J Autism Dev Disord (2007) 37:1469–1484
DOI 10.1007/s10803-006-0223-x

ORIGINAL PAPER

Slowing Down Presentation of Facial Movements and Vocal Sounds Enhances Facial Expression Recognition and Induces Facial–Vocal Imitation in Children with Autism

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Published online: 7 October 2006

Abstract This study examined the effects of slowing down presentation of facial expressions and their corresponding vocal sounds on facial expression recognition and facial and/or vocal imitation in children with autism. Twelve autistic children and twenty-four normal control children were presented with emotional and non-emotional facial expressions on CD-Rom, under audio or silent conditions, and under dynamic visual conditions (*slowly, very slowly, at normal speed*) plus a static control. Overall, children with autism showed lower performance in expression recognition and more induced facial–vocal imitation than controls. In the autistic group, facial expression recognition and induced facial–vocal imitation were significantly enhanced in slow conditions. Findings may give new perspectives for understanding and intervention for verbal and emotional perceptive and communicative impairments in autistic populations.

Keywords Autism · Emotional facial expression · Expression recognition · Facial imitation · Facial movements · Vocal sounds · Slowing down · Synchrony · Connectivity · Reeducation

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Introduction

Autistic spectrum disorders (ASD) are known as neurodevelopmental disorders marked by social interaction and verbal and non-verbal communication impairments (APA, 1994; Kanner, 1943; Rapin, 2002; Tardif & Gepner, 2003; Volkmar & Pauls, 2003; WHO, 1992). Since human face is the primary and most powerful source of information mediating emotional and verbal communication as well as social interaction, it is not surprising that face processing has often and regularly been studied in autistic population for the past 25 years. Indeed, a growing body of data demonstrated that individuals with ASD generally process various aspects of faces in a different way than typically developing and/or mentally retarded control subjects. Peculiarities have been shown in the processing of facial identity (Boucher & Lewis, 1992; Davies, Bishop, Manstead, & Tantam, 1994; Deruelle, Rondan, Gepner, & Tardif, 2004; Klin et al., 1999; Langdell, 1978; Volkmar, Sparrow, Rende, & Cohen, 1989) and emotional facial expression (Celani, Battacchi, & Arcidiacono, 1999; Hobson, 1986a, b; Hobson, Ouston, & Lee, 1988a), in lip-reading (De Gelder, Vroomen, & Van der Heide, 1991) and eye direction detection or interpretation (Baron-Cohen, Campbell, Karmiloff-Smith, & Grant, 1995; Gepner, de Gelder, & de Schonen, 1996). It was also shown that all these aspects of facial processing were affected in a same group of children with autism, but not to the same extent, i.e., aspects of facial processing that were the most specifically impaired in children with autism, as compared to typically developing and mentally retarded control children, involved or were related to *facial dynamics* (emotional facial movements,

movements of the lips, movements of the eyes), as well as to facial configuration and visuo-auditory association (Gepner et al., 1996).

A new line of research was then open through various paradigms, aimed at assessing directly visual-motion processing in ASD, both in physical and biological domains. In the domain of physical motion processing, it was first established that children with autism have a poor postural reactivity to visually perceived environmental movements (Gepner, Mestre, Masson, & de Schonen, 1995). In a replication and extension study, it was confirmed that children with autism suffer postural hypo-reactivity to environmental motion, particularly when speed of movement is high, whereas children with Asperger syndrome (the mildest autistic spectrum disorder) are reacting normally, and even maybe overreacting, to the same kind of stimuli (Gepner & Mestre, 2002a). It was also shown that autistic children have severe difficulties when they have to compare velocities of two moving small squares on a computer screen, particularly for high motion velocities and complex trajectories (Gepner, 1997). Individuals with high functioning autism were also shown to be impaired in the perception of second order radial, translational and rotational direction of motion (Bertone, Mottron, Jelenic, & Faubert, 2003). With a visuo-oculomotor paradigm, it was found that children with autism have higher motion coherence thresholds than normal control children (Spencer et al., 2000; Milne et al., 2002), particularly for high motion velocities (Mestre et al., 2002), and that they have pursuit eye movement deficits (Takarae et al., 2004; see also Milne, Swettenham, & Campbell, 2005, for a review on motion perception in autism spectrum disorders).

In the domain of biological motion, a new paradigm, i.e., facial motion, was introduced in a pilot study by Gepner, Deruelle, and Grynfeltt (2001) aimed at questioning results of the literature on facial processing in autism. In this study, it was shown that children with autism perform as well as typically developing control children of the same developmental age in dynamic emotional and non-emotional facial expressions recognition tasks. Considering the generally poorer performance of individuals with autism compared to control subjects in facial processing, particularly but not only in the emotional domain (see above), results of Gepner et al. had been partly attributed to the fact that facial expressions were displayed *dynamically* and *slowly* on video. Moreover, this study revealed that while viewing the visual stimuli, children with autism exhibited induced facial imitation of these stimuli. However, several methodological bias or insufficiencies were observed in this study, e.g., there was no rigorous static control condition, facial expressions were displayed without sound, and induced facial imitation was not systematically measured. The present study therefore aimed at replicating, improving and extending Gepner et al. (2001) study.

Given these experimental results on motion perception in autism, as well as other convergent arguments coming from (i) family home movies, which reveal early signs of autism in sensory perception and sensorymotor integration (Sauvage, 1988; Teitelbaum, Teitelbaum, Nye, Fryman, 1998), (ii) self-reports of adults with autism (Grandin, 1995; Williams, 1992) and (iii) adult neuropsychology (Zihl, Von Cramon, & Mai, 1983), the conclusion was then reached that at least some children with autism have a rapid visual-motion integration deficit (Gepner & Mestre, 2002b), that has also been named *Motion mis-sight* (Gepner, 2001, 2005) and *E-Motion mis-sight* (Gepner, Lainé, & Tardif, 2005). More precisely, the visual environmental world (whether physical or biological) might be moving or changing too fast for at least some subjects with autism, thus resulting in social avoidance or other social peculiarities, as well as in defects in verbal and emotional comprehension, imitation and expression, *via* several *mis-developmental cascades*, i.e., by ''snow ball'' or ''blot of oil'' effects (Gepner, 2001, 2004, 2005; Gepner et al., 2005).

Besides, in the auditory domain, Tardif, Thomas, Gepner, and Rey (2002) demonstrated that some children with autism have a speech phonem categorization impairment compared to normal control children of the same verbal mental age, especially when complex phonems are concerned. Interestingly, when the same speech phonems are acoustically slowed down twice, speech phonem categorization is normalized in children with autism, i.e., it is similar to that of control children. Thus, autistic children also suffer a deficit in rapid temporal processing of speech sounds, a disorder that was previously reported 30 years ago in children with language learning impairments (LLI) such as developmental aphasia or dysphasia and dyslexia (Tallal, 1976; Tallal & Piercy, 1973, 1974;). Yet it has been shown that the verbal language impairments seen in children affected by the so-called autistic spectrum disorders (ASD) were very similar to those observed in children affected by LLI (e.g., Rapin, 2002).

All in all, the visual and auditory environmental world is probably going too fast for at least some children with ASD. This neuropsychological condition has therefore been related to a temporal processing disorder (Gepner & Massion (directed by), 2002; Gepner et al., 2005). According to this hypothesis, subjects with autism present more or less disabilities to perceive and integrate the environmental world's sensory events *online* and to produce *real-time* multisensory association and sensorymotor coupling, postural adjustments and adequate verbal and non-verbal outputs. Pursuing this line, the prediction has been made that slowing down visual and auditory environmental events may logically improve the perception, and possibly recognition, of these events by children with ASD.

The aim of the present study is therefore to replicate, improve and extend a previous pilot study by Gepner et al. (2001), and thus to determine whether, and to what extent, slowing down the presentation on CD-Rom of emotional and non-emotional facial expressions, with their corresponding vocal sounds, would enhance the recognition of these facial expressions on photographs, and induce facial and/or vocal imitation, in children with autism compared to typically developing children.

Methods

Participants

Three groups of children were tested in this study, after their parents' informed consent was obtained.

The first group included 12 children with autism (9 boys and 3 girls), aged 7;3 to 14;2 (mean = 10;5 ; *SD* = 2; 6), who were diagnosed according to DSM-IV (APA, 1994) criteria for autism by an experienced clinician (BG), and recruited in special schools for children with ASD in Aix-en-Provence.

All 12 patients had normal visual acuity and none were affected by neurological illness nor were they taking medication. The severity of autism of the 12 patients was assessed with the Childhood Autism Rating Scale (CARS by Schopler et al., 1980). Their verbal mental age (VMA) was measured with the Test de Vocabulaire Actif Passif[1] (Deltour & Hupkens, 1981). Their non-verbal mental age (NVMA) was measured with Progressive Matrices of Raven (Raven, 1981) (see characteristics of children with autism in Table 1). The CARS's score and VMA of children with autism were found to be correlated ($r = -.70$; $p < .01$), which means that the children having the highest degrees of autism (moderate-to-severe autism, with CARS's score equal or above 35) also have the lowest levels of verbal comprehension.

The second group consisted of 12 typically developing children individually matched with autistic children on the basis of gender and VMA. Children of the second group were aged 3;3 to 7;3 (mean = 5;1 ; *SD* = 1;4). The third group consisted of typically developing children individually matched with autistic children on the basis of gender and NVMA. They were aged 3;4 to 11;1 (mean = 6;1 ; *SD* = 2;6). Children of the second and third group were recruited in primary and elementary schools in Marseille and Aix-en-Provence.

Materials

Filmed Sequences

A professional actress had been selected for her talent in portraying clearly distinguishable facial gestures. In a professional audio–video studio (Service Commun Audio-visuel et Multimédia (SCAM), at University of Provence), her face was filmed in live while displaying series of four emotional and four non-emotional facial expressions. Facial expressions were displayed naturally and slowly, according to previous studies (Kamachi et al., 2001; Pollick, Hill, Calder, & Paterson, 2003; see also Gepner et al., 2001), i.e., they were lasting more than 1200 ms. Each facial gesture started with a neutral expression and reached the full expression within approximately 2 s. The four emotional expressions were *joy*, *surprise*, *sadness* and *disgust*; the four non-emotional expressions were *pronunciation of the three vowels A, O, I*, and *tongue protrusion*. Each emotional and non-emotional facial expression was displayed with its corresponding vocal sound (e.g., ''yeah!'' corresponding to joy).

The eight most expressive filmed sequences (four emotional and four non-emotional facial expressions) were selected and then computerized in the audio–video studio. Then, all the sequences were manipulated so as to last exactly 2 s. Then, each 2-second sequence was visually and acoustically manipulated.

Visual Conditions

In the first condition of visual presentation, which is our *reference condition* named *'Slow condition'*, facial expressions were those of the live film, i.e., they were slowly displayed in a natural and ecological way. Then

[1] The TVAP (Active and Passive Vocabulary Test) is a french vocabulary test. It is made up of 30 sets of five pictures. These pictures represent either objects or actions. This test is divided in two subtests (Active and PassiveVocabulary subtests). In the Passive vocabulary subtest, the experimenter asks the child to point to one of the five pictures. This subtest assesses verbal comprehension level. In the Active Vocabulary subtest, the experimenter asks the child to give a definition of one of the five pictures. This subtest assesses verbal expression level. In our study, children with autism were matched with typically developing children using the passive Vocabulary subtest only.

Table 1 Characteristics of children with autism: sex, age, verbal mental age (VMA), non-verbal mental age (NVMA), and score at the Childhood Autism Rating Scale (CARS)[a]

Subjects	Sex	Age (y;m)	VMA (y;m)	NVMA (y;m)	CARS score
1	M	11;11	6;9	7;6	34
2	F	14;2	6;0	5;8	37
3	F	7;3	5;3	4;6	34
4	F	14;1	7;3	6;8	31
5	M	8;5	5;3	4;6	37
6	M	9;3	4;6	4;0	36
7	M	11;5	4;9	11;0	36
8	M	11;8	6;0	11;0	34
9	M	11;1	3;0	3;0	38
10	M	12;1	6;0	5 ;6	36
11	M	7;4	3;6	4;0	35
12	M	8;8	3;0	5;3	38
Mean	-	10;5	5;1	6;5	35.5
SD	-	2;6	1;5	2;7	2.02

[a] A score comprised between 30 and 34 corresponds to a mild degree of autism. A score comprised between 35 and 39 corresponds to moderate to severe autism

the duration of each sequence was shortened, whether at the beginning or at the end of the sequence so as to last exactly 2 s (with 25 frames per second, i.e., 50 frames).

The second condition, named *'Very Slow condition'*, was constituted from the 'Slow condition': sequences of the 'Slow condition' were artificially slowed down twice, thus lasting 4 s (=100 frames). In order to obtain 2-second sequences, we suppressed 25 frames at the beginning of each sequence when facial expression is neutral, and 25 frames at the end of each sequence when facial expression exhibits its full expression. The result obtained was that the dynamic part itself of the facial expression was slowed down twice, and therefore displayed very slowly.

The third condition, named *'Normal condition'*, was also constituted from the 'Slow condition': sequences of the 'Slow condition' were artificially accelerated twice, thus lasting 1 s (= 25 frames). In order to obtain a 2-s sequence, we added 10 frames at the beginning of each sequence when face is neutral, and 15 frames at the end of each sequence when the face exhibits its full expression. The result obtained was that the dynamic part itself of the facial expression was accelerated twice, and therefore displayed at a normal everyday life speed.

The fourth condition, named *'Static condition'*, was showing either a photograph of one of the four emotional or one of the four non-emotional expression statically, for 2 s. These photographs were extracted from the dynamic sequences, when facial expression is full, i.e., the last frame of the 2-second sequence.

Sound Conditions

Each 2-second sequence was either sounded or silent. In the *'Sounded conditions'*, vocal sounds corresponding to emotional or non-emotional gestures were superimposed to facial movements (e.g. "yeah !" corresponding to joy). Corresponding to facial expressions displayed in the natural 'Slow condition' of presentation, vocal sounds were displayed slowly and in a natural way, simultaneously to facial gestures. Corresponding to facial expressions displayed in the 'Very Slow condition', vocal sounds were artificially slowed down twice and then superimposed to the very slow facial movements. Corresponding to facial expressions in the 'Normal condition', vocal sounds were artificially accelerated twice and then superimposed to the facial movements. Corresponding to the 'Static condition', vocal sounds were the same as those displayed in the 'Slow condition' of facial presentation, i.e., they were displayed slowly. An acoustic frequency compensation of sounds was operated automatically on the sounds of the 'Very slow' and 'Normal' conditions of facial presentation by an audio software (Protools®, DigiDesign), in order to prevent against vocal transformation. In the *'Silent conditions'*, sound was deleted.

Overall, the four Emotional and four Non-emotional facial expressions were displayed under two Sound conditions (sounded or silent) and four Visual conditions (slowly, very slowly, at normal speed, or statically). We therefore obtained 64 2-second sequences that were digitized and recorded randomly on a CD-Rom, for being displayed on a computer screen.

Photographs of Facial Expressions

Thirty-two sets of four digitized photographs of the full emotional expression, and 32 sets of four digitized photographs of the full non-emotional expression were constituted. Each set of photographs was then implemented on the CD-Rom, after a 1-second blank interval following each 2-second sequence. The respective position of each photograph was random and different from one sequence to another.

Procedure

The children were tested in their usual everyday environment, that is, at home for the children with autism, at school for the typically developing children. Children were placed in a quiet room, in front and at a distance of 30 cm of the computer screen (28.6 cm × 21.6 cm). The children were tested by two experimenters (FL and MR), who were familiar to all the children with autism. The first experimenter (FL) was sitting at the right and slightly in front of the children in order to prompt him/her to look carefully at the screen, to note his/her answers, and to manipulate the computer. The second experimenter (MR) was sitting in front of the children in order to check that he/she was looking at, and paying attention to the screen during the trials and to note systematically facial and/or vocal imitations of the children; besides, MR filmed the facial and vocal expressions and reactions of the children with autism for further analysis.

Then first experimenter explained the task to the children slowly and as clearly as possible: ''*Please! The game is going to start. You are going to see a woman on the screen, she will make a facial gesture, and then you will have to point to the photograph on which the woman makes the same gesture, allright?*''. Children were then presented eight training trials (including the eight facial expressions, displayed under the four visual conditions and the two sound conditions). After presentation of the target stimulus for a 2-second sequence, a blank interval appeared for one second, then a set of four photographs was displayed (four emotional photographs when the target stimulus was emotional, and four non-emotional photographs when the target stimulus was non-emotional). This procedure was repeated for the eight training trials. Then the experience itself started. The 64 2-second sequences were displayed one by one. After each sequence (i) the first experimenter noted which one of the four photographs was pointed to by the children, and scored 1 for a correct answer, or 0 for a wrong answer; and (ii) the second experimenter noted if the children exhibited immediate induced facial and/or vocal imitation, and scored 1 for the presence of a facial and/or a vocal imitation, or 0 when neither facial nor vocal imitation was induced. The next trial began when the child returned to an attentive state. Every sequence in which experimenters observed that the children looked away from the screen was displayed again.

We thus obtained a score (out of 64) in facial expression recognition and a score (out of 64) in facial–vocal induced imitation.

Statistical Analyses

Concerning facial expression recognition, analyses of variance (ANOVA) were performed on the mean of correct responses, with the Group (Autistic, VMA, NVMA) as the between-subject factor, and Facial Expression (Emotion, Non-emotion), Sound condition (Sounded, Silent) and Visual condition (Slow, Very Slow, Normal, Static) as the repeated measures.

Concerning facial and vocal imitation, analyses of variance were performed on the mean of facial and vocal imitations, with the Group (Autistic, VMA, NVMA) as the between-subject factor, and Facial Expression (Emotion, Non-emotion), Sound Condition (Sounded, Silent) and Visual Condition (Slow, Very Slow, Normal, Static) as the repeated measures.

An exact one-tailed Fisher test was performed in order to identify, among the Autistic group, which children benefited from the Slow and/or the Very Slow conditions of presentation.

Results

Results in Facial Expression Recognition

Scores obtained by both autistic and typically developing children of the two control groups were above chance level in all conditions, indicating that the children understood the task.

The Group effect was overall significant [$F(2, 33) = 10{,}58; p < .0003$], showing lower performance in the Autistic group compared with the VMA group ($p < .0008$) and the NVMA group ($p < .0002$) (see Fig. 1). Further analyses revealed that this lower performance of children with autism was found in all the

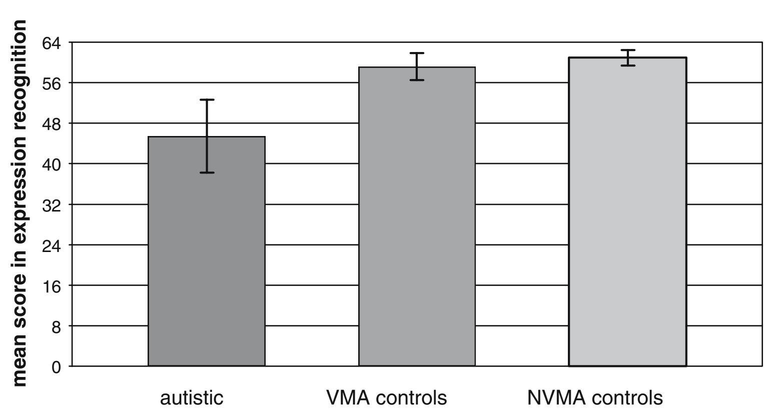

Fig. 1 Mean score (and standard deviations) in facial expression recognition tasks for the three groups of children: autistic, VMA (verbal mental age) controls, NVMA (non-verbal mental age) controls

conditions of presentation (all ps < .01). Conversely, no significant difference was found between the two control groups (p = .63).

The Facial Expression effect was overall not significant [$F(1, 33) = 0.31$; $p = .58$].

However, the Group by Facial Expression interaction was significant [$F(2, 33) = 10.53$; $p < .0003$]. Further analysis of this interaction revealed that the Facial Expression effect was significant in the Autistic group only, with higher performance in Non-emotion than in Emotion [$F(1, 11) = 16.09$; $p < .0003$].

The Sound condition effect was significant [$F(1, 33) = 8.62$; $p < .006$]. Further analysis revealed that this effect was significant in the Autistic group only, with higher performance in Sounded than in Silent condition [$F(1, 11) = 10.43$; $p < .008$], and a planned comparison revealed that Sound effect was significant only in the Static condition [$F(1, 33) = 19.37$; $p < .0001$].

Overall, the Visual condition effect was not significant [$F(3, 99) = 1.32$; $p = .27$].

The Group by Visual Condition interaction was not significant [$F(6, 99) = 1.13$; $p = .35$]. However, since we made the hypothesis that slow presentation of facial expression would increase facial expression recognition in children with autism, we made planned comparisons using polynomial contrast analysis which revealed that, in the Autistic group, performance was significantly better in Slow condition (mean = 12.17 ; SD = 3.46) than in Static (mean = 11.08; SD = 4.25), Very Slow (mean = 11.08 ; SD = 3.53) and Normal conditions (mean = 11.08; SD = 4.29), with all ps < .02 (see Fig. 2).

Thus, the Slow-condition was inducing the best performance in facial expression recognition in children with autism. Further planned comparisons in the Autistic group revealed that emotional facial expression recognition was better in Slow than in Normal condition of presentation [$F(1, 33) = 6.88$; $p < .01$], and that non-emotional facial expression recognition was better in Slow than in Static condition [$F(1, 33) = 4.23$; $p < .04$].

An exact one-tailed Fisher test was also performed in order to identify, among the Autistic group, which children benefited from the Slow and/or the Very Slow conditions of presentation. Result of Fisher test is significant (one tailed exact Fisher, $p = .026$), showing that children with moderate-to-severe autism (i.e., with CARS > or =35) have better performance in facial expression recognition when facial expressions are displayed slowly and/or very slowly.

Finally, in the Autistic group, there is a correlation between overall performance in facial expression recognition and mildness of autism measured with CARS ($r = .77$; $p < .004$).

Results in Facial–Vocal Imitation

The Group effect was overall significant [$F(2, 33) = 9.4$; $p < .0006$], showing that the Autistic group had more facial–vocal imitation than the VMA group [$F(1, 33) = 12.8$; $p < .001$] and the NVMA group [$F(1, 33) = 15.3$; $p < .0004$] (see Fig. 3). Conversely, no significant difference was found between the two control groups (p = .74).

The Group by Sound condition interaction was significant [$F(2, 33) = 12.97$; $p < .00007$]. Further analysis of this interaction revealed that the Sound effect was significant in the Autistic group only, with higher amount of imitation in Sounded than in Silent condition [$F(1, 33) = 38.08$; $p < .000001$].

The Group by Facial expression by Visual condition interaction was significant [$F(6, 99) = 3.14$; $p < .007$],

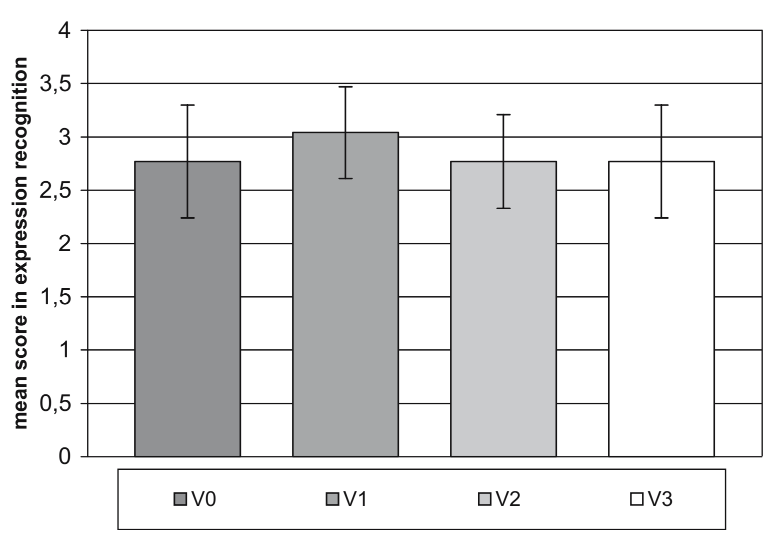

Fig. 2 Mean score (and standard deviations) in facial expression recognition tasks for the autistic children in the four visual conditions (V0 = 'static'; V1 = 'slow'; V2 = 'very slow'; V3 = 'normal speed')

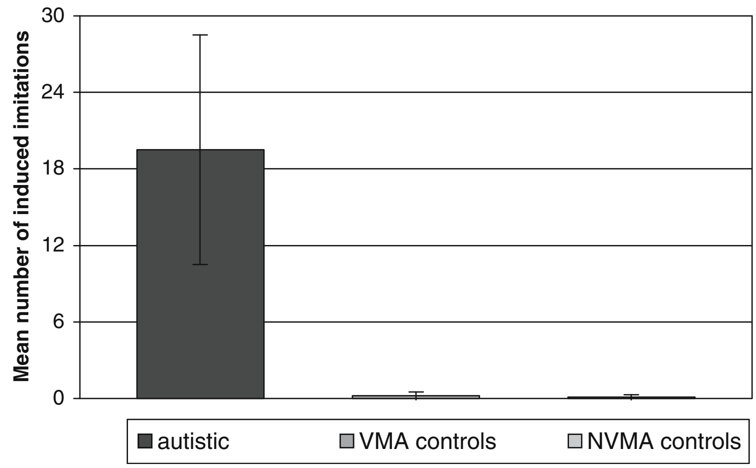

Fig. 3 Mean number (and Standard deviations) of induced facial–vocal imitations for the three groups of children: autistic, VMA (verbal mental age) controls, NVMA (non-verbal mental age) controls

and further analysis showed that it was significant in the Autistic group only. Indeed, further planned comparisons revealed that in children with autism facial–vocal imitation of Non-emotional facial expressions was significantly more induced when presented Very slowly than when presented Statically, Slowly or at Normal speed ($F(1, 33) = 4.92$; $p < .03$; $F(1,33) = 9.44$; $p < .004$; and $F(1, 33) = 3.98$; $p < .05$, respectively). Moreover, in children with autism, facial–vocal imitation of Emotional facial expressions was significantly more induced when they were presented Slowly than when presented Very slowly ($F(1, 33) = 5.77$; $p < .02$).

Conversely, no difference was observed between the two control groups in any Visual or Sound condition of presentation.

Finally, no correlation was observed in the Autistic group between severity of autism (measured with CARS) and amount of facial–vocal imitation.

Discussion

Summary of Results

Results of our study are as follows: (i) children with autism perform significantly worse than their typically developing matched control children in emotional and non-emotional facial expression recognition tasks, in all the sound or visual conditions of presentation; (ii) performance of children with autism in facial expression recognition is correlated to mildness of autism (the less affected autistic children having the highest scores); (iii) children with autism perform significantly better in non-emotional than in emotional recognition taks; (iv) in the autistic group, the best performance in facial expression recognition is elicited in the slow condition of presentation, and within this group, children with moderate-to-severe autism perform significantly better in the slow and/or very slow conditions of presentation; (v) static facial expressions are significantly more recognized when slow vocal sounds are added; (vi) children with autism also exhibit significantly more induced facial and/or vocal imitation than their typically developing control children; (vii) in children with autism, induced facial–vocal imitation is significantly enhanced when facial expressions are sounded, and when sounds are slowed or very slowed down.

Facial Expression Recognition

Correlation Between Performance in Recognition and Severity of Autism

Performance of children with autism in facial expression recognition is correlated to the mildness of their autistic syndrome, that is, while children with mild autism perform like their half-aged control children, children with moderate-to-severe autism show lower performance than their controls. Thus our results confirm the existence of a correlation between severity of autistic disorder and the degree of their visual-motion processing impairment, as already found in two previous studies on other physical and biological movements processing in autism (Gepner & Mestre, 2002a and Blake, Turner, Smoski, Pozdol, & Stone, 2003, respectively). Moreover, the same children having moderate-to-severe autism are also those whose performance in facial recognition tasks is significantly improved by slow and/or very slow presentation of facial expressions. Our study also strongly suggests that the most severely impaired children with autism would probably benefit the most from a slowed down environment (see below).

Emotion vs. Non-Emotion, Configural vs. Local: A New Approach

Our results confirm previous data showing that compared to control children of the same developmental age, children with autism have a deficit in facial expression recognition, not only in the emotional domain (Celani et al., 1999; Hobson, 1986a, b, 1988a) but also to a less extent in the non-emotional one (Gepner et al., 1996, 2001). Thus, our study shows that children with autism do not show specific impairments in emotional facial expression recognition, since their performance in non-emotional facial expression recognition is also significantly poorer than that of VMA and NVMA control children. The present study is not the only one showing an absence of specificity of emotional processing impairment in the autistic population (e.g., Davies et al., 1994). However, in the present study autistic children have significantly more difficulty to recognize an emotional than a non-emotional facial expression. Why?

Our interpretation is based on the processing of configural information and quantity of facial movements. On the one hand, it is known that facial motion of several facial features, even in the absence of information about the shape and position of these facial features, is informative about facial emotions (Bassili, 1979). It is also of evidence that emotional facial gestures involve movements of several facial areas (lips, cheeks, eyes and forehead), as well as changes in spatial relationships between them, i.e., changes of facial configuration. Conversely, a non-emotional facial gesture involves mainly movements of the lips, and thus a local change. It is also known that informations both on movement and on global and configural forms are conveyed by the visual magnocellular pathways, whilst informations on details of form and texture (i.e., local informations) are conveyed by the parvocellular pathways (Livingstone & Hubel, 1988). On the other hand, although there is a debate on the degree to which subjects with autism show a local processing precedence of objects or faces, at the expense or not of global processing, (see e.g., Deruelle, Rondan, Gepner, & Fagot, 2006; Mottron, Burack, Iarocci, Belleville, & Enns, 2003; Plaisted, Swettenham, & Rees, 1999; Rinehart, Bradshaw, Moss, Brereton, & Toge, 2000; Teunisse & de Gelder, 2003), numerous studies have shown however that autistic subjects perform generally better in local and analytic processing of objects and faces than in holistic and configural one (see e.g., Gepner et al., 1996; Shah & Frith, 1993; see also Happé, 1999 and Dawson, Webb, & Mc Partland, 2005 for reviews), leading to the so-called *central coherence deficiency* theory of autism (Frith, 1989; Happé, 1999). Besides, some autistic children present rapid visual-motion processing disorders (see "Introduction" section).

Considering all these facts, it is therefore not surprising that children with autism perform worse in facial recognition tasks involving configural changes and/or a large quantity of rapid facial movements than in those involving local changes and/or a small quantity of facial movements. This explanation may be a solution to the old debate on the specificity or absence of specificity of facial emotional processing in autism.

Finally, it appears that the slow dynamic presentation of facial expressions used in the present study, which is intermediary between a non-ecological static presentation of faces and the rapid changes of moving faces in ordinary everyday life, increases emotional and non-emotional facial expression recognition in children with autism. The slow dynamic presentation, *via* slow and discrete changes of facial configuration, is likely to enhance configural processing at the expense of analytic one in the autistic children, and therefore inverts the frequently observed precedence of local-analytic processing on configural-global one in autistic population. This interpretation may bring new ideas for reeducating facial processing disorders in autistic population (see below).

Interest of Slow Facial Motion

Indeed, our results clearly confirm and extend our previous results (Gepner et al., 2001), insofar as a slow dynamic presentation of emotional and non-emotional facial expressions has a positive impact on the attention to, as well as on the perception and recognition of these facial expressions by children with autism, and particularly those having moderate-to-severe autism (who generally have rather poor visual attention to objects and/or persons in their everyday life). The slow presentation enhances the ability of these children to perceive various facial expressions and recognize them on photographs, or at least to match the slow dynamic presentation of a facial expression with its photographic counterpart, i.e., *in fine*, to extract a relevant facial information from a slow dynamic presentation of facial gestures. It should be noted that, according to the emotional or non-emotional nature of the facial expression, and according to the children, the slow presentation elicits sometimes more facial expression recognition than the very slow presentation, sometimes it is the opposite; in other terms each autistic child has his own individual pattern of perceptual and cognitive reactivity to the *speed* of facial motion.

Indeed, the slow presentation elicits the best performance in the whole group of children with autism, i.e., their performance is overall better in slow presentation than in static, very slow and normal speed presentations. This result gives strength to the already suggested idea (Gepner et al., 2001) that a slow presentation of facial movements offers an optimal psychophysical condition to some autistic children for extracting a relevant information from environmental sensory flows, i.e., environmental noise. This optimal slow condition of facial expressions presentation is likely to be intermediary between static pictures of faces (which appeal for a local processing, see above) and rapidly moving faces in the everyday life, that often provokes overarousal and gaze or face aversion in children with autism (Kanner, 1943; see reports of Grandin, 1995; Williams, 1992; see also Hutt, Hutt, Lee, & Ounsted, 1964; Hutt & Ounsted, 1966).

The slow and/or very slow presentations of facial expressions, i.e., the naturally and/or artificially slowed down presentations, enhance the performance of the most affected autistic children. It was previously reported that children having low-functioning autism are significantly more impaired than high-functioning autistic or Asperger syndrome children in visuo-postural integration of rapid environmental movements (Gepner & Mestre, 2002a). The present result shows that, whereas mild autistic children, who also have the highest verbal comprehension level, are not affected by the speed of facial movements, children having moderate-to-severe autism and a lower verbal comprehension are significantly and positively influenced by slow and/or very slow facial motion for recognizing emotional and non-emotional facial expressions. Therefore, it appears that the most impaired autistic children may benefit the most from a slow environment.

Interest of Adding Slow Vocal Sounds

Adding vocal sounds to facial expressions has a facilitating effect on overall performance in facial expression recognition of children with autism, and this effect is observed mainly in the static presentation of facial expressions, in which sound is displayed slowly (see ‘‘Materials’’ section). Recognition of photographs of emotional as well as of non-emotional facial expressions is enhanced when a slow vocal sound is added. Whilst matching faces and voices having an emotional content has been shown to be difficult in the autistic population (Hobson, Ouston, & Lee, 1988b; Loveland et al., 1995), our result shows that this difficulty may at least be attenuated by using slow vocal sounds.

More generally, and although visuo-auditory integration has not been often studied in autism, several electrophysiological and behavioral studies have shown however that at least some autistic children have difficulties to associate events coming from two different sensory modalities (e.g., association of simple ‘bip’ sounds with lights in Martineau et al., 1992; association of lip movements with simple phonems in de Gelder et al., 1991, Gepner et al., 1996; Williams, Massaro, Peel, Bosseler, & Suddendorf, 2004a; see Waterhouse, Fein, & Modahl, 1996, for a review). Once again, the present study shows that this defect of visuo-auditory association in autism may be attenuated when auditory stimuli are displayed slowly.

It is possible that adding sound did not significantly impact recognition of dynamic facial expressions because the facial cues per se were informative enough for autistic children to identify the various facial gestures on photograph. It remains that, despite the use of slow and very slow combinations of facial and vocal cues, visuo-auditory association (integration of facial and vocal stimuli) remains poor in the autistic children of this study as compared to typically developing control children.

Anyhow, these two findings, i.e., interest of slow facial motion and interest of adding slow vocal sounds for enhancing facial expression recognition, are a direct confirmation of the rapid visual-motion integration deficit hypothesis and of the temporal processing disorder hypothesis of autism (Gepner & Mestre, 2002b; Gepner & Massion (directed by), 2002; Gepner et al., 2005). The visual and auditory environmental events are most probably going too fast for at least some children with autism to be correctly perceived separately and integrated together into a coherent whole. It appears in the present study that slowing down (naturally or artificially) these sensory events enhances the ability of children with autism, particularly the most affected ones, to extract relevant facial and vocal informations from slow dynamic visual–vocal presentations of emotional and non-emotional facial expressions, and also possibly enhances a higher order recognition of these expressions.

Another positive effect of a slowing down process of verbal flow on the cognitive abilities of children suffering LLI was already demonstrated by Tallal et al. (1996) insofar as slowing down speech sounds’ flow improves their verbal comprehension and reading abilities. These results have been widely confirmed in the past 10 years (see e.g., Habib et al., 1999; Habib, 2006, for a systematic review). These results therefore confirmed a temporal processing deficit approach of LLI (but see also Ramus et al., 2003 for phonetic and motor interpretations). A possible common physiopathogenic basis (i.e., a rapid temporal processing disorder) for ASD and LLI has been suspected previously in the visual-motion domain (Gepner & Mestre, 2002b).

Induced Imitation

Our results also clearly confirm and extend previous observations made by Gepner et al. (2001) in that induced facial and/or vocal imitation of facial expressions is observed much more frequently in children with autism than in their typically developing control children (in which it is nearly non-existent), and that slowing down facial movements and their corresponding vocal sounds, whether naturally ('slow condition') or artificially ('very slow condition'), elicits significantly more facial and/or vocal imitation in the autistic group than normal speed or static presentations. Again, it should be noted that, according to the emotional or non-emotional nature of the facial expression, and according to the children, the slow presentation sometimes induces more imitation than the very slow presentation, sometimes it is the opposite; in other terms each autistic child has his own individual pattern of reactivity to the *speed* of facial motion and sound flow. It must also be added that the mimetic reactions of children with autism were not necessarily predictive of a correct answer in facial expression recognition tasks.

This induced imitation of facial expression is a spontaneous reflex-like behavior, and we assume that it could be related to spontaneous imitative behaviors observed in neonates. Neonatal imitation was first observed by Zazzo (1957) and confirmed by Meltzoff and Moore (Meltzoff & Moore, 1977, 1993, Meltzoff, 1996). This very early (innate) imitation decreases around 6 months of age and is progressively replaced by voluntary and intentional imitation (Nadel, 1989), but obviously remains as traces in typically developing children and normal adults. Interestingly, a direct link between motion and neonatal imitation has been demonstrated in that imitation is elicited only when stimuli are dynamic (Vinter, 1986). Yet, whereas typically developing children of the present study exhibited very few induced imitation, induced facial–vocal imitation was strongly elicited in children with autism and particularly when facial and vocal stimuli were slowed down.

The exact significance and consequences of this induced facial and vocal imitation are uncertain: it could at least be considered as echopraxia and echolalia, that have been shown themselves to be not necessarily meaningless symptoms due to executive dysfunction (e.g., Hughes, Russell, & Robbins, 1994), but also a mean and attempt used by children with autism to communicate (Nadel, 1992, 2005). Anyhow, the slow presentation of facial–vocal expressions seem to be a powerful facial–vocal imitation *inducer* in at least some children with autism.

Imitation of action, whether having or not an emotional content, be that induced reflexically or intentional, has been regularly shown to be deviant and/or delayed in individuals with autism since more than 30 years (see Smith & Bryson, 1994; Williams, Whiten, & Singh, 2004b, for reviews on the topic), very early in their development (Rogers, Hepburn, Stackhouse, & Wehner, 2003; Sauvage, 1988; Zwaigenbaum et al., 2005), and particularly in the domain of facial expressions' imitation (e.g., Hertzig, Snow, & Sherman, 1989; Loveland et al., 1994). Our results showing that facial–vocal imitation is enhanced when facial–vocal stimuli are slowed down, are compatible with the existence of a link between rapid biological motion processing disorders and deficits of imitation in autism, via *mis-developmental cascades* in which a deficit of perception–action coupling would play a major role (Gepner, 2001, 2005; Gepner & Mestre, 2002a, 2002b; Gepner et al., 2005). From a neurobiological point of view, imitation in humans is also currently related to the functioning of the mirror neuron system (MNS) (Grèzes & de Gelder, 2005 for a review), which has been found to be impaired in some individuals with ASD (see e.g., Oberman et al., 2005; Theoret et al., 2005). The question as to know whether the *facial–vocal imitation induction* observed in the present study would be correlated to activation of MNS is open, and should be further explored.

Neurobiological Bases

It was previously hypothesized that the various deficits affecting the processing of visual-motion and vocal sounds may be related to a common basic disorder in the *temporal processing* of multisensory events. As already said, according to this hypothesis subjects with autism present more or less disabilities to perceive the environmental world's multisensory events online, proceed to real-time multisensory integration and sensorymotor coupling, and produce postural adjustments and adequate verbal and non-verbal events (Gepner & Massion (directed by), 2002); Gepner & Mestre, 2002a, 2002b; Gepner et al., 2005).

Local and Distant Dyssynchrony in Autism

At the neurofunctional level, we already proposed that this anomaly of temporal processing may be related to a deficit in *temporal coding* of multisensory inputs and motor outputs and in sensorymotor *temporal coupling*, in which cerebellum would play a crucial role (Doya, 2000; Ito, 1984; Johnson & Ebner, 2000; Middleton & Strick, 2000).

This view is also compatible with the *temporal binding deficit hypothesis* of autism (Brock, Brown, Boucher, & Rippon, 2002) according which autistic individuals would suffer a deficit in synchronization of high frequency (30–100 Hz) gamma activity between distant neural networks. More precisely, and according to Welsh, Ahn and Placantonakis (2005), disturbances in inferior olive structure (and consequently in olivo-cerebellar pathways) found in autism (Bailey et al., 1998; Kemper & Bauman, 1993) would disrupt the ability of inferior olive neurons to become electrically synchronized and to generate coherent rythmic output, thus impairing the ability of individuals with autism to process rapid information, and therefore slowing their overall cognitive processing speed. Fitting well with this assumption, adults with Asperger's syndrome show a delayed cortical activation from occipital cortex to superior temporal sulcus, inferior parietal lobe and inferior frontal lobe, when imitating still pictures of lip forms (Nishitani, Avikainen, & Hari, 2004). Following Welsh et al. (2005), and according to numerous data on neural synchrony in animal and human brain (Varela, Lachaux, Rodriguez, & Martinerie, 2001, for a review), rapid sensory information (rapid sensory flows) would arrive too quickly to be processed online by the autistic brain, thus disrupting simultaneous firing (synchronization) of neurons of a same assembly, and information processing would consequently be disorganized, desynchronized and slowed down. Abnormal temporal synchronization of local neural networks within each sensory modalities would in turn produce a deficit of temporal binding-coupling between multiple sensory modalities.

In a recent study, however, and contrary to their own theoretical prediction (Brock et al., 2002), individuals with autism showed an overall *increased* gamma-activity whilst identifying the presence or absence of an illusory Kanizsa shape (Brown, Gruber, Boucher, Rippon, & Brock, 2005).

We therefore propose that, according to the type of stimuli they are exposed to, individuals with autism suffer either neural desynchronization (e.g., for rapidly moving or changing sensory stimuli) or neural hyper- or oversynchronization (e.g., for local or static sensory stimuli), that would be both responsible for impaired and peculiar attentional, perceptive and/or cognitive acts in these patients (as also suggested by Spencer et al., 2004 for schizophrenic patients). Besides, hypersynchronization may appear during autistic development as a neuropsychological mechanism aimed at compensating a previous desynchronization but which would go 'beyond its target'. In particular, a hypersynchronization phenomenon within and between local neural networks, which is the mechanism of partial and general epilepsy (see also Percha, Dzakpasu, Zochowski, & Parent, 2005 for a neuromimetic model of generalization of epilepsy), would fit well with the very frequent association between autism and clinical and/or infraclinical epilepsy (see e.g., Hughes & Melyn, 2005).

For our purpose, in some individuals with autism, a local neural desynchronization within visual and auditory pathways, respectively, would occur during everyday life facial motion and vocal sound processing, resulting in difficulties to extract a relevant information from these relatively rapid sensory flows, and would generate a distant neural desynchronization between these sensory pathways, resulting in difficulties to associate these rapid visual and auditory cues into a coherent, unified and meaningful pattern.

In the general context of visual and auditory processing, a *temporal dyssynchrony* (hypo- and/or hyper-synchronization) within and/or between key neural networks and pathways, including especially visual magnocellular system (Gepner & Mestre, 2002a, b; Deruelle et al., 2004), dorsal stream (Pellicano, Gibson, Maybery, Durkin, & Badcock, 2005; Spencer et al., 2000; Villalobos, Mizuno, Dahl, Kemmotsu, 2005), cerebellum (Courchesne, 1997; Courchesne et al., 1994), mirror neurons system (Oberman et al., 2005; Theoret et al., 2005), and superior temporal sulcus (Castelli, Frith, Happé, & Frith, 2002; Gervais et al., 2004), i.e., a *multi-system temporal dyssynchrony*, may be a crucial neuropsychological mechanism of ASD, responsible for various attentional, perceptive, sensorymotor, communicative and cognitive impairments in this pathology.

Besides, a rapidly growing body of data coming from (i) animal and human physiology (Varela et al., 2001, for a review), (ii) human psychophysiopathology (see Babiloni et al., 2004 for epilepsy; Symond, Harris, Gordon, & Williams, 2005 for schizophrenia; Just, Cherkassky, Keller, & Minshew, 2004 for autism) and (iii) neuromimetic models (Borgers & Kopell, 2003; Breakspear, 2004), has evidenced the links, i.e., correlation, functional interdependence and equivalence, between neural synchronization, brain rythmicity and functional connectivity (which constitutes a spatial correlation and coactivation between brain areas): synchrony is the mechanism of temporal connectivity. More precisely, and relevant for our purpose, the speed of synchronization depends on the dynamical and network parameters, and is most probably limited by the network connectivity (Timme, Wolf, & Geisel, 2004).

Dysconnectivity in Autism

The spatial counterpart of this *multisystem temporal dyssynchrony* is therefore a *functional dysconnectivity* (hypo- and/or hyper-connectivity, as suggested by Cohen, 1994) within/between multiple neurofunctional networks. Anatomic or functional under- and/or over-connectivity have already been suspected (Brock et al., 2002; Courchesne & Pierce, 2005) and found (Belmonte et al., 2004; Just et al; 2004) in the brain of individuals with autism. This dysconnectivity may partly be due to mutations of the X-linked genes encoding neuroligins NLGN3 and NLGN4, which are normally responsible for cell-adhesion and synaptogenesis (Jamain et al., 2003).

As far as facial processing is concerned, recent neuroimaging studies have revealed several candidates as possible neurofunctional markers of facial processing impairments in autism. Evidence appeared that individuals with autism have reduced functional activity in the middle lateral fusiform gyrus when viewing faces, be it associated to decoding of facial emotions or not (Critchley et al., 2000; Schultz et al., 2000; Pierce, Muller, Ambrose, Allen, & Courchesne, 2001). Dalton et al. (2005) found that hypoactivation of the fusiform gyrus is observed only when individuals with autism fail to fixate the eye region. Another study showed reduced amygdala activity in response to faces (e.g., Baron-Cohen et al., 2000). However, several authors have raised the question that activation of fusiform gyrus and amygdala in subjects with ASD differ from normality (e.g., Hadjikhani et al., 2004) and concluded that it is merely the modulation of activity (Pierce, Haist, Sedaghat, & Courchesne, 2004) or the connectivity (Wickelgren, 2005; Wicker et al., submitted) between regions of the so-called 'social brain' (including fusiform gyrus, superior temporal sulcus, amygdala), rather than a specific region, that is impaired in autism.

Applications and Perspectives

When considering results of the present study with such a temporospatial approach of autistic disorders, i.e., *E-Motion mis-sight and other temporospatial processing disorders*, and *multisystem dyssynchrony and functional dysconnectivity*, it could be proposed that slowing down facial movements and their corresponding vocal sounds increases time for signal processing and therefore facilitates neural synchronization and connectivity within as well as between visual and auditory pathways. Slowing down may act on temporospatial processing like a *synchronizating* factor thus reinforcing perceptual and cognitive integration. This assumption should however be tested in further studies using electroencephalography.

Overall, our results show that slowing down facial and vocal cues facilitates autistic children's attention to, as well as perception, recognition and induced imitation of facial–vocal emotional and non-emotional expressions. The crucial question of a correlative or consecutive improvement of affect and verbal comprehension in children with autism is open, and should also be addressed in the future.

On the basis of these present and previous results, our group created an original software aimed at slowing down *automatically* and *simultaneously* visual and auditory cues of the environment. This software may have at least two possible applications in the future, for diagnosis and reeducation of children with ASD. First, new instruments of assessment may be built using this software aimed at detecting or confirming early signs of autism in babies and young children. That is, in babies suspected of autism, one could test their attention to facial and vocal stimuli displayed by their care-takers, at either normal or slowed down speed. Secondly, we are currently testing this software on induced and voluntary imitation of facial and body movements, and on verbal comprehension of words and sentences, in children and adolescents with ASD. Positive results of these tests would have direct consequences for the reeducation of verbal and emotional communication impairments in children with ASD. Such findings should indeed lead clinicians and care-takers to slow down the environmental world around autistic children, as soon as possible during their development, *via* natural/ecological means (e.g., by speaking and moving slowly) and artificial ones (e.g., by using this software).

Acknowledgments We wish to thank very sincerely all the parents who accepted the participation of their children in this study. We also thank all the children who participated in this study and hope that the results obtained will contribute to their rehabilitation in the future. We are grateful to David Béchu, Damien Penalba and Pierrick Leborgne, from the SCAM (Service Commun Audio-visuel et Multimédia, University of Provence), for their valuable technical assistance in the realization of facial and vocal stimuli.

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