Reducing Information's Speed Improves Verbal Cognition and Behavior in Autism: A 2-Cases Report

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

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 time the 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, verbal/nonverbal communication, social reciprocity), and analyzed the effects of speed and order of the stimuli presentation on these factors. 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 presentation. 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.

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

[a]*Centre de recherche Psychologie de la Connaissance, du Langage et de l'Émotion (PsyCLE), Aix-Marseille University, Marseille, France; and* [b]*Laboratoire de Neurobiologie des Interactions Cellulaires et Neurophysiopathologie (NICN), Aix-Marseille University, Marseille, France*

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.

DOI: https://doi.org/10.1542/peds.2015-4207

Accepted for publication Nov 22, 2016

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

PEDIATRICS (ISSN Numbers: Print, 0031-4005; Online, 1098-4275).

FINANCIAL DISCLOSURE: The authors have indicated they have no financial relationships relevant to this article to disclose.

FUNDING: Funded by Conseil Régional PACA, Fondation de France.

POTENTIAL CONFLICT OF INTEREST: The authors have indicated they have no potential conflicts of interest to disclose.

To cite: Tardif C, Latzko L, Arciszewski T, et al. Reducing Information's Speed Improves Verbal Cognition and Behavior in Autism: A 2-Cases Report. *Pediatrics*. 2017;139(6):e20154207

TABLE 1 Clinical Characteristics of E.K.

Variable	Developmental and Cognitive Domains	Score	Year; Month
Age			5; 6
CARS		37	
ADOS	Communication	6	
	Reciprocal social interaction	9	
	Interests and repetitive behavior	3	
VABS	Communication		2; 9
	Autonomy		3
	Socialization		2
	Motor development		2; 7
ECSP	Social interaction		1; 9
	Joint attention		1; 9
	Behavioral regulation		2; 4
	Verbal comprehension		3; 3
	Verbal expression		2; 9
PEP-3	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		

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

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.

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 generate

the 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 a 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 the 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.)

Data Scoring

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

TABLE 2 Clinical Characteristics of R.S.

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

ADOS, Autism Diagnostic Observation Schedule; CARS, Childhood Autism Rating Scale; K-ABC II, Kaufman Assessment Battery for Children, Second Edition.

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

ELO, Evaluation of Oral Language.

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

ELO, Evaluation of Oral Language.

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,

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).

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-SDS	2.7 ± 0.08	1.48 ± 0.52

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

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).

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).

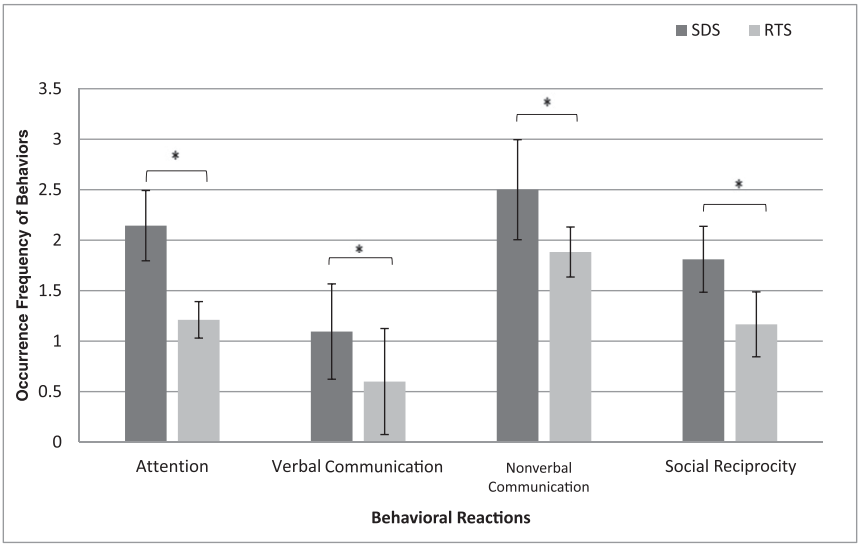

FIGURE 1
Behavioral reactions of participant R.S. according to speed of presentation (SDS or RTS). * $P < .001$.

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 2 participants are presented below in Tables 6 and 7, Figs 1 and 2, and in the Supplemental Information.

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 significantly enhanced overall when dynamic audiovisual stimuli

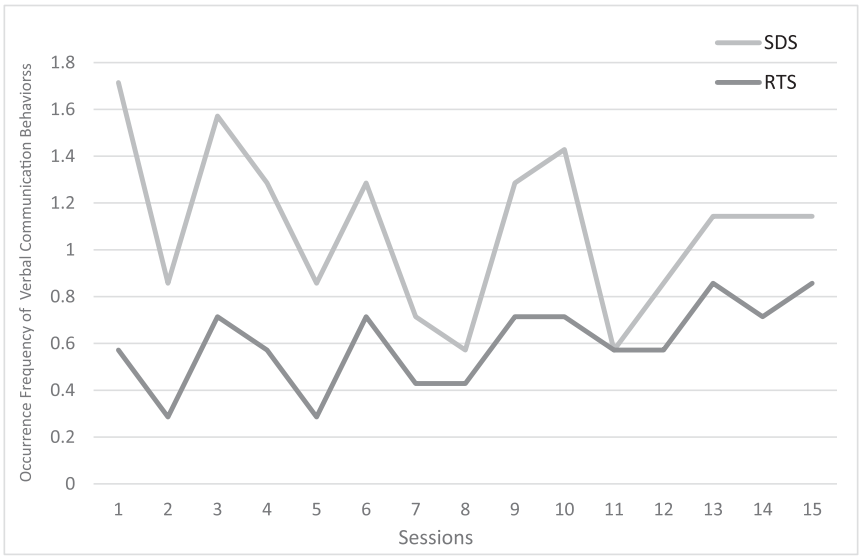

FIGURE 2
Verbal communication behaviors of participant R.S. according to speed of presentation (SDS or RTS) across sessions.

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, this was not 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 order. 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 were displayed slowly.[7]

A new finding was made in 1 of the participants (R.S.), whose verbal communication as well improved overall in slow conditions of presentation compared to in real-time presentation; this finding was particularly interesting in this 16-year-old boy with extremely poor verbal expression. Moreover, although the frequency of his verbal communication behaviors decreased across sessions in SDS conditions 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.

ACKNOWLEDGMENTS

We are very grateful to E.K., R.S., and their parents for their kind participation in this study. We thank Fondation de France and Conseil Régional PACA for funding our study, and Bruno Dauvier (PsyCLE, Aix-Marseille University) for his attention on the manuscript.

ABBREVIATIONS

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

REFERENCES

1. Gepner B, Féron F. Autism: a world changing too fast for a mis-wired brain? *Neurosci Biobehav Rev*. 2009;33(8):1227–1242
2. Gepner B, Mestre D. Rapid visual-motion integration deficit in autism. *Trends Cogn Sci*. 2002;6(11):455
3. Oram Cardy JE, Flagg EJ, Roberts W, Brian J, Roberts TP. Magnetoencephalography identifies rapid temporal processing deficit in autism and language impairment. *Neuroreport*. 2005;16(4):329–332
4. Schmitz C, Martineau J, Barthélémy C, Assaiante C. Motor control and children with autism: deficit of anticipatory function? *Neurosci Lett*. 2003;348(1):17–20
5. Tardif C, Lainé F, Rodriguez M, Gepner B. Slowing down presentation of facial movements and vocal sounds enhances facial expression recognition and induces facial-vocal imitation in children with autism. *J Autism Dev Disord*. 2007;37(8):1469–1484
6. Lainé F, Rauzy S, Tardif C, Gepner B. Slowing down the presentation of facial and body movements enhances imitation performance in children with severe autism. *J Autism Dev Disord*. 2011;41(8):983–996
7. Charrier A, Tardif C, Gepner B. Slowing down the flow of facial information enhances facial scanning in children with autism spectrum disorders: a pilot eye tracking study [in French]. *Encephale*. 2017;43(1):32–40
8. World Health Organization. *The ICD-10 Classification of Mental and Behavioural Disorders (ICD-10)*. Geneva, Switzerland: World Health Organization; 1993
9. American Psychiatric Association. *Diagnostic and Statistical Manual of Mental Disorders Fifth Edition (DSM-5)*. Washington, DC: American Psychiatric Association; 2013
10. Tardif C, Gepner B. Logiral. Available at: http://centrepsycle-amu.fr/logiral/. Accessed 2012
11. Meiss E, Tardif C, Arciszewski T, Dauvier B, Gepner B. Effets positifs d'une exposition à des séquences vidéo ralenties sur l'attention, la communication sociale et les troubles du comportement chez 4 enfants autistes sévères: une étude translationnelle pilote. *Neuropsychiatr Enfance Adolesc*. 2015;63:302–309
12. Lelord G, Barthélémy C. *Evaluation des comportements autistiques (ECA-R)*. Issy-les-Moulineaux: Editions du Centre de Psychologie Appliquée; 1989
13. Schopler E, Lansing MD, Reichler RJ, Marcus LM. *Psychoeducational profile (PEP-3). Pro-Ed, 2005. Traduction de la 3ème édition américaine: PEP-3: Profil Psycho-Educatif*. Bruxelles: De Boeck; 2010
14. Ballinger GA. Using generalized estimating equations for longitudinal data analysis. *Organ Res Methods*. 2004;7(2):127–150
15. Prentice RL, Zhao LP. Estimating equations for parameters in means and covariances of multivariate discrete and continuous responses. *Biometrics*. 1991;47(3):825–839
16. Tardif C, Thomas K, Gepner B, Rey V. Evaluation du système phonologique explicite chez des enfants autistes. *Revue Parole*. 2002;21:35–71
17. Tallal P, Miller SL, Bedi G, et al. Language comprehension in language-learning impaired children improved with acoustically modified speech. *Science*. 1996;271(5245):81–84
18. Gepner B, Deruelle C, Grynfeltt S. Motion and emotion: a novel approach to the study of face processing by young autistic children. *J Autism Dev Disord*. 2001;31(1):37–45
19. Grynszpan O, Weiss PL, Perez-Diaz F, Gal E. Innovative technology-based interventions for autism spectrum disorders: a meta-analysis. *Autism*. 2014;18(4):346–361
20. Chen Y, Norton DJ, McBain R, Gold J, Frazier JA, Coyle JT. Enhanced local processing of dynamic visual information in autism: evidence from speed discrimination. *Neuropsychologia*. 2012;50(5):733–739
21. Manning C, Tibber MS, Charman T, Dakin SC, Pellicano E. Enhanced integration of motion information in children with autism. *J Neurosci*. 2015;35(18):6979–6986