry out actions in accordance with what is requested (professional 1: "So the tablet helps him to be able to do the different steps"). The child's movement to the location of the next activity shows a learning process in reading the information displayed on the digital tablet.

During the activities carried out, children were more cognitively available according to educators in groups 1 and 3. Indeed, the educators' observations underlined that young learners were more inclined to follow and carry out the requested actions.

- Professional 1: "It's good for him, we help him to channel himself. To get his attention".
- Professional 3: "The tablet helped him stay on his chair."

According to P1, the supporting function of this digital tool allows the child to "channel" himself during an activity and to work effectively. The child who had knowledge of the progress of the current activity, fully invested himself in it. This instrumented support also allows the emergence of new behaviors among such learners.

- Professional 1: "So he can look at the tablet. When he came the last time, it is the first time that he came at 'bread time' (to feed the ponies)".

Thus, Professional 1 points out that E1 was able to come for “the first time” to give bread to the ponies. The cognitive availability of children produced by the use of the digital agenda therefore makes it possible to encourage new behaviors that promote access to new learning opportunities.

These data provide us with new insights into the development of each child during the study. The educators highlighted the children's new behaviors that promoted their cognitive availability during learning activities.

## Discussion and Conclusion

In our study, we wanted to identify the effects of the use of a digital agenda on the cognitive availability of children with autism in specialized schools. Cognitive load can have an impact on the daily lives of children with ASD and possibly reduce their performance. Technological solutions are needed that will help these young people to carry out learning tasks. All our conclusions should be taken with caution because they cannot be generalized. It would be appropriate to replicate the entire protocol with a larger cohort.

The collection of data on cognitive availability was based on an objective measure oriented by a behavioral method. All quantitative data were collected from the ELAN software used to encode the videotape. All of the child's moments of action made it possible to derive a total duration of when the child was cognitively available during the workshop. One of the limitations of this rating is the coding made by the researcher in charge of the study. It would have been necessary to work on a double-blind scoring of the filmed data in order to ensure the objectivity of the rating. The behavioral measurement of the child's performance may therefore have been biased by the researcher's representations.

Qualitative data were also collected during this study. Educators' comments were collected during a semi-structured interview conducted once a month. This complementary measure helps us to understand the quantitative data and its nuances. Analysis of the professionals' statements provides additional information to assess the child's development over the year studied and to identify new behaviors that promote cognitive availability and thus the performance and execution of the learning task. This objective measure allowed us to identify the effects of the digital tool on the child's availability in the year over which this study was conducted.

Unfortunately, these quantitative data did not allow us to conclude there was a possible effect of using the digital tool in the child's various living spaces on cognitive availability. However, the qualitative data allowed us to see the evolution of some children during the workshops. Indeed, the feedback from some professionals led us to conclude that children's cognitive availability improved during the workshops. They also suggest that the digital tool promoted the mediation of learning content in the educator-child dyad by providing a supporting function.

Tau-U is a relevant tool for working on the singularity of people with autism in a specific context and it would be interesting to continue research in this same direction in order to identify all its potential. However, it is necessary to cross-reference quantitative data with qualitative data in order to qualify results of this type. Tau-U does not seem to be sensitive to small amount successes of children with autism. However, any victory is a big success for education professionals and parents. Adopting a hybrid methodology with Tau-U could therefore be beneficial in social sciences and humanities research.

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