On the annotation of gestures in multimodal autistic behaviour

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Abstract

Autistic people seldom use verbal speech to communicate. Thus, it is important to try to understand signs of communication that may appear in their multimodal behaviour, which encompasses speech, gesture, gaze, facial expression etc. In this paper, we review some of the literature on autistic non-verbal behaviour. We describe our methodology and the architecture of a system we have developed for the analysis of autistic multimodal behaviour observed in videos of speech therapy sessions. We explain the coding scheme that we have conceived and illustrate it on some selected gestures and non-verbal behaviours. We consider some of the coding schemes for gestures and explain their limitations for the annotation of autistic gestures. We conclude on the current benefits versus limitations of our approach and prospects such as a project for the design of accessible educational software.

1 Multimodal behavior of autistic people

1.1 Definitions of autism

Autism is defined as a pervasive developmental disorder by international reference documents, namely the Diagnostic and Statistical Manual Fourth Edition (DSM-IV, 1994) published by the American Psychiatric Association and the World Health Organisation's International Classification of Diseases Tenth Version (ICD-10, 1992). These documents contain precise criteria used for diagnostic and research purposes. Regarding autism, all the criteria rely on the observation of behaviour. Three main categories of impairments are mentioned in the DSM-IV: qualitative impairments in social interaction; qualitative impairments in communication ; restricted, repetitive, and stereotyped patterns of behaviour, interests and activities. Moreover, development delays or abnormalities can be observed in language used to communicate and symbolic or imaginative play. Both verbal and non-verbal means to communicate are altered. Spoken language does not always develop. When it does, it might not convey reciprocal exchange. Instead, words or sentences are often repeated as an echo. Verbal repetitions of this sort are called echolalies. Yet, despite these general considerations about autism, communicative abilities and behavioural particularities differ enormously from one individual to another.

1.2 Clinical issues regarding behaviour of persons with autism

1.2.1 Diagnosis

From a clinical viewpoint, the behaviour analysis of persons with autism has two major outcomes: diagnosis of autism and assessment for treatment. Autism being defined as a syndrome based on behavioural observations, it is diagnosed through behavioural examinations. There are several means to perform a diagnosis, which are usually combined in order to secure the validity of the result: questionnaires about the development of their child are submitted to the parents, checklists and schedules are completed by a specialist while the child performs series of tests, family members may also be interviewed. For the last 25 years, there have been a large number of diagnostic tools developed (Trevarthen et al, 1996) as for example the CARS (Childhood Autism Rating Scale), BOS (Behaviour Observation Scale for Autism), ADI (Autism Diagnostic Interview) or ADOS (Autism Diagnostic Observation Schedule).

1.2.2 Assessment for treatment

Once autism has been diagnosed, behaviour analysis is still needed to decide what treatment to administer. Again parents have to fill in questionnaires and checklists but for a different reason. As described by (Howlin, 1998), the goal is to link a particular communication act with a particular behavioural expression. During an interview, parents are asked what happens when their child is in a given situation. The interviewer derives from their answer what type of behaviour corresponds to the communication act assumed to be encouraged by the described scene. For instance, the verbal or non-verbal response of the child when given food that she doesn't like might correspond to a refusal communication act. Thus, functions are attached to apparently "odd" movements which used to puzzle or annoy the family and carers. Also proper remedial treatment may be sought that would help the autistic person to display more acceptable reactions.

Behaviour assessment is the starting point of one of today's most widespread treatment programmes for autism: the TEACCH programme. Indeed, a person enrolled in this programme is regularly evaluated with a protocol called the PEP-R (Psychoeducational profile revised) which was conceived by Eric Schopler (Schopler et al. 1990). It is designed to test imitation, perception, precise and global motor functions, eye-hand co-ordination, cognitive and verbal performance as well as some typical autistic behaviours. This profile serves as an assessment tool to plan the treatment programme.

1.3 General descriptions of non-verbal behaviour of autistic people

Non-verbal communication of autistic people is usually mentioned as being altered both on the receptive side and on the expressive side (Rogé, 1994). On the receptive side, autistic people have difficulties in discriminating facial expressions and in understanding communicative gestures. On the expressive side, there are qualitative and quantitative problems. The number of facial expressions is limited and they may be misused. Visual contact is often avoided, more so if the gaze of the interlocutor holds a social response. It is often hard to engage an autistic person in joint attention on an object. Autistic people use less expressive gestures than non-autistic people. They might use a lot of instrumental gestures, which can regulate or modify others' behaviours. They may use pointing gestures but usually to designate a wanted object. Unlike ordinary children, children with autism rarely use pointing gestures to direct someone's attention towards an object for the purpose of sharing experience. Instead they tend to grab someone's hand and use it as a tool to fetch what they need (Frith, 1993). Nevertheless, behaviour varies a lot from one person with autism to another. For instance, some are very skilled at imitating gestures or speech while others barely ever make use of imitation.

Several behaviour types are strongly associated with autism such as stereotypies, persevering movements, tantrums and self-injurious behaviours (Koegel et al., 1994).

They may cause pain and distress to the person as well as to the family or carers. Also they disturb learning and prevent social integration.

The word stereotypy stands for a movement which is repetitive and follows a precise and rigid pattern in a ritualistic manner like flapping hands, tapping or flipping an object over and over again. Stereotypies may appear during leisure time when the person with autism is left alone. According to Theo Peeters (Peeters, 1996), such repetitive movements have very diverse functions. They may be pleasurable, communicative, a reaction to stress, an exploration impulse, used to avoid failure, unpleasant or difficult situations, or to learn about the environment. They may also result from an irrepressible need, insure stability or help to prepare for the next task. Stereotypies usually seem "odd" at first sight. Their functions can only be induced from a careful study of the autistic person. Interpreting a stereotypy is a non-trivial task that requires expertise.

A gesture is persevering when the person cannot stop its execution. For instance, when asked to perform a manipulation, the person with autism would persevere in repeating a response though it is no longer appropriate (Attwood, 2000). The initiation of the movement was voluntary but the person lost control and was unable to inhibit the movement after it became unnecessary. Persevering gestures often disturb the teaching of motor skills as the person with autism focuses on an irrelevant movement. Besides, the feeling of loss of control might produce distress that leads to a tantrum or a self-injurious behaviour.

Although some autistic individuals may use Sign Language (Denni-Krichel 2001), it seems to be exceptional. The first attempts to teach them communicating gestures were based on sign language used by deaf people. However, some signs convey abstract and conceptual meaning that can be hard to grasp for autistic people. Both hands are needed along with good manual coordination. Also, subtle variations in the hand movements may alter the meaning of the sign. For such reasons, the results were not satisfying. Several studies cited in (Howlin, 1998) indicate that children with autism show better performance at acquiring iconic gestures rather than more abstract signs.

A technique called Makaton that combines gesture and pictograms was developed by (Walker & Armfield, 1981). This system uses simplified and concrete signs that require only one hand. It seems quite successful and is used by a growing number of institutions worldwide. There was some fear that communicating by gesture would prevent persons with autism from ever acquiring spoken language, but the opposite seems to be true.

Yet, results are very variable. According to the different experiments quoted in (Howlin, 1998), some children with autism can acquire a large amount of sign combinations while others are merely able to learn one or two. Moreover, children who assimilate communicative signs eventually develop spoken language. Hence there might be a correlation between capacities to integrate language using gesture or using speech. All the more so since the communicative aspects of spoken and sign language used by autistic children have common characteristics: repetitive stereotyped expressions, lack of sharing experiences and emotions, lack of reciprocal communication.

1.4 Experimental studies of multimodal autistic behaviour

Several experimental studies have been made regarding the analysis of autistic multimodal behaviour. In this section, we survey some of them.

The study described in (Watson et al. 2000) examined the emergence of gestures in 9-12 month old infants, via retrospective analysis of home videotapes. One group gathered infants later diagnosed with autism; a second group, infants later diagnosed with other developmental disabilities; and a third group, infants who exhibited typical development into their preschool years. The videotapes were divided into 1-minute intervals for the purpose of rating gestures. A rating scale was developed reflecting both the quantity and diversity of gestures used in each interval, as follows: no clear gestures observed; one gesture used one time; one gesture used more than one time; two or more different gestures, used at least once each. The results of this study suggest that it is not possible to differentiate infants who will be later diagnosed with autism based on quantitative ratings of gesture use. The authors suggest careful examination of the qualitative aspects of emerging gestures at this age, in terms of variables such as type (e.g., contact gestures versus distal gestures), function (behaviour regulation, social interaction, and joint attention), coordination of gesture with vocalizations and gaze, and role of parental behaviour in eliciting gestures.

The phatic function of non-verbal behaviour in rupture situations during interaction between therapists and three autistic children was studied in (Bergé 2001). Verbal and non-verbal behaviour of both the therapist and the children have been transcribed from video-taped sessions. When the autistic child displays avoidance behaviour (e.g. the child hides behind a chair or turns back), the therapist was observed to use the short gaze behaviour displayed by the child to restart the communication. During such sequences, the therapist often displays "manipulator" gestures (e.g. the therapist scratches himself) as it helps him to start communication again. When the therapist does not keep the relational flow (e.g. she is preparing some material for the session), the autistic children was often observed to display stereotypic gestures.

Finally, pragmatic abilities, especially the organisation of discourses were investigated in (Stibi and Amorosa 1998) for 9 children between the ages of 6 and 10 years, 3 each with early infantile autism, specific developmental disorder of receptive language[1] and normally developing children respectively. Their experiment uses a microanalysis of a communicative sequence, which is part of a diagnostic interview (ADOS-G). The purpose includes finding out which verbal and non-verbal means (intonation, eye contact, facial expression, facing the partner and gesturing) children use to initiate and maintain a conversation. For each turn, a decision was made, which of the verbal or non-verbal means was initiative in character. An initiation was defined as a turn that induces a subsequent utterance and secures the conversation continuing for at least one further turn. Preliminary results included: all children were able to take turns in the conversation; only autistic children introduce new topics; autistic children use shorter answers; intonation, eye contact, facing partner, employed to initiate the next turn, increase in rate from the autistic children to the control group ; facial expression and gesturing are used most often by the autistic children but they do not employ them to initiate the next turn ; communicative acts almost exclusively from the autistic children were judged to be "odd" (intonation, facial expression, gesturing). These "odd" interactive means are used successfully to keep up the conversation but they appear artificial. The children with a receptive language disorder resembled the children of the control group in most variables assessed. The autistic children differed in the types of non-verbal means employed and in the quality of these means. The autistic children have means to continue a conversation but they use mainly verbal means, and from the non verbal means only intonation.

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[1] The *receptive language disorder* shows a primary impairment in language comprehension, often accompanied by problems in emotional and social areas.

2 A methodology and architecture for the analysis of multimodal autistic behavior

2.1 Goals of the project

Taking care of people with autism requires a thorough understanding of their behaviour. All modalities have to be considered: gesture, speech, facial expressions, gaze etc. As suggested by (Schreibman, 1994), analysis of particular movements has to be very precise. It enhances the work of therapists on several levels. They rely on it to evaluate the capacities of the person with autism. It helps them to collect knowledge that influences their interpretations of various unusual gestures or vocalisations. Hence, it can give them hints on how to decipher the person's behaviour. Finally, they may use it to assess their treatment and gain awareness about the positive or negative effects it might have.

Some specialists film their therapy sessions to examine the behaviour of a person with autism. Commonly, they perform an analysis by manually writing down observations using a VCR. Several research projects have been done using this technique. For example, (Guillemard-Lagarenne, 1998) annotated videos of a child to demonstrate the communicative content of his stereotypies. For this purpose, she had to devise a coding methodology based on codes and iconic representation. However, these methods turn out to be time consuming. They do not allow detection of subtle movements and precise description of behaviour is complicated. Neither do they provide support for a systematic computation of behavioural statistics. Also, it may prove to be useful to have a tool manage different annotations made for the same video by various persons at various times.

Researchers in computer science are also interested by the study of multimodal behaviour to evaluate different communication possibilities between human and machine (Maybury & Martin, 2002). Software has been developed to assist the annotation of video resources. In the next section, we present a method that aims at using such recent tools for helping analyse the behaviour of persons with autism.

2.2 The proposed method

2.2.1 Model and architecture

Our project's goal is to design a method to annotate and analyse video sequences of work sessions between a therapist and a person with autism. The annotation and analysis processes are achieved using software tools that we have developed or adapted. Various questions arise about the behavior of a person with autism. They lead to different hypotheses. We conceived a coding scheme of multimodal behaviour and statistical metrics to test selected hypotheses. Due to the inter-individual diversity among persons with autism, our transcription system was designed so that it can be customised for each person observed. Thus, rather than trying to grasp general characteristics of autism, we concentrated on case studies. Algorithms were also implemented to compute statistics derived from the resulting annotations. The study was mainly concerned with hypotheses about imitation. Imitation is one of the possible deficits listed in the DSM-IV description of autism. It holds crucial functions in two main domains: learning and communicating (Nadel, 1999). Imitation normally appears at a very early stage of development. Therefore, we chose to analyse and compare imitation performance in several modalities of behaviour. The method is divided into 4 stages: 1) Videotape therapy session of a person with autism, 2) Select relevant video extracts, 3) Visualise and annotate these relevant video extracts, 4) Process the annotation results with programs that calculate statistics.

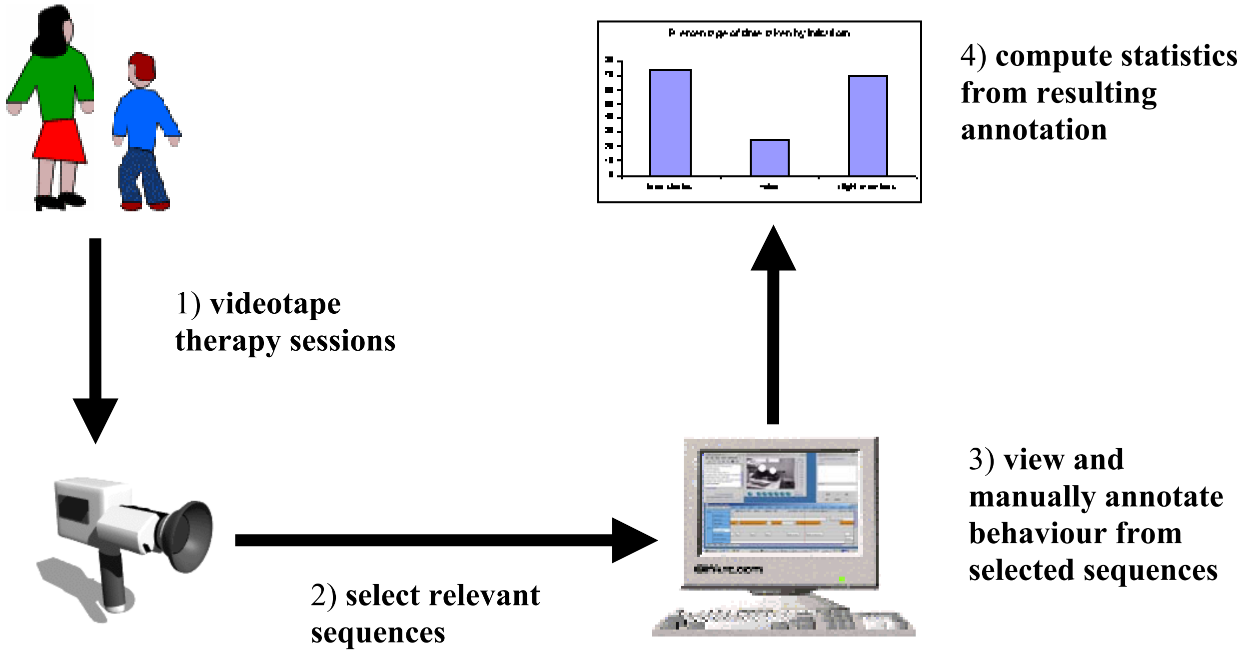

Figure 1: four stages of the method to analyse autistic multimodal behaviour.

This method was applied to five children with autism during speech therapy sessions that occurred over a period of one year. Eight video extracts were selected and annotated. Their total duration was of 147 seconds. Our speech therapist partner provided the video resources. Figure 2 provides three examples of observed gestures (repetitive gesture, deictic gesture and "odd" gesture).

Figure 2: three examples of gestures observed in the video corpus: on the left-hand side, a repetitive gesture (the child is tapping on the wall) ; on the middle, a deictic gesture (imitated from a previous gesture from the speech therapist), on the right-hand side, an "odd" gesture (it was unexpected and its purpose remained unexplained).

To annotate video excerpts, we used a tool called ANVIL (Kipp, 2001). It enables manual coding of observed events on a video window in a practical way. It is configured with an XML file that represents the code scheme used. The output of ANVIL consists of an XML file containing the annotation results, which are processed by statistic calculation programmes that we conceived. Figure 3 describes the whole architecture.

The coding scheme that we devised comprises the following upper body modalities: head motions, gaze, face states, voice, right gestures, left gestures, proximy, posture. Indeed, as the therapist and the children with autism were sitting at a table, only the upper part of the body could be seen. The behaviour of the therapist was annotated as well. Codes are alike for both the person with autism and the therapist. Each modality possesses specific attributes. Behaviours in a given modality are represented by setting the values of these attributes. An extract of the coding scheme in XML is given in Figure 4.

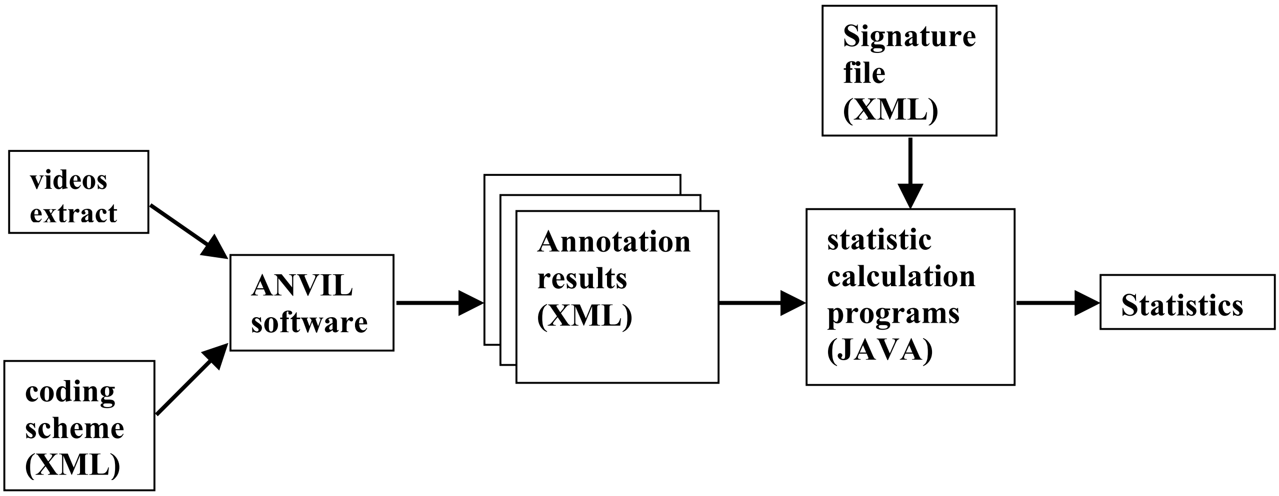

Figure 3: diagram of the overall system architecture.

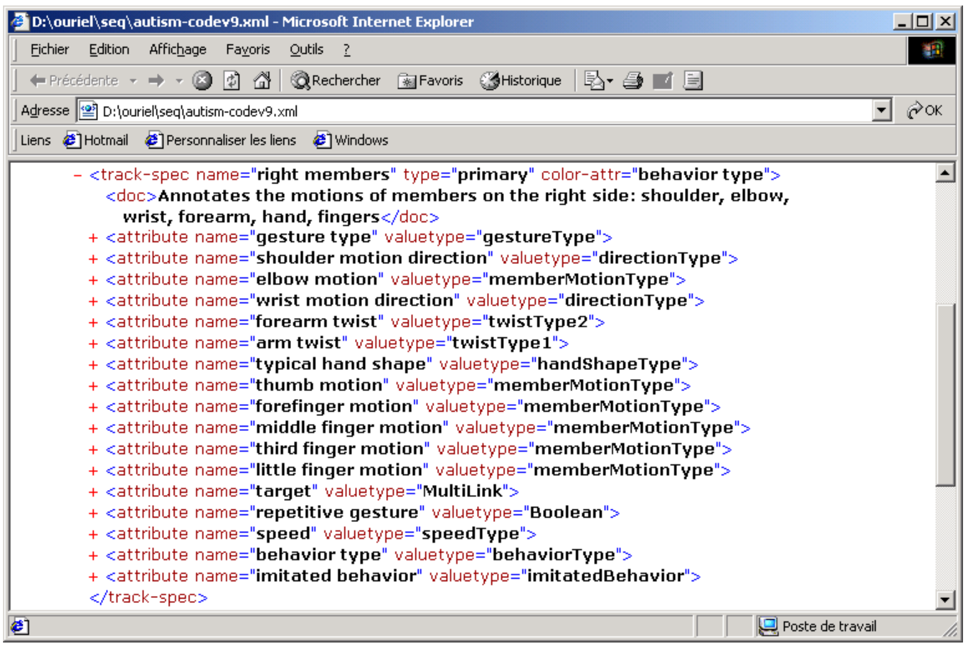

Figure 4: Extract of coding scheme in XML format that displays the attributes used to code the right gestures modality.

As previously said, the transcription system was customized to each individual with autism. Indeed, each child has her own peculiar patterns of behaviour. Moreover, they are most of the time quite unconventional and idiosyncratic, just like in the right-hand picture of figure 2. Thus, every other person with autism has his very own lexicon of gestures. Rather than try to encompass all possible behaviours for people with autism in a single coding scheme, we chose to customize it for each child. When detecting a new movement that seems peculiar to the child, the coder labels it and inserts it in the coding scheme as a new value for an attribute. Initially, the coding scheme contains generic gesture types, some of which can be found in literature (Cosnier, 1982).

To compute statistics on an annotated video sequence, different annotation elements representing the same behaviour have to be grouped together. If the behaviour holds a label, then it is easy: annotation elements are grouped according to their label. Each modality contains a particular attribute that holds behaviour labels. However, quite often, an annotation element does not correspond to a movement with a clear label. Instead, it is characterised by other values of attributes in the modality where it appears. In such cases, the annotation elements are grouped according to a set of attributes considered to be representative of movements in a given modality. For example, if a hand gesture has the label “closed fist”, then it should be grouped with other occurrences of “closed fist”. If it is defined by “raising little finger”, “half raising third finger” when “all other fingers are contacted”, then it may be characterised by the attributes for the finger positions and grouped with other movements that have similar attributes. The coding scheme has been designed to deal with such issues: the annotation elements are either grouped according to their label or according to a given set of attributes. The label and this set of attributes are called signatures for a modality as they “sign” the movement corresponding to an annotation element. Signatures are specified in a separate XML file, which is used to configure the statistic calculation programs.

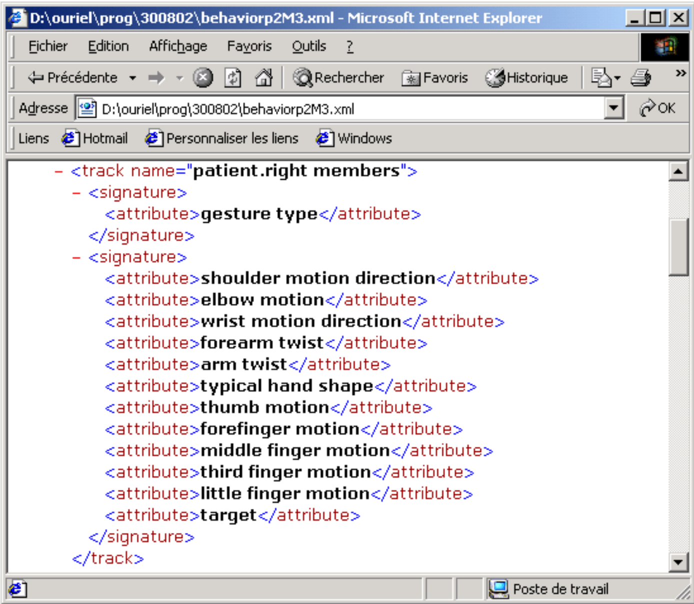

Figure 5: Extract of a signature file in XML. It is used to specify sets of attributes in the right gestures modality that will be used to compare and group gesture annotations: annotations that have the same value for attribute ‘gesture type’ (which is the label) are grouped together; annotations for which this attribute is void are grouped with other gestures holding similar values for selected attributes ‘shoulder motion direction’, ‘elbow motion’, ‘wrist motion direction’ etc.

2.2.2 Application for the study of imitation

Imitation may occur in several modalities: gestures, facial expression, voice etc. To compare imitation performances in the different modalities, we tested the following hypothesis : “imitation of the therapist is more frequent in some modalities than in others”. Two distinct categories of movements have to be taken into account: ‘imitative’ movements, which are produced by the person with autism as a reproduction of a movement from the therapist, and ‘imitated’ movements, which are produced by the therapist and serve as models for imitation by the person with autism. We conceived the following metrics to estimate the hypothesis: ‘list of imitative and imitated behaviours’, ‘percentage of time taken by imitation in each modality for the person with autism’, ‘ratio between the duration of imitative behaviours and imitated behaviours in each modality’. Figure 6 displays an example of the annotation of a video with imitation of the speech therapist by the person with autism.

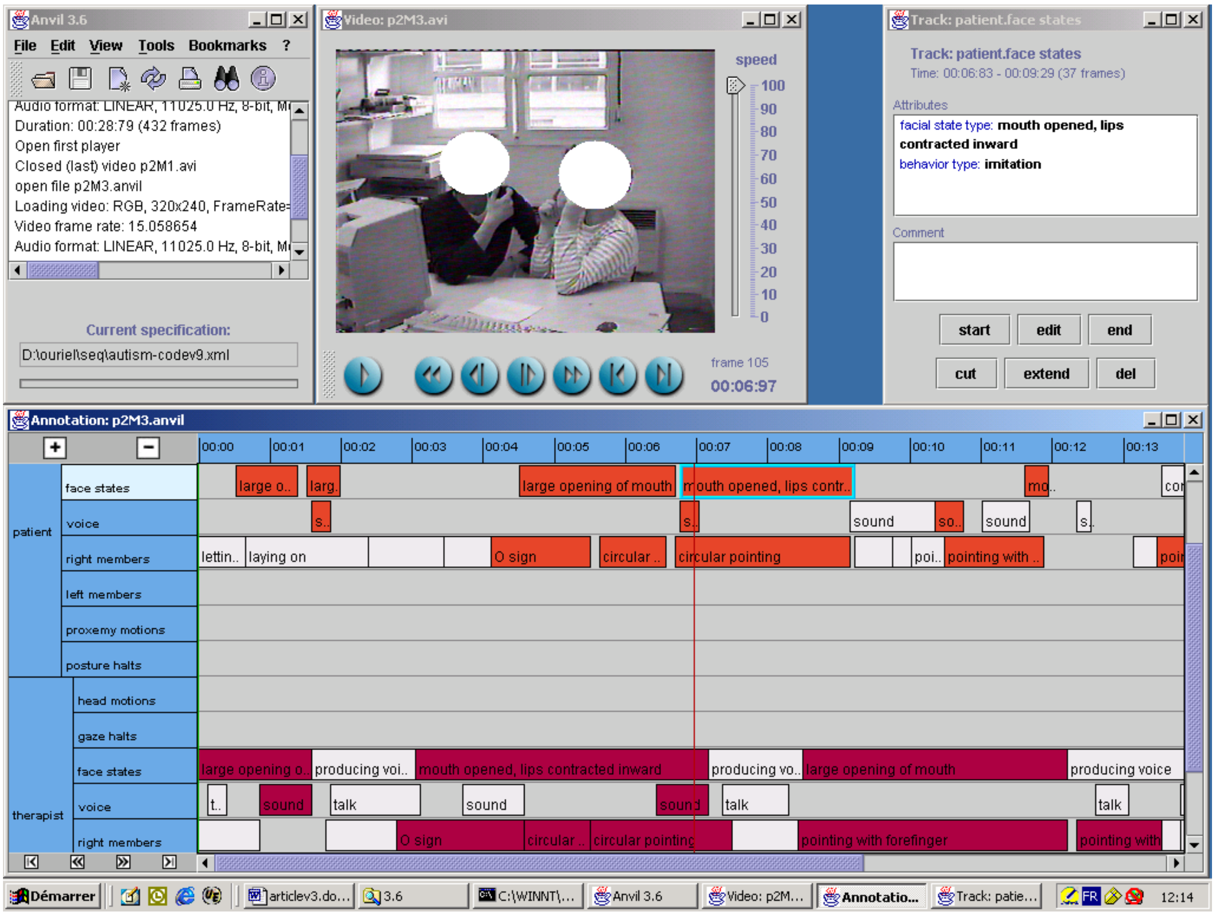

Figure 6: Example of the annotation of a video where a person with autism imitates the speech therapist using the Anvil tool (Kipp, 2001). The upper middle window contains the video that can be controlled with buttons similar to a VCR. The lower window contains the annotation elements that are manually inserted. The column on the left of this window displays the modalities considered. Time is represented by the horizontal axis of this window: each box stands for an annotation element representing a behaviour with a starting and ending time. The dark grey annotation elements on the bottom part of the window represent the imitated movements performed by the therapist. Their reproduction by the person with autism is represented by light grey annotation elements (imitative behaviour).

Viewing the above figure, one may assume that imitation occurs more frequently in the modalities ‘right member gestures’ and ‘facial states’ than in the modality ‘voice’. The calculation of the metric ‘ratio between durations of imitative and imitated behaviours’ helps realise that imitation is more important in the modality ‘right member gestures’ compared to the modalities ‘facial states’ and ‘voice’ (Figure 7). This data provides information to the therapist about which modality is most favourable to imitation.

3 Discussion and future directions

Several classifications and coding schemes have been developed for the annotation of gestures, facial expressions and other non-verbal behaviour at different levels of description (see Wegener Knudsen et al. 2002 for a review). In this section, we briefly review some of them and consider their adequacy (or how part of it is relevant) to the annotation of autistic gestures.

A commonly used classification and coding scheme has been proposed by (McNeill 1992) who described four steps in co-verbal gesture transcription. The first step is identification of movements that are gestures. McNeill considers as gestures all hand, arm, leg, and head movements, except self- and object- “adaptators” (manipulations). Yet, the formers are of importance for the understanding of autistic behaviour.

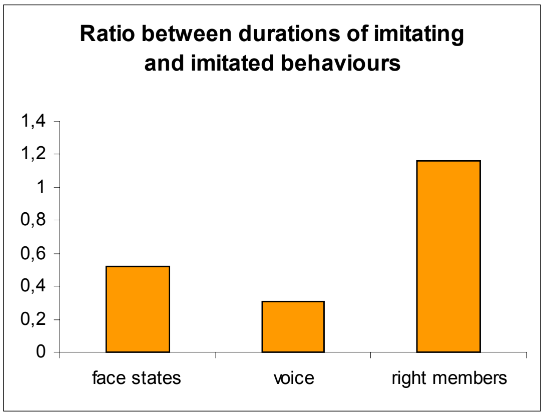

Figure 7: ratio between durations of imitating and imitated behaviours.

The second step is to identify the preparation, stroke, and retraction phases of the gestures (preparation and/or retraction may not occur). Based on Kendon's work a more accurate scheme was developed by (Kita et al. 1998; Wittenburg et al. 2002) to separate various phases in a gesture. A movement unit can consist of several movement phases. Each of these can be seen as a sequence of a preparation phase, an expressive phase and a retraction phase. An expressive phase which covers the meaningful nucleus of a gesture is either an independent hold or a sequence of a dependent hold, a stroke, and another dependent hold. Although we have not annotated such phases in our current corpus, we will consider their potential for future annotations.

The third step is to locate the boundaries of the gesture phases in the relevant part of the phonological speech transcription. This step seems relevant only for autistic persons with a sufficient verbal communication level. The fourth step is to locate the gesture movements in space (that is included in our coding scheme).

Regarding the coding of the data, McNeill suggests encoding the following types of gestures: representational (i.e. represents attributes, actions, or relationships between objects or characters) which can be either iconic or metaphoric; deictic (i.e. finger points or other indications of objects and people); beats (i.e. formless hands that convey no information but move in rhythmic relationships to speech; their meaning is usually that what it accompanies in speech is emphasized). Each representational and deictic gesture is then coded according to its form (hand form, motion form) and its meaning (hand form meaning, motion meaning). The coding of hand form includes handedness, shape (McNeill suggested to use ASL hand forms to approximate), palm and finger orientation, place in gesture space. The coding of the motion includes its shape, the place in space and its direction. The four types of gesture (iconic, metaphoric, deictic or beat) are also called "illustrators" and need to be merged with the associated spoken utterance in order to understand their meaning, which could prove quite problematic in the case of autism. Another type of co-verbal gesture is "emblem" the semantics of which can be independent of co-occuring speech. A coding scheme to describe the articulator movements in the expressive phase has been proposed by (Kita et al. 1998). It is this phase where annotators are confronted with approximately 60 degrees of freedom and where not only the location and shape have to be described but also for example changes in motion and direction. The following aspects are described: shape and direction of path movement, change of hand shape and orientation. For the hand shape they use the HamNoSys coding scheme. HamNoSys is one of the systems of sign transcription featuring annotation of non-verbal behavior (Messing 1999). It includes around 200 symbolic representations of: basic hand shapes, position of the hand with respect to head and body, indication of whether the gesture is one-handed or two-handed, movements of shoulders, elbow or head.

There are three main difficulties regarding the annotation of autistic persons' behaviour: the wide variety of possible gestures due to inter-individual differences, their unconventional and idiosyncratic aspects and the problems to interpret them. Moreover, verbal communication is often lacking. The gesture classifications presented above are mostly designed for co-verbal gestures or Sign Language. However, in the case of autism, speech seldom accompanies gesture. Furthermore the communication systems based on hand gestures and used for autistic people, such as Makaton, hold significant differences with the Sign Language used for deaf persons. Their usefulness for the annotation of autistic gestures is thus questionable. For example, beat like gestures that we observed in our video resources did not occur during speech production. Far from emphasizing speech, they seemed to be the expression of dissatisfaction. We could identify pointing gestures, yet they appeared to be imitations of a deictic gesture performed by the therapist, without the intent from the child to direct the partner's attention toward a specific object. Also, we have not detected any iconic or metaphoric gesture. Hence, previously mentioned systems might be mostly useful for describing the shapes and movements of gestures. Interpretation requires alternative methods.

The solution that we suggest is customizing the coding scheme for each individual with autism. Hence, interpretation may be made according to the person's behavioural context. An advantage is that a customised coding scheme can serve to build a model for the person's behaviour. A major drawback appears to be that different coding schemes have to be managed. However the time spent customizing the coding scheme may be regained if several video extracts of the same person have to be annotated. Thus, this technique seems especially appropriate for case studies.

Autistic persons' impairment of communicative gestures forces the analysis of fundamental behaviour processes such as imitation. In future works, we plan to analyse other types of behaviour, for example eye-hand coordination, joint attention or the pointing gesture. These assessments would be highly beneficial for therapeutic treatment. New recording of videos and further annotation will be necessary to test the coding scheme with more subjects. Also, we will use this method to analyse the behaviours of autistic persons in front of a computer. Indeed, computers are increasingly used as educational support for people with autism. The effects of educational software on the behaviour might be studied with the help of our system. It could yield a methodology for design and evaluation of specialised human-computer interfaces for persons with autism.

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