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Carole Tardif, Laura Latzko, Thomas Arciszewski, Bruno Gepner

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Reducing Information's Speed Improves Verbal Cognition and Behavior in Autism: A Two-Cases Report

Carole Tardif, PhD,[a] Laura Latzko, MSc,[a] Thomas Arciszewski, PhD ,[a] Bruno Gepner, MD, PhD[b]

[a]Centre de recherche Psychologie de la Connaissance, du Langage et de l'Émotion (PsyCLE), Aix-Marseille University, France; and

[b]Laboratoire de Neurobiologie des Interactions Cellulaires et Neurophysiopathologie (NICN), Aix-Marseille University, France

Address correspondence to Bruno Gepner, MD, PhD, Laboratoire de Neurobiologie des Interactions Cellulaires et Neurophysiopathologie (NICN), UMR CNRS 7259, 15, rue Pierre Dramard, Faculté de Médecine Marseille Nord, Aix-Marseille University, France. E-mail: bruno.gepner@univ-amu.fr

Short Description

This case report describes the first demonstration of enhanced verbal cognition due to reducing the speed of audiovisual information in 2 children with autism spectrum disorders.

Abstract

According to the temporal theory of autism spectrum disorders (ASDs), audiovisual changes in environment, particularly those linked to facial and verbal language, are often too fast to be faced, perceived, and/or interpreted online by many children with ASD, which could help explain their facial, verbal, and/or socioemotional interaction impairments. Our goal here was to test for the first timethe impact of slowed-down audiovisual information on verbal cognition and behavior in 2 boys with ASD and verbal delay. Using 15 experimental sessions during 4 months, both boys were presented with various stimuli (eg, pictures, words, sentences, cartoons) and were then asked questions or given instructions regarding stimuli. The audiovisual stimuli and instructions/questions were presented on a computer's screen and were always displayed twice: at real-time speed (RTS) and at slowed-down speed (SDS) using the software Logiral. We scored the boys' verbal cognition performance (ie, ability to understand questions/instructions and answer them verbally/nonverbally) and their behavioral reactions (ie, attention, verba/nonverbal communication, social reciprocity), and analyzed the effects of speed and order of the stimuli presentation on these factor. According to the results, both participants exhibited significant improvements in verbal cognition performance with SDS presentation compared with RTS presentation and they scored better with RTS presentation when having SDS presentation before rather than after RTS one. Behavioral reactions were also improved in SDS conditions compared with RTS conditions. This initial evidence of a positive impact of slowed-down audiovisual information on verbal cognition should be tested in a large cohort of children with ASD and associated speech/language impairments.

Introduction

The temporo-spatial processing disorders theory of autism spectrum disorders (ASD) postulates that perception in individuals with ASD can be characterized by deficits in rapid dynamic and temporal processing in addition to enhancements in static and local processing.[1] The transient

events of daily life, in either the visual,[2] the auditory,[3] or the proprioceptive modality,[4] may often be too fast to be faced in real time, processed online, and integrated on time by many children (and adults) with ASD. This scenario may possibly lead to the gaze and face avoidance, impaired facial processing, and various other sensory-motor, cognitive, and socioemotional and behavioral deficits and peculiarities observed in individuals with ASD.[1] Strengthening this temporal approach to ASD, experimental studies have shown that children with ASD perform better in emotional and nonemotional facial recognition tasks[5] and in facial and body imitation tasks,[6] and they improve their facial exploration,[7] when the dynamic facial stimuli are displayed slowly on a screen, compared with a presentation at a real-time daily life speed.

In the present 2-case study, we investigate for the very first time - to our knowledge - whether and to what extent reducing the velocity of audiovisual information might improve verbal comprehension and cognition, as well as related attentional, communicative, and social behaviors, in 2 boys with ASD and verbal delay.

Methods

Participants

Two boys participated in this study after the full informed consent of their parents was received; this consent included the right to film the boys during the experiment. Both boys had been diagnosed with typical autism according to *International Classification of Diseases, 10th Revision*,[8] criteria for pervasive developmental disorders, as well as a moderate to severe form of autism requiring substantial support according to Diagnostic and Statistical Manual of Mental Disorders, *Fifth Edition*, criteria for ASDs.[9]

E.K., a 5½-year-old boy, had a moderate to severe form of ASD, marked by very few social interactions with his peers, restricted activities, several motor stereotypes, sensory self-stimulations, and some self-injuries. He also presented a moderately delayed verbal development with verbal stereotypes and a moderate level of attention-deficit/hyperactivity disorder.

R.S., a 16-year-old boy, had a moderate form of ASD, marked by gaze and social avoidance, shyness, poor social interaction, stress and anxiety, motor stereotypes, and some self-injuries; he had an extremely poor level of verbal expression (he could pronounce some syllables and repeat some words approximately but never spontaneously). Since 5 years of age, he had been trained by speech therapists with the Picture Exchange Communication System and could use ~300 pictograms. At the age of 14 years, he had learned Makaton gestures (inspired by French sign language) and used ~200 signs.

Neither of the participants had vision deficits. Tables 1 and 2 present the clinical characteristics of the 2 boys.

Table 1 : Clinical Characteristics of E.K.

Variable	Developmental and Cognitive Domains	Score	Year; Month
Age			5; 6
CARS[1]		37	
ADOS[2]	Communication	6	
	Reciprocal social interaction	9	
	Interests and repetitive behavior	3	
VABS[3]	Communication		2; 9
	Autonomy		3
	Socialization		2
	Motor development		2; 7

Variable	Developmental and Cognitive Domains	Score	Year; Month
ECSP[4]	Social interaction		1; 9
	Joint attention		1; 9
	Behavioral regulation		2; 4
	Verbal comprehension		3; 3
	Verbal expression		2; 9
PEP-3[5]	Verbal cognition		2; 6
	Verbal expression		2; 9
	Verbal comprehension		3
	Fine motor development		2; 6
	Gross motor development		2; 8
	Oculomotor imitation		2
Early signs of autism	Smiling and babbling quasi-normally in the first months, sleeping disorders; first few words in the first year, numerous verbal and motor stereotypes and poor and inappropriate social interaction in the second year; signs of attention-deficit in the third year		
Therapies and occupations	4 half-days in a primary school with the help of an adult tutor; 1 session per week of sensory-motor therapy, 2 sessions per week of speech therapy, and 2 afternoons per week in a child day-care psychiatric unit		

[1]CARS, Childhood Autism Rating Scale; [2]ADOS, Autism Diagnostic Observation Schedule; [3]VABS, Vineland Adaptive Behavior Scale; [4]ECSP, Echelle de Communication Sociale Précoce (Early Social Communication Scale); [5]PEP-3, Psychoeducational Profile: Third Edition.

Table 2 : Clinical Characteristics of R.S.

Variable	Developmental and Cognitive Domains	Score	Age (Year; month)
Chronological age			16
CARS[1]		38	
ADOS[2]	Communication	9	
	Reciprocal social interaction	8	
	Interests and repetitive behavior	3	
K-ABC II[3] (nonverbal scale, 7–12)	Story completion		4;6
	Triangles		10

Variable	Developmental and Cognitive Domains	Score	Age (Year; month)
	Block counting		11
	Number recall		4
	Conceptual thinking		5
	Hand movements		4
First signs of autism	Development was about normal in the first year; some words appeared between the first and second year and declined when he was 2 years old (words disappeared first, then syllables). No gaze interaction, no pointing, very poor joint attention, inappropriate use of objects in the second year; motor stereotypes, obsessions, and rituals, with a moderate hyperactivity, in the third year		
Therapies and occupations	Speech therapy once a week; horse therapy once a week; 2 afternoons per week in a special school section for adolescents with ASD, using structured educational strategies (eg, visual planning, timer). Mother stopped working when he was 7 years old, spent enormous time with him to stimulate his competencies in all areas of development, particularly communication, autonomy, and socialization		

[1]CARS, Childhood Autism Rating Scale; [2]ADOS, Autism Diagnostic Observation Schedule; [3]K-ABC II, Kaufman Assessment Battery for Children, Second Edition

Methods

Experimental Stimuli

Experimental stimuli (ie, the static visual and dynamic audiovisual stimuli) were presented through 8 different types of materials and supports. The experimental stimuli are discussed in detail in the Supplemental Information.

Software and Computer

A free online software called Logiral[10] (see the Graph interface of Logiral in Supplemental Fig 3) was implemented on a PC (Dell Latitude, 17-inch; Dell, Round Rock, TX). The main goal of Logiral is to simultaneously decrease the velocity of visual and auditory information, with perfect synchrony, by steps of 5% or 10%, and with a very limited tone distortion at the speed used in this study. Logiral was used to slow-down both the dynamic audiovisual stimuli and the comprehension questions and instructions on the PC.

Camera

A Sanyo VPC-FH1 Full 1080p HD video camera was used. It had 2 purposes: (1) to record and generatethe audiovisual comprehension questions and instructions verbalized by the investigator for the experiment; and (2) to record the experimental sessions for fine analysis and scoring.

Experimental Procedure

Fifteen sessions were performed with each child (ie, 1 session per week over 4 months). Sessions were performed at their home, in a quiet room, and lasted ~30 minutes. The participant was sitting in front of the computer, at a distance of 25 to 30 cm. The investigator was sitting next

to the child. The camera was placed in front of the child and filmed his face and upper part of his body.

During each session, 3 different materials were used: Material 1 (“Sentences”) and 2 other materials among 4 other choices, according to the participant’s interests, motivation, verbal, and cognitive level (Tables 3 and 4). After each presentation of one material, a set of 5 comprehension questions or instructions regarding the material were verbalized by the investigator either via the PC (for 6 out of 8 materials) or in person (for 2 materials). The dynamic audiovisual stimuli and the questions or instructions regarding the materials were always displayed twice on PC, at a real-time speed (RTS) and at a slowed-down speed (SDS). Order of presentation (either SDS-RTS or RTS-SDS) was counterbalanced between sessions. SDS velocity corresponded to 70% of the RTS for both participants, and it was chosen because it has been shown to enhance positive behavioral reactions in children with ASD while producing very limited tone distortion of the acoustic stimuli.[11] (For details see Materials in Supplemental Information).

Table 3 : Materials Used With E.K. During the 15 Sessions

Materials	No. of Sessions Using This Material
Sentences	15
Pictures with changing details	4
ELO pictures	10
Films of everyday life	7
Complex picture	9

Table 4 : Materials Used With R.S. During the 15 Sessions

Materials	No. of Sessions Using This Material
Sentences	15
Close words	4
ELO pictures	12
Mirror sentences	13
Cartoon	1

Data Scoring

Two types of data were scored for further statistical analyses: verbal cognition performance and behavioral reactions.

Verbal Cognition Performance

Verbal cognition performance as designated here indicates the ability of the participants to understand questions and instructions of various length and complexity and to answer either orally or by pointing and/or signing. Each answer was scored from 0 to 3 according to its accuracy: 0, error or no answer; 1, random answer (ie, participant was not attentive enough to consider his answer reliable); 2, emergence (ie, incomplete or not enough accurate answer); and 3, complete and correct answer.

Behavioral Reactions

Eighteen items investigating 4 behavioral domains (attention, verbal communication, nonverbal communication, and social reciprocity) were extracted from the French Echelle de Comportement Autistique-Révisée[12] and from the Psychoeducational Profile: Third Edition,[13] constituting an ad hoc behavioral scale. Each of the 18 items was scored from 0 to 4, according to frequency of the corresponding behaviors during the experimental sessions (Table 5).

Table 5 : The 18-Item Behavioral Scale

Attention	Verbal Communication	Nonverbal Communication	Social Reciprocity
1. Visual attention	4. Verbal comprehension	8. Comprehension of communicative gestures	14. Participation and involvement in the session
2. Auditory attention	5. Immediate or delayed echolalia	9. Comprehension of emotional facial expressions	15. Immediate answers to questions or solicitations
3. Joint attention	6. Vocal imitation (sounds, words, sentences)	10. Gestural imitation	16. Delayed answers
	7. Use of an appropriate language	11. Gaze interaction	17. Spontaneous initiatives
		12. Production of communicative gestures (eg, pointing)	18. Maintaining interaction
		13. Emotional expression	

Each item is scored from 0 to 4 (0, never happens during the session; 1, happens rarely during the session; 2, happens rather often during the session; 3, happens often during the session; 4, happens very often during the session).

Scoring Procedure

The investigator (L.L.) scored verbal cognition performance (ie, answers to the comprehension questions and instructions) during each of the 15 sessions. After each session, she watched the film of the recorded session to check her ratings on verbal cognition performance and to score the behavioral reactions. A second rater (C.T.) reanalyzed films of the 15 sessions (numbered from 1 to 15) for a second blind scoring, that is, she ignored what session number corresponded to the film session she was watching and its scoring.

Specific and general inter-rater correlations were between $r = 0.90$ and $r = 0.95$ computed with a Spearman ρ (ie, strong correlations allowed us to make the following analyses).

Statistical Analyses

The Generalized Estimating Equation was used for statistical analyses of the data of both participants along the sessions.[14,15] Models included speed of presentation (SDS and RTS) and order of presentation (SDS-RTS and RTS-SDS) as factors, and sessions as repeated measures.

Results

Results of the two participants are presented in Tables 6 and 7, Figs 1 and 2.

Results of E.K.

Verbal Cognition

There was a simple effect of speed of presentation on verbal cognition performance, which was significantly enhanced with SDS presentation compared with RTS presentation (b = –0.69, SD = 0.14, Wilcoxon (W) = 23.77, $P < .001$, $R^2 = 0.45$). There was no simple effect of order of presentation on verbal cognition performance.

There was, however, a significant interaction between speed of presentation and order of presentation (b = –0.52, SD = 0.19, W = 8.16, $P < .01$, $R^2 = 0.71$), illustrating that E.K. scored better in RTS presentation when having the SDS presentation first than when having it second (Table 5). Specifically, although his scores in verbal cognition were not significantly different between SDS and RTS conditions of presentation when RTS came after SDS, they differed significantly when SDS came before RTS (Wilcoxon W = 36; $P < .01$).

Table 6 : Mean ± SD Scores of Verbal Cognition Performance in E.K. according to Speed and Order of Presentation of Experimental Stimuli

Order of Presentation	SDS	RTS
SDS-RTS	2.66 ± 0.09	1.96 ± 0.59
RTS	2.7 ± 0.08	1.48 ± 0.52
SDS		

Behavioral Reactions

Scores in attention, nonverbal communication, and social reciprocity were significantly enhanced during SDS presentation compared with RTS presentation (b = –1.13, SD = 0.12, W = 90.94, P < .001, R^2 = 0.68; b = –0.91, SD = 0.04, W = 701.6, P < .001, R^2 = .78; and b = –0.95; SD = 0.12; W = 62.92; P < .001, R^2 = 0.17, respectively). Only verbal communication did not improve with SDS presentation compared with RTS presentation (b = 0.19, SD = 0.14, W = 1.72; NS).
No interaction was found between speed of presentation and session. Attention, nonverbal communication, and social reciprocity were always enhanced during SDS presentation compared with RTS presentation, but they did not improve significantly during the experiment.

Results of R.S.

Verbal Cognition

There was a significant simple effect of speed of presentation on verbal cognition. Verbal cognition was significantly enhanced with SDS presentation compared with RTS presentation (b = –0.73, SD = 0.14, W = 25.73, P < .001, R^2 = 0.43). There was also a significant simple effect of order of presentation on verbal cognition (b = –0.42, SD = 0.12, W = 11.80, P < .001, R^2 = 0.14), illustrating that performance in RTS conditions was significantly better with the SDS-RTS order of presentation than with RTS-SDS.
We also found a significant interaction between speed of presentation and order of presentation (b = –0.87, SD = 0.18, W = 23.04, P < .001, R^2 = 0.71), showing that R.S. scored better with RTS presentation when having SDS presentation first than when having SDS presentation second; that is, although his scores in verbal cognition were not significantly different between SDS and RTS presentations when RTS came after SDS, they differed significantly when SDS came before RTS (Wilcoxon W = 36; P < .01) (Table 6).

Table 7 : Mean ± SD Scores of Verbal Cognition Performance in R.S. According to Speed and Order of Presentation of Experimental Stimuli

Order of Presentation	SDS	RTS
SDS-RTS	2.66 ± 0.1	2.4 ± 0.27
RTS-SDS	2.7 ± 0.11	1.48 ± 0.43

Behavioral Reactions

The 4 domains of behavioral reactions were significantly improved in SDS conditions compared with RTS conditions: attention (b = –0.93, SD = 0.09, W = 98.54, P < .001, R^2 = 0.60), nonverbal communication (b = –0.62, SD = 0.12, W = 26.72, P < .001, R^2 = 0.29), social reciprocity with the experimenter (b = –0.64, SD = 0.08, W = 56.31, P < .001, R^2 = 0.51), and verbal communication (b = –0.49, SD = 0.07, W = 45.26, P < .001, R^2 = 0.46) (Figure 1).
We also found an interaction between speed of presentation and session for verbal communication only (b = 0.04, SD = 0.01, W = 14.38; P < .001, R^2 = 0.53). Although the boy's verbal communication behaviors decreased across sessions with SDS, they increased during the same period with RTS presentation, although they never reached those observed in SDS condition of presentation (Figure 2).

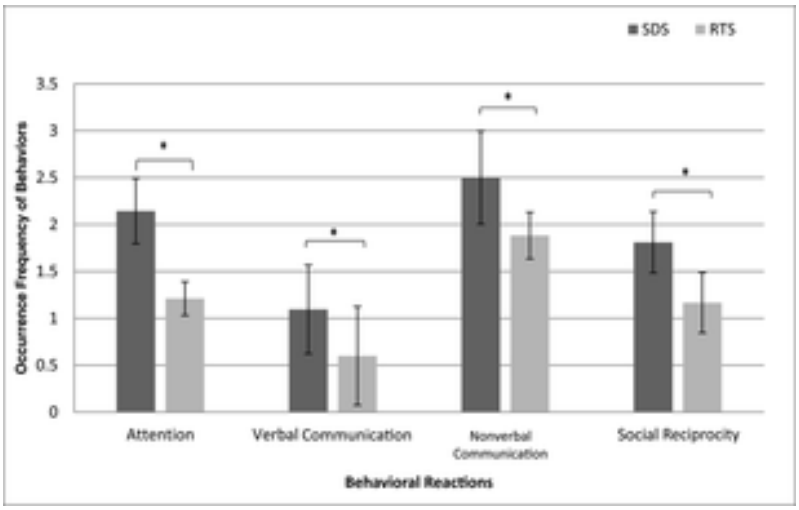

Figure 1 : Behavioral reactions of participant R.S. according to speed of presentation (SDS or RTS). * *P* < .001.

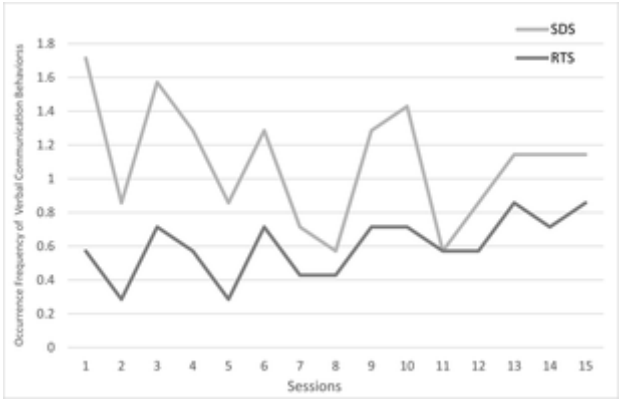

Figure 2 : Verbal communication behaviors of participant R.S. according to speed of presentation (SDS or RTS) across sessions.

Discussion

First, most of the effect sizes reported in both participants are either medium (>0.30) or strong (>0.50), illustrating that our results are reliable.

Second, the verbal cognition performance of both participants was overall significantly enhanced when dynamic audiovisual stimuli and comprehension questions and instructions were displayed slowly (SDS) compared with real-time (RTS) presentation. Moreover, in both children, while verbal cognition performance was significantly lower in RTS than in SDS condition when RTS presentation preceded SDS presentation, it was not anymore the case when SDS presentation preceded RTS condition. In one of the children, verbal cognition performance in RTS was even better in SDS-RTS order of presentation than in RTS-SDS one. This finding is, to the best of our knowledge, the first evidence of comprehension improvements in words and sentences due to slowed-down audiovisual information presentation in children with ASD. It extends preliminary findings showing an improvement of phoneme categorization in children with ASD when auditory stimuli are displayed slowly,[16] and it might be important for early speech and language learning strategies in children with ASD and associated verbal and language disorders.

A similar verbal comprehension improvement due to slowed speech had previously been observed in children with language-learning impairments.[17]
Third, assessment of behavioral reactions showed that attention, nonverbal communication, and social reciprocity of both participants were improved during the SDS presentations compared with the RTS presentations of the same stimuli. This finding confirms results of an open trial using slowness via Logiral with 4 children with severe autism and very low cognitive and verbal abilities.[11] An increased attention to slowed video sequences had also been previously observed in a group of children with ASD,[18] and results of an eye-tracking study demonstrated an increased mean duration of visual fixation on the mouth of a speaker in a group of children with ASD when facial dynamics was displayed slowly.[7]
A new finding was made in 1 of the participants (R.S.), whose verbal communication as well was overall improved in slow conditions of presentation compared to real-time presentation; this finding was particularly interesting in this 16-year-old boy having extremely poor verbal expression. Moreover, although the frequency of his verbal communication behaviors decreased across sessions in SDS condition of presentation, it increased in RTS conditions during the same period (but never reached that observed in the SDS condition). It seems as if his verbal competencies acquired with slowness progressively enlarged his verbal competencies in the RTS conditions, which is in agreement with the significant simple effect of order presentation and significant interaction between speed and order of presentation on his verbal cognition.
In the context of the well-documented interest of technology-based interventions (eg, desktop computer, interactive DVD, shared active surface) for prompting attention and motivation in children with ASD,[19] it seems that slowness provided additional benefit. Despite their age difference and verbal/cognitive level discrepancies, both participants benefited from a slowed-down presentation of audiovisual speech information in terms of enhanced verbal cognition performance and improved behavioral reactions (attention, communication, and social reciprocity).
The rapid temporal theory of ASD[1,2] has been disputed in several studies.[20,21] However, because these other investigators were using very different types of visual stimuli from ours, at slow velocities, and in participants having mild autism and no verbal nor cognitive deficiencies, this temporal approach cannot be ruled out. On the contrary, it is reinforced by the present results, which, although limited to only 2 participants, suggest a therapeutic potential for slowness in speech and language interventions, as well as in behavioral ones, for children with ASD. In our opinion, this preliminary result should be tested in a large cohort of children on the whole autism spectrum, with or without verbal impairments, as well as in typically developing and verbally disabled control children.

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Footnotes

Dr Tardif conceptualized, designed, and supervised the study; scored and analyzed the data; and reviewed and revised the manuscript; Ms Latzko collected, scored, and analyzed the data; Dr Arciszewski provided technical assistance, conducted the statistical analyses, and reviewed and revised the manuscript; Dr Gepner conceptualized, designed, and supervised the study; analyzed the data; and drafted the manuscript; and all authors approved the final manuscript as submitted.
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Glossary

ASD autism spectrum disorders
RTS real-time speed
SDS slowed-down speed

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Supplemental Materials

Experimental Stimuli

Material 1: Sentences

Sentences varying in length and complexity (eg, “the boy takes a piece of bread in his hand”) are verbalized by the investigator on the PC (the participant sees her face and shoulders on the screen). Sentences are displayed twice, first at RTS and then at SDS, or vice versa. After each sentence, the investigator asks the participants short questions regarding this sentence (eg, What…? Where…? Who…? Why...? To whom…?).

Material 2: ELO Pictures

Pictures from ELO (ie, Evaluation of Oral Language), a French vocabulary subtest assessing verbal comprehension, are randomly presented to the participants by sets of 4. Instructions to give or point at 1 of the 4 pictures are then verbalized twice by the investigator via the PC (ie, at the 2 different velocities, as noted above).

Material 3: Cartoon

Various short sequences of the cartoon *King Lion 2* (maximum, 30 seconds) are presented twice (at the 2 velocities) to the participants on the PC. After each presentation, the investigator asks short questions regarding the sequence to the participants.

Material 4: Mirror Sentences

Twelve sets of 2 pictures, exhibiting 2 similar visual scenes in which characters are either the subject or the object (eg, “the dog catches the cat” or “the cat catches the dog”), are presented to the participants. Instructions to point at the correct picture (eg, “show me the picture where the dog catches the cat”) are then verbalized twice by the investigator via the PC.

Material 5: Complex Pictures

One of 10 large pictures (29,7 cm x 42 cm) displaying a daily life situation involving many characters and objects (eg, a street scene, a classroom scene) is presented to the participant. Questions regarding the picture are then verbalizedtwice by the investigator via the PC.

Material 6: Film of Daily Life

Ten short daily life scenes (maximum, 30 seconds) are recorded by the parents of the participants. After viewing 1 scene, short questions regarding the scene are verbalized twice by the investigator via the PC.

Material 7: Close Words

Sets of phonologically close words (eg, “head/bread”) are verbalized twice by the investigator via the PC. After hearing 1 of the close words, participants are prompted by the investigator to repeat it either vocally or by pointing or signing.

Material 8: Pictures With Changing Details

A set of 14 simple pictures depicting the same character with 1 unique detail varying from 1 picture to another (form or color) is presented to the participant. Instructions to point to 1 or more pictures (eg, “show me the pictures of the boy with a red T-shirt and glasses”) are then displayed twice by the investigator via the PC.

Figure 3 : Graph Interface of Logiral. Black screen: where audiovisual sequences are displayed. Blue outline: control board; contains standard buttons of a multimedia reader, and particularly, the possibility to control the speed of playing by 5% or 10% steps. Red outline: playlist, where audiovisual sequences are stored and ready for playing. Blue and red outlined boxes disappear from the screen after 5 seconds. “Media” menu contains “Read a file,” gives access to a file in the computer ready to transfer in the playlist.