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Dynamique, synchronie, réciprocité et mamanais dans les interactions des bébés autistes à travers les films familiaux

Catherine Saint Georges

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Catherine Saint Georges. Dynamique, synchronie, réciprocité et mamanais dans les interactions des bébés autistes à travers les films familiaux. Automatique / Robotique. Université Pierre et Marie Curie - Paris VI, 2011. Français. NNT: . tel-00646608

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THESE DE DOCTORAT DE
L'UNIVERSITE PIERRE ET MARIE CURIE

Spécialité

Cerveau, Cognition, Comportement
(Ecole doctorale ED3C)

Présentée par

Mme SAINT GEORGES CHAUMET Catherine

Pour obtenir le grade de

DOCTEUR de l'UNIVERSITÉ PIERRE ET MARIE CURIE

Sujet de la thèse :

**Dynamique, synchronie, réciprocité et mamans dans les interactions des
bébés autistes à travers les films familiaux**

Soutenance le 30 septembre 2011

devant le jury composé de :

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Remerciements

Je suis heureuse de pouvoir témoigner ici ma gratitude à Colwyn Trevarthen pour sa disponibilité en acceptant de venir participer au jury de cette thèse et d'en être rapporteur, ainsi que pour ses très sympathiques encouragements

Je tiens à remercier Nicolas Georgieff d'avoir la gentillesse d'accorder du temps à mon travail en acceptant de me faire l'honneur d'être rapporteur de cette thèse

Je remercie aussi Philippe Mazet, dont les encouragements m'ont aidée au début de ce projet, d'avoir accepté de venir examiner son aboutissement en participant au jury

Je tiens aussi à remercier spécialement Jacqueline Nadel d'avoir accepté de me faire l'honneur de se pencher sur mon travail en participant à mon jury,

Je remercie tout particulièrement Filippo Muratori sans qui rien n'aurait été possible puisqu'il a eu la gentillesse de mettre à notre disposition toute une masse de données issues d'un travail considérable de l'équipe de Pise, puisqu'il s'est aussi impliqué dans cette recherche, et a enfin accepté de participer à mon jury.

Je remercie Marie-Christine Laznik dont le dynamisme et les idées ont participé à faire naître ce projet et l'accompagnent encore aujourd'hui

Je remercie Mohamed Chetouani, qui m'a accueillie à l'ISIR, a participé à mon encadrement et s'est toujours montré disponible, attentif et judicieux

Je remercie spécialement David Cohen, qui après avoir dirigé ma thèse de médecine, a accepté de diriger cette thèse de sciences, s'y est impliqué avec un enthousiasme communicatif, et avec qui j'ai énormément appris.

Je remercie aussi tous les collègues ou amis qui m'ont aidée ou accompagnée au fil de ce travail.

Enfin je remercie mes proches pour leurs encouragements, leur soutien... et leur patience !

Résumé

Ce travail est centré sur le fonctionnement précoce des bébés autistes, encore mal connu.

Notre étude développementale des films familiaux montre qu'ils manquent d'intérêt pour autrui dès la 1^e année mais un évitement actif n'apparaît que la 2^e année. Il y aurait donc une dynamique aboutissant au "déficit" relationnel final (passant peut-être par un défaut d'intersubjectivité).

Pour comprendre cette dynamique, nous avons pris en compte à l'aide de méthodes computationnelles la synchronie parents-bébé sur des films familiaux: les bébés ont un déficit très précoce en orientation vers l'autre puis en "intersubjectivité"; les parents répondent normalement à leur bébé, mais le sollicitent plus intensément dès le premier semestre.

Mais le déficit relationnel du bébé a-t-il des répercussions affectives sur ses parents ? Le *mamanais* (IDS) marque l'émotion dans l'interaction; pris dans une boucle interactive, il stimule à la fois l'engagement social et le développement cognitif (attention, langage). Soutient-il les interactions du bébé autiste ? Décroît-il au fil du temps du fait du dysfonctionnement interactif (manque d'intérêt pour autrui et défaut d'intersubjectivité)?

Un algorithme détectant l'IDS a été créé et appliqué à une étude pilote avant d'étudier l'ensemble de nos films. Les premiers résultats, à confirmer, suggèrent que l'IDS soutient efficacement l'interaction du bébé autiste, mais l'efficacité de l'IDS *maternel* (et non *paternel*) pourrait chuter au fil du temps.

En conclusion, nous avons apporté des bases à l'étude dynamique des interactions des bébés autistes avec leurs parents, en vue d'approcher les processus menant au tableau final.

Mots-clés:

autisme - interaction parents-bébé – synchronie – *mamanais* – films familiaux – acquisition du langage

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Title:

Dynamic, synchrony, reciprocity and motherese in interactions of infants who will develop autism through family home movies

Summary:

This thesis studies early functioning of autistic infants, still unclear.

Our developmental study of family home movies shows that they lack interest in others since the first year of life, but begin to actively avoid others only during the second year of life. Thus there could be a dynamic leading to this final relational deficit (maybe through an intersubjective deficit).

To shed light on this dynamic, we took parents-infant synchrony into account, using computational methods on family home movies: infants show a very early deficit in orienting toward others and then in intersubjectivity; parents do respond normally to their infant but they are more insistent in soliciting it as early as the first semester.

However, may the infant relational deficit have affective consequences on its parents in the long run? Motherese or infant-directed speech (IDS) reveals emotion in parent-infant interaction; belonging to an interactive loop, it supports both affective interaction and cognitive development: attention, language... May it sustain autistic infant's social engagement? And may it decrease over time because of the interactive dysfunction (lack of social interest and lack of intersubjectivity)?

An algorithm detecting IDS was created and applied to a pilot study before to use it on all our films. First results, to be confirmed, suggest that IDS may be efficient in sustaining autistic infant's reactivity, but *maternal, not paternal* IDS efficiency could drop over time.

In conclusion, we have laid a groundwork for studying dynamic interactions of autistic infants with their parents in order to approach the processes leading to the final autistic syndrome.

Keywords:

autism – parent-infant interaction – synchrony - infant-directed speech - family home movie - language development

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Liste des publications en lien avec cette thèse

Chapitre de livre (publié)

2009: "Automatic Motherese Detection for Face-to-Face Interaction Analysis". A. Mahdhaoui, M. Chetouani, C. Zong, R.S. Cassel, C. Saint-Georges, M-C. Laznik, S. Maestro, F. Apicella, F. Muratori, and D. Cohen. A Esposito et al. (Eds.): **Multimodal signals**, LNAI 5398, pp. 248-255, Springer-Verlag Berlin Heidelberg.

Articles Publiés

2010: Catherine Saint-Georges, Raquel S. Cassel, David Cohen, Mohamed Chetouani, Marie-Christine Laznik, Sandra Maestro, Filippo Muratori. "What studies of family home movies can teach us about autistic infants: A literature review". **Research in Autism Spectrum Disorders**, 4, 355–366.

2011: Ammar Mahdhaoui, Mohamed Chetouani, Raquel S. Cassel, Catherine Saint-Georges, Erika Parlato, Marie Christine Laznik, Fabio Apicella, Filippo Muratori, Sandra Maestro, David Cohen. "Home video segmentation for motherese may help to detect impaired interaction between infants who become autistic and their parents". **International Journal of Methods in Psychiatric Research**. 20(1): e6–e18.

2011: Saint-Georges C, Mahdhaoui A, Chetouani M, Cassel RS, Laznik M-C, et al. 2011 Do Parents Recognize Autistic Deviant Behavior Long before Diagnosis? Taking into Account Interaction Using Computational Methods. **PLoS ONE** 6(7): e22393. doi:10.1371/journal.pone.0022393

Articles Soumis

"Motherese, an emotion and interaction based process, impacts infant's cognitive development". Catherine Saint-Georges; Mohamed Chetouani; Raquel Cassel; Ammar Mahdhaoui ; Filippo Muratori ; Marie-Christine Laznik; David Cohen. **Child Development**

"Course of maternal prosodic incitation (motherese) during early development in autism: an exploratory home movie study". Raquel S. Cassel, Catherine Saint-Georges, Ammar Mahdhaoui, Mohamed Chetouani, Marie Christine Laznik, Filippo Muratori, Jean-Louis Adrien, David Cohen. **Interaction studies**.

Introduction

L'autisme est une pathologie de la communication et de la relation, débutant avant 3 ans et définie par une perturbation caractéristique du fonctionnement dans chacun des trois domaines suivants : interactions sociales, communication, comportement (au caractère restreint et répétitif) (APA, 1994). L'origine en reste encore insuffisamment connue, multifactorielle, impliquant probablement dans des poids variables des facteurs génétiques et environnementaux (Newschaffer et al., 2007; Rutter et al., 2007). La pathogénie reste elle aussi encore obscure, malgré les récentes avancées et les facteurs de risque répertoriés (Gardener, Spiegelman, & Buka, 2009), au premier rang desquels les facteurs génétiques (Cohen et al., 2005). Du fait du diagnostic tardif (rarement avant 3 ans), au delà des débats sur la pathogénèse et sur l'approche thérapeutique, on manque de données scientifiques pour étayer certaines affirmations ou répondre aux questions que nous pose l'autisme.

Une meilleure connaissance des fonctionnements et dysfonctionnements précoces et leur évolution devrait contribuer à une compréhension voire une modélisation des processus pathogéniques en jeu au cours du développement. Il paraît en effet essentiel de connaître non seulement les symptômes précoces mais aussi les compétences effectives de ces bébés. En effet, les "déficits" observés plus tard et qui font le diagnostic positif du tableau d'autisme à partir de 3 ans, sont-ils présents dès la naissance (ou dès le moment de leur émergence théorique au cours du développement: non-apparition de la compétence), ou bien la compétence est-elle bien présente au début, et disparaît-elle ultérieurement ?

Par ailleurs, les thérapeutiques proposées ont généralement des résultats incomplets voire médiocres (Eaves & Ho, 2008), alors qu'un consensus existe sur l'amélioration du pronostic en cas de diagnostic et traitement très précoces (Dawson & Zanolli). Ce qui signifie qu'un dépistage très précoce et donc là encore la connaissance des signes précurseurs est de la plus haute importance du point de vue du pronostic.

L'étude des premières années nous semble donc la clé à la fois d'un dépistage et traitement plus précoces, donc de meilleur pronostic, et aussi d'une meilleure compréhension de la pathogénie de cette pathologie complexe (d'où on peut espérer une approche thérapeutique plus affinée et pertinente). Malheureusement, du fait même du diagnostic tardif, cette étude reste difficile.

Les films familiaux sont une méthode riche pour obtenir des informations sur les premiers mois et années des bébés qui deviendront autistes (Palomo, Belinchon, & Ozonoff, 2006), cependant jusqu'ici les études ont essentiellement tenté de recenser les symptômes précoces des bébés. Au delà des symptômes, l'approche du *fonctionnement interactif* précoce de ces bébés pourrait nécessiter la prise en compte dans les comportements du bébé, de leur dynamique temporelle (aspects développementaux), mais aussi des comportements du partenaire de l'interaction, et de leur synchronie, et, enfin dans la mesure du possible, l'intégration de la dimension affective et émotionnelle de l'interaction. Ce sont les objectifs que nous allons tenter d'atteindre dans ce travail de thèse. Il s'inscrit dans le cadre plus large d'un travail d'équipe multidisciplinaire (médecine – psychologie – ingénierie) qui nous a ouvert des horizons pour prendre en compte et modéliser la synchronie et la prosodie dans les films familiaux.

Dans la première partie de cette thèse sur articles, nous nous intéresserons aux caractéristiques précoces des bébés à devenir autistique, telles qu'elles apparaissent dans la littérature sur les films familiaux, en mettant l'accent sur leur émergence et leur évolution du point de vue développemental, afin de les intégrer dans une dynamique temporelle qui permettrait une tentative d'approche des processus en jeu.

Dans une deuxième partie, nous introduirons la dimension de réciprocité et de synchronie dans l'interaction à la faveur de l'utilisation de méthodes computationnelles appliquées à des analyses de films familiaux.

Notre troisième partie sera dédiée à l'étude d'un marqueur potentiel de l'émotion dans l'interaction, le *mamanais*: celui-ci pourrait être un reflet de la qualité de l'interaction dans sa réciprocité.

La quatrième partie de notre thèse sera consacrée à un projet d'étude de la dynamique interactive affective dans les films familiaux utilisant le *mamanais* comme marqueur et même comme vecteur (ou cofacteur) de l'interaction. Ce projet se déroule en 3 étapes: 1) construction d'un outil de détection automatisée du *mamanais*, 2) réalisation d'une étude pilote de 2 cas uniques (un bébé autiste, un bébé contrôle à développement normal), 3) étude de groupe en cours et dont nous ne développerons donc dans ce travail que les aspects méthodologiques.

Notre dernière partie sera une discussion générale reprenant et discutant les principaux résultats obtenus dans une perspective intégrative d'élaboration théorique au sujet des processus psychopathologiques potentiellement en jeu dans la dynamique autistique et des répercussions possibles sur des stratégies de dépistage et de prise en charge précoce. Nous tenterons enfin de dégager les limites de ce travail et les perspectives pour la poursuite des recherches.

Mais tout d'abord, une petite note nosographique: les troubles envahissants du développement (TED) comprennent actuellement d'une part les troubles proprement autistiques et les troubles envahissants du développement "non spécifiés" (TED-NOS) (APA, 1994). Cependant la nomenclature peut fluctuer et l'idée d'un continuum entre ces 2 sous-catégories n'est pas exclue, c'est pourquoi la synthèse de la revue de littérature prendra en compte l'ensemble des troubles envahissants du développement (TED) y compris les TED-NOS (d'autant plus que les différentes études n'ont pas toujours utilisé les mêmes découpages nosographiques). Mais dans un souci d'homogénéité, nous étudierons par la suite dans notre protocole expérimental uniquement des bébés diagnostiqués "trouble autistique".

1. Signes précoces d'autisme

1.1. Méthodes d'étude des premières années des bébés à devenir autistique

La connaissance scientifique des premières années repose principalement sur 3 méthodes: les questionnaires rétrospectifs renseignés par les parents, les études prospectives, et l'étude des films familiaux.

1.1.1. Les questionnaires rétrospectifs

Renseignés par les parents, ils sont peu coûteux et précieux pour recueillir de multiples informations en milieu naturel, et notamment dans l'interaction (Dahlgren & Gillberg, 1989; Ohta, Nagai, Hara, & Sasaki, 1987; Watson et al., 2007). Mais ils posent divers problèmes de fiabilité. Il y a d'abord un problème de "fidélité interjuge", les cotateurs étant finalement les parents avec toute leur subjectivité, ce qui limite la comparabilité des cotations. Il existe ensuite un problème de fiabilité de la remémoration de détails plus ou moins anciens. Un troisième problème est lié au biais affectif: la forte implication affective des parents par rapport aux soins apportés et au développement de leur enfant et leur échec stimulent, en fonction de l'histoire de chacun, différents modes de défense favorisant les déformations et reconstructions: projection, déni, identification...

1.1.2. Les études prospectives

C'est la méthode la plus fiable puisqu'elle supprime les différents biais répertoriés ci-dessus: elle permet les protocoles méthodologiques les plus rigoureux, notamment un double aveugle puisqu'au moment de la cotation, l'examineur ne sait pas encore quel sera le diagnostic de l'enfant, qui ne sera établi qu'ultérieurement, à l'âge de 2 ou 3 ans.

Mais ces études sont très coûteuses du fait de la faible prévalence: 13 cas d'autisme infantile, ou 60 cas de TED pour 10000 enfants (Fombonne, 2005). Il faut donc étudier beaucoup d'enfants pour analyser au final un petit échantillon d'autistes. De plus, il faut bien définir à l'avance ce qu'on recherche puisque, comme dans la plupart des études expérimentales, on ne trouvera à la fin que ce qu'on aura cherché ! Du fait de la lourdeur et du

coût de cette méthode, les résultats en sont encore parcimonieux. Mais les études de fratrie (Bryson et al., 2007; Landa & Garrett-Mayer, 2006; Landa, Holman, & Garrett-Mayer, 2007; Zwaigenbaum et al., 2005) permettent de contourner en partie cette difficulté puisque la prévalence de l'autisme infantile est alors multipliée par 100 (APA, 2000). Cependant ces études autorisent alors quelques biais éventuels, liés à l'inquiétude des parents, l'influence de l'aîné, la sélection d'un sous-groupe à plus fort poids génétique...

1.1.3. L'étude des films familiaux

L'analyse méthodique de vidéos du bébé, filmé par les parents eux-mêmes avant toute question diagnostique, est une méthode d'étude des premières années économique. Si elle ouvre la porte à divers biais (modification du comportement des parents, voire du bébé, liée à la présence de la caméra; sélection par les parents des scènes agréables et suppression des scènes difficiles), elle présente l'avantage d'être "écologique" puisqu'elle étudie le bébé dans son environnement naturel, en interaction spontanée avec ses parents, et sans aucun dispositif expérimental (qui constitue un biais dans les études classiques). La constitution préalable d'une banque de films constitue un travail important comprenant la récupération des films de bébés pathologiques et normaux, l'évaluation des sujets par une batterie de tests et d'examen, etc., mais une fois la banque constituée, la légèreté de cette méthode, relativement aux études prospectives, permet de multiplier les focus et aussi les cotateurs pour avoir des doubles cotations avec une bonne fidélité interjuge. Finalement, l'étude des films familiaux constitue une méthode de choix, qui peut apporter de nombreuses pistes et informations qui pourront éventuellement être re-validées ensuite par les études prospectives.

Nous avons donc choisi de réaliser une revue complète et critique des études de films familiaux de bébés à devenir autistique, en vue de répondre aux questions suivantes: 1) quels sont les signes précoces et spécifiques d'autisme (et notamment ceux qui distinguent les bébés à devenir autistique de ceux qui évolueront vers un retard mental) et quelle en est la chronologie d'apparition ?; 2) les compétences, sociales notamment, sont-elles déficitaires et absentes d'emblée ou bien sont-elles présentes au début pour disparaître ensuite au fil d'un processus pathogénique articulé au développement ?; 3) les résultats des études de films familiaux sont-ils concordants avec ceux des études prospectives ?

1.2. Compétences et signaux d'alerte chez les bébés à devenir autistique durant les 2 premières années

Notre premier article (Saint-Georges et al., 2010) est centré sur l'étude des publications sur les films familiaux, d'une part pour la qualité et la richesse de leurs résultats, d'autre part parce qu'il s'agit d'une première étape dans notre recherche qui justement utilisera cet outil. Il importait donc d'en connaître les diverses méthodes d'analyse et leurs avantages et inconvénients.

1.2.1. Approche méthodologique

A l'aide des moteurs de recherche Pubmed et PsycInfo, nous avons répertorié l'ensemble de la littérature publiée depuis les premières études (depuis 1975) et jusqu'en janvier 2008, sur les films familiaux d'enfants qui seront diagnostiqués autiste ou TED. Dans la bibliographie de ces articles, nous avons trouvé 7 références supplémentaires. Après avoir exclu les articles "hors-sujet", nous avons recensé 41 études originales.

Pour étudier les signes qui distinguent significativement les bébés à devenir autistique des bébés contrôles (normaux ou à retard mental), compte-tenu de la grande diversité de design méthodologique, nous avons décidé de prendre en compte la rigueur scientifique. Nous avons donc construit une grille de qualité comportant 9 points (avec, pour chaque point, un score de 0, 1 ou 2): la taille de l'échantillon, la précision du diagnostic, la précision de l'âge, l'évaluation du QI, l'utilisation d'un groupe contrôle, le recours à un cotateur "aveugle", l'utilisation d'un instrument de cotation, la fiabilité de la cotation (double cotation ou pas, calcul de la fidélité interjuge), l'utilisation de statistiques. Chaque étude a ainsi obtenu un score de qualité de 0 à 18 points. Sur les 41 études recensées, nous en avons ainsi retenu 18 qui avaient reçu un score supérieur ou égal à 13, ce qui correspond alors à une totalité de 317 sujets (autistes et contrôles) au maximum.

Par ailleurs, pour l'étude développementale, étant donné la rareté des études de ce type, à partir du pool de départ de 41 études, nous avons sélectionné et conservé toutes les 11 études longitudinales. De plus, nous sommes spécialement intéressés au phénomène de régression autistique (tableau clinique ne débutant qu'après le 1er anniversaire), sur lequel portaient 9 études.

Enfin, nous avons comparé ces résultats provenant de l'étude des films familiaux à ceux des études prospectives publiées.

1.2.2. Principaux résultats

Quels sont les premiers signes d'autisme au cours des 2 premières années ?

Nous avons tenté d'en faire une synthèse éclairée (voir figure 1). Au cours des 6 premiers mois, l'équipe de Pise a observé, à travers 4 études différentes (Maestro et al., 2001; Maestro et al., 2002; Maestro, Muratori, Cesari, et al., 2005; Maestro et al., 2006), des différences statistiquement significatives entre bébés normaux et futurs autistes; une seule étude d'une autre équipe (Zakian, Malvy, Desombre, Roux, & Lenoir, 2000) portait sur cette tranche d'âge et n'a retrouvé aucun signe. Les signes observés par l'équipe de Pise concernent essentiellement le manque d'intérêt pour autrui (regarder, sourire, se tourner en direction d'autrui, et rechercher le contact d'autrui), un manque de communication (vocalisations) et le manque d'intersubjectivité (conduites d'accordage, compréhension du pointing, anticipation des intentions de l'autre).

De nombreuses équipes ont travaillé sur la première année et les études portant sur la fin ou la totalité de cette première année sont nombreuses (Adrien et al., 1993; Baranek, 1999; Baranek et al., 2005; Clifford & Dissanayake, 2008; Colgan et al., 2006; Losche, 1990; Maestro et al., 2001; Maestro, Muratori, Cesari, et al., 2005; Maestro et al., 2006; Osterling & Dawson, 1994; Osterling, Dawson, & Munson, 2002; Ozonoff et al., 2008; Werner & Dawson, 2005; Werner, Dawson, Osterling, & Dinno, 2000) et observent à nouveau, de façon concordante, les mêmes types de signes: manque d'intérêt social, de communication et d'intersubjectivité, Notamment on observe une moins bonne qualité d'expression faciale, moins de gestes communicatifs et moins de réactivité à l'appel du prénom. En revanche, hypotonie, hypoactivité, retard psychomoteur et comportement répétitif sont inconstamment retrouvés et semblent non spécifiques lorsqu'on compare bébés autistes et bébés avec retard mental. Enfin les comportements d'autostimulations et les stéréotypies ne sont pas des signes observés significativement au cours de la première année. C'est donc bien la relation à autrui, et spécialement l'appétence pour autrui (intérêt social), la compréhension d'autrui (intersubjectivité) et la communication avec autrui (vocalisations adressées et gestes communicatifs) qui semblent spécifiquement inhabituelles et défailtantes chez les bébés autistes au cours de la première année de vie, et ceci dès les 6 premiers mois.

Au cours de la seconde année (Adrien et al., 1993; Clifford, Young, & Williamson, 2007; Clifford & Dissanayake, 2008; Losche, 1990; Maestro et al., 2001; Maestro et al., 2006; Mars, Mauk, & Dowrick, 1998; Ozonoff et al., 2008; Werner & Dawson, 2005; Zakian et al., 2000), les mêmes signes sont observés (manque d'intérêt social, d'intersubjectivité et de communication) mais de nouveaux signes apparaissent: mauvais contact visuel, isolement, manque de câlin et d'imitation, manque de mots et de phrases avec plus de vocalisations stéréotypées et moins de réponse aux consignes verbales, manque de pointing et d'attention conjointe. Ces signes (en particulier

l'évitement actif de la relation et du regard) pourraient signer l'échec de la mise en place de la relation (Muratori & Maestro, 2007) et de l'entrée dans le langage. De plus l'attention apparaît instable et on retrouve plus nettement une hypotonie et une hypoactivité, ainsi qu'un manque de jeu social et symbolique.

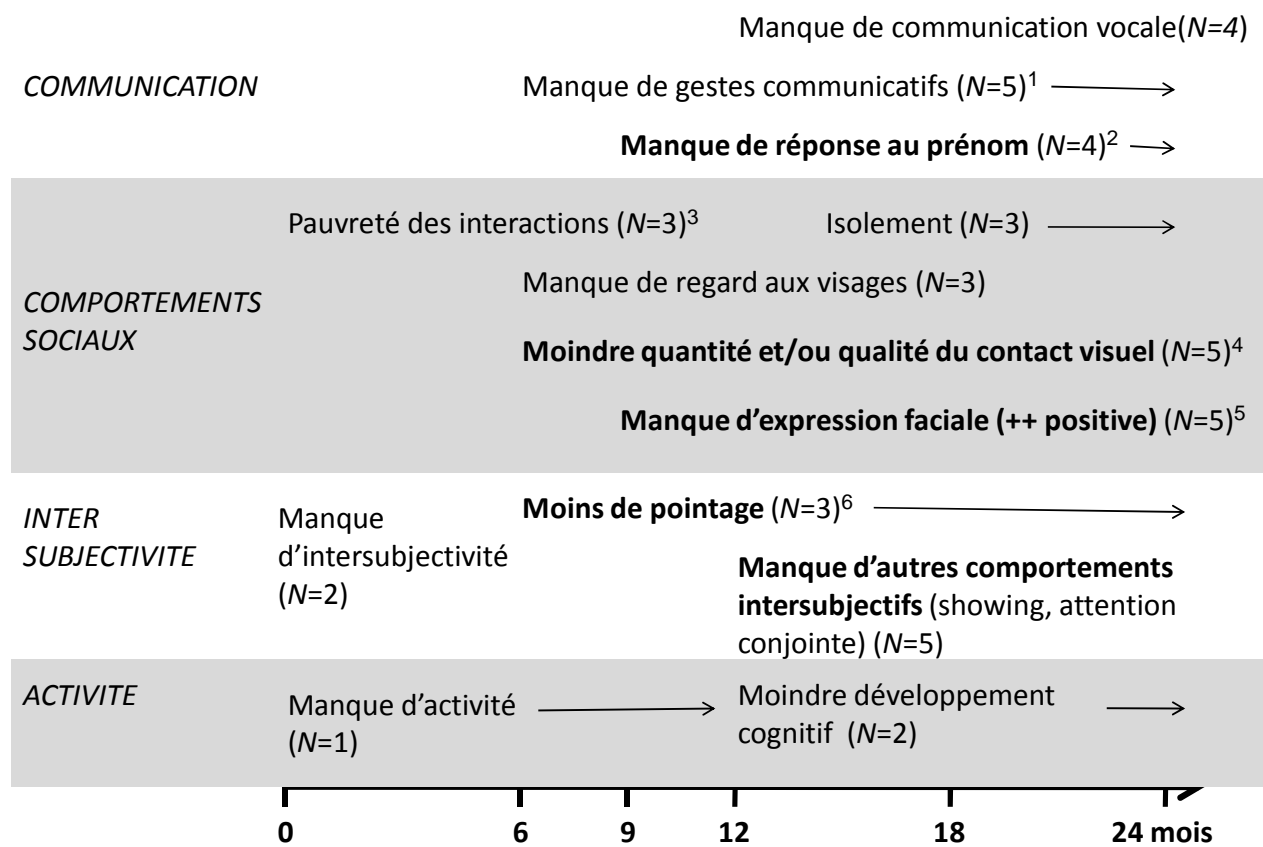


Figure 1. Signes précoces d'autisme en fonction de l'âge et des principaux axes de développement issus de l'étude des films familiaux

Les signes reconnus pour être spécifiques de l'autisme, comparé au retard de développement, apparaissent en gras. N indique le nombre d'études rapportant l'item correspondant.¹ Significatif au 2^e semestre dans 1 étude; ² significatif dans les derniers mois de la 1^e année dans 3 études; ³ significatif au 1^{er} semestre dans 1 étude; ⁴ significatif au 2^e semestre dans 2 études; ⁵ significatif dans les derniers mois de la première année dans 2 études; ⁶ significatif au 2^e semestre dans 1 étude.

Quels sont les signes dont la spécificité vis-à-vis de l'autisme est attestée ?

Aucune étude n'a comparé bébés autistes et bébés avec retard mental dans les 6 premiers mois. Quelques études ont utilisé un groupe contrôle avec retard mental (Baranek, 1999; Baranek et al., 2005; Clifford et al., 2007; Clifford & Dissanayake, 2008; Osterling et al., 2002; Ozonoff et al., 2008). Au cours de la première année, les signes dont la spécificité pour l'autisme a été vérifiée sont le manque de regard à autrui, la mauvaise qualité de l'affect et le manque de réponse au prénom. Au cours de la deuxième année, de plus nombreuses différences sont attestées avec moins d'affect positif, mauvais contact visuel, manque d'intérêt social, défaut d'intersubjectivité (postures anticipatrices et showing protodéclaratif) et de jeux conventionnels. Mais les études ayant utilisé un groupe contrôle avec retard mental étant finalement peu nombreuses, l'incertitude demeure concernant la spécificité d'un certain nombre de signes. Quoiqu'il en soit, si la distinction des bébés à risque de développement autistique des bébés à risque de développement retardé pourrait être délicate au cours de la première année, les signes d'alerte non spécifiques sont assez nombreux et pourraient justifier une attitude préventive.

Existe-t-il un autisme à début tardif (late-onset autism) ?

Peut-il y avoir un phénomène de régression autistique après une première année de développement normal ? 9 études portent sur ce point. 2 études de cas unique (Bernabei & Camaioni, 2001; Eriksson & de Chateau, 1992) démontrent une régression avec l'apparition d'un repli faisant suite à un engagement social pourtant bien installé lors de la première année, et notamment, dans un cas, une claire et éloquente perte de la réponse au prénom. Dans les 2 cas rapportés, simultanément au repli, le bébé s'engage dans des conduites répétitives. Les 3 études de groupe comparant autisme à début précoce (Early-Onset Autism: EOA) et autisme à début tardif (Late-Onset Autism: LOA) montrent globalement qu'à 1 an les LOA se comportent comme les bébé normaux (regard, sourire, vocalisation adressée, réponse au prénom, pointing) et diffèrent des EOA, tandis qu'à 2 ans, les LOA ne se distinguent plus des EOA (Maestro et al., 2006; Osterling et al., 2002; Werner & Dawson, 2005).

Les résultats des études prospectives confirment-ils ceux des films familiaux et donc la validité de ces études ?

Oui, globalement, les études prospectives (Bryson et al., 2007; Landa & Garrett-Mayer, 2006; Landa et al., 2007; Loh et al., 2007; Mitchell et al., 2006; Nadig et al., 2007; Sullivan et al., 2007; Zwaigenbaum et al., 2005) retrouvent la réduction de l'engagement social, des compétences communicatives (réponse au prénom, compréhension et production du langage), et de

l'intersubjectivité (voir tableau 1). De plus des difficultés affectives ont été rapportées dès le 2^e semestre ainsi qu'une hypoactivité et des comportements stéréotypés (peut-être y a-t-il un biais ici du fait de l'imitation du grand frère autiste ?). Du point de vue dynamique, les études prospectives confirment aussi la validité du concept de régression autistique, et montrent de plus la concomitance du retrait relationnel et d'un comportement d'irritabilité et d'intolérance aux intrusions.

Comment les symptômes autistiques s'installent-ils et comment les compétences interactives du bébé à devenir autistique évoluent-elles ?

Nous avons vu à travers nos études transversales, comparant sur la même tranche d'âge bébés normaux et bébés à devenir autistique, que le cœur de la symptomatologie autistique (désintérêt pour autrui, déficit de communication et d'intersubjectivité) est présent dès les premiers mois de vie, quoique à un degré assez discret. La discrétion de ces symptômes renvoie au fait que le comportement n'est généralement pas franchement absent mais seulement moins fréquent: les compétences relationnelles semblent présentes mais les bébés autistes en usent moins que les autres. D'après les 12 études longitudinales que nous avons trouvées (Adrien et al., 1993; Bernabei, Camaigni, & Levi, 1998; Bernard, Adrien, Roux, & Barthélemy, 2005; Bernard, Adrien, Roux, & C., 2006; Bernard, Guidetti, Adrien, & Barthélémy, 2002; Clifford & Dissanayake, 2008; Maestro, Casella, Milone, Muratori, & Palacio-Espasa, 1999; Maestro et al., 2001; Maestro, Muratori, Cesari, et al., 2005; Malvy, Adrien, Roux, Lataste, & Sauvage, 1994; Receveur et al., 2005; Werner & Dawson, 2005) même si chaque bébé semble suivre un parcours propre, globalement, les compétences relationnelles (sociales, communicatives et intersubjectives) sont présentes au début de la vie, quoique insuffisamment exploitées, et tendent même à se développer au 2^e semestre ou au début de la 2^e année, avant de stagner ou décroître durant la seconde année, alors que les bébés normaux connaissent un développement verbal et intersubjectif majeurs. Il s'ensuit donc que même les EOA connaissent des phénomènes de régression au fil des mois, avec, notamment une diminution frappante des regards en direction d'autrui au cours de la 2^e année (Werner & Dawson, 2005). Une étude prospective de Ozonoff a récemment confirmé cette régression dans les regards, sourires et vocalisations de bébés à risque autistique à partir de 12 mois, alors qu'à 6 mois, la fréquence était à peu près normale (Ozonoff et al., 2010), chez des bébés pour lesquels une régression autistique n'avait pas été rapportée par les parents. Les auteurs ont conclu que les signes relationnels n'émergeaient qu'à partir de 12 mois mais ils n'ont malheureusement pas étudié les bébés avant 6 mois et ils ont donc vraisemblablement été trompés par l'amélioration que nous avons rapportée au 2^e semestre.

Tableau 1. Critères de dépistage précoce du risque d'autisme à partir des résultats des études prospectives et de films familiaux

	Signes	Sensibilité		Spécificité
		Etudes prospectives	Etudes de films familiaux	
1er semestre	Manque d'attention et d'activité sociales		3/3	
	Manque d'intersubjectivité		2/2	
	Hypoactivité/hypotonie	1/2	1/1	
Fin de la 1ère année	Manque de regards/d'orientation vers autrui	2/3	6/9	++
	Pauvreté des interactions		3/3	
	Manque d'expression faciale	1/2	2/2	-
	Manque de sourire social		3/6	
	Moindre qualité de l'affect		1/2	++
	Manque de gestes communicatifs	3/3 (S= 0.33)	2/4	-
	Manque de vocalisations sociales		2/2	
	Manque de réponse au prénom	2/2 (S=0.5)	4/5	++
	Manque de pointage	1/1	3/3	+/-
	Autres déficits InterSubjectifs	2/2	5/6	-
Seconde année (18-24 mois)	Manque de regards aux personnes	3	5/6	++
	Mauvaise qualité du contact visuel		2/3	++
	Manque d'affect positif		½	++
	Manque de gestes/attitudes communicatives	3/3	2/3	
	Manque de communication vocale	4/4	4/4	
	Manque de compréhension du langage	3/3	1/1	
	Manque de réponse au prénom	2/2	3/4	
	Manque de pointage	2/2	3/3	+/-
Autres déficits IS: showing, RAC, anticipation	5/5	4/4	+++	

IS: Intersubjectif; RAC: Réponse à l'attention conjointe.

Spécificité dans la comparaison autisme/retard mental: (-) non spécifique dans les films familiaux; (+/-) partiellement spécifique dans les films familiaux; (++) spécifique dans les films familiaux; (+++) spécifique dans les films familiaux + les études prospectives.

Sensibilité: taux d'études qui ont trouvé cet item significatif rapporté à l'ensemble des études qui l'ont recherché; S = sensibilité calculée dans une étude.

1.2.3. Discussion

Parmi tous les signes rapportés, quels signes utiliser pour le dépistage ?

Dès la fin de la première année, le manque de réponse au prénom, de regard des visages et de contact visuel, et le manque de pointing ou showing (montrer l'objet en le tenant) constituent des signes assez prédictifs. Cependant du fait de la variabilité de l'évolution des compétences relationnelles au cours du temps, avec par exemple parfois des fluctuations (et notamment une tendance à l'amélioration de la réactivité au second semestre), la sensibilité peut être insuffisante et obliger à rechercher des signes plus complexes qui seraient permanents, comme par exemple peut-être un défaut d'initiation de l'interaction. En ce qui concerne la spécificité, les signes liés au retard mental (comportements répétitifs, retard d'intersubjectivité...) peuvent aussi révéler un autisme puisque un retard cognitif peut être associé à l'autisme, et ceci très précocement.

Comment interpréter le profil développemental des bébés à devenir autistique ?

L'extrême précocité du manque d'intérêt social, et les aleas évolutifs des comportements relationnels et de communication avant l'entrée dans un tableau autistique caractérisé par un repli massif sont à prendre en compte dans les hypothèses pathogéniques sur l'autisme. Les bébés autistes ont au départ des compétences relationnelles (quoique trop faibles), qui ont même tendance à se développer (quoique insuffisamment) jusqu'à ce qu'il semble y avoir un décrochage et même un évitement de la relation avec, de façon contemporaine, apparition de comportements stéréotypés (comme le montrent les études de cas uniques de LOA). Peut-être cette simultanéité entre retrait relationnel et entrée dans des comportements stéréotypés serait-elle intéressante à confirmer aussi sur des études d'EOA de type cas unique.

Une première hypothèse pour rendre compte de cette double donnée (insuffisance au début puis aggravation) serait que la faiblesse des compétences relationnelles des EOA au début ne soit qu'un effet statistique correspondant à des âges de début variables échelonnés sur la première année. En fait les compétences relationnelles seraient normales au début et effondrées après un repli survenant à un âge variable. Il y aurait dans ce cas un continuum entre EOA et LOA. Des études longitudinales de type cas uniques pourraient permettre d'affiner ces questions.

Une hypothèse différente, pour rendre compte du fait qu'une aggravation succède au déficit initial, serait que ces bébés n'arrivent pas à franchir un certain cap dans la relation, ce qui les amène à régresser secondairement. Cela pourrait concorder avec la notion d'intersubjectivité secondaire développée par Trevarthen (Trevarthen & Daniel, 2005): vers la fin de la première année, le bébé normal accède à cette intersubjectivité au fil de son expérience d'une relation de "sympathie" et d'échange avec l'adulte.

Mais cela est conditionné par l'existence d'une motivation primaire innée poussant le bébé à entrer en contact et à partager avec l'autre, et qui serait partiellement défaillante chez les bébés autistes. Trevarthen soutient que l'intersubjectivité secondaire se construit à partir d'une prédisposition innée du bébé mais aussi de la rencontre et du partage affectif et cognitif avec un autre, ce qui va conditionner le développement du cerveau dans le sens du développement de l'intersubjectivité. C'est pourquoi il suggère que le bébé autiste, qui manque d'élan vers l'autre devrait cependant bénéficier d'un effort particulier pour communiquer avec lui, dans le sens de l'aider à développer ses capacités d'échange intersubjectif (Trevarthen & Daniel, 2005). Muratori a également de son côté soutenu l'hypothèse que l'autisme serait l'effet dans un second temps, d'un déficit initial en intersubjectivité (Muratori & Maestro, 2007). Ainsi, nous proposons l'hypothèse que le déficit primaire d'intérêt pour autrui, notamment le manque de regard des visages, pourrait engendrer les déficits secondaires en attention conjointe (mis en évidence dans les films familiaux: pointing, showing...) et donc des déficits en communication gestuelle et verbale. En effet, l'attention conjointe est un pré-requis de l'acquisition du langage (Carpenter, Nagell, & Tomasello, 1998) et des auteurs ont montré que les compétences en attention conjointe prédisent le développement ultérieur du langage chez les enfants autistes (Mundy, Sigman, & Kasari, 1990; Sigman et al., 1999). Selon Bruner, l'enfant acquiert le langage en tant qu'instrument de régulation de l'activité conjointe et de l'attention conjointe (Bruner, 1983). Wetherby a également souligné, dans la deuxième partie de la deuxième année des enfants autistes, l'importance des déficits de fonctions pivots de la communication, et a suggéré l'existence de processus en cascade impactant le devenir socio-communicatif de ces enfants (Wetherby, Watt, Morgan, & Shumway, 2007). Même au niveau perceptif, Kuhl a montré chez des bébés de 9 mois que la présence (épisode) d'un étranger en interaction réelle, contingente (et non en vidéo) était nécessaire à la non-disparition des capacités perceptives de discrimination de phonèmes étrangers à la langue maternelle (Kuhl, Tsao, & Liu, 2003). Les prémisses de l'acquisition du langage dépendent donc de l'interaction, avant même la fin de la première année. Hobson a également souligné l'importance de l'interaction affective dyadique dans le développement des compétences intersubjectives et cognitives (Hobson, 1993). Ainsi, chez le bébé autiste, les troubles de l'attention conjointe et du langage (déficit de la production mais aussi de la *compréhension* verbale) découleraient du manque d'intérêt pour autrui et d'expériences interactives, et aggraveraient en retour le dysfonctionnement de la communication et le défaut d'intersubjectivité (secondaire). In fine, l'enfant ne comprend pas autrui et ne se fait pas comprendre (et ceci s'inscrirait dans le cerveau en développement sous forme d'une absence de mise en fonction et de développement des structures destinées à l'échange et la communication) d'où un dysfonctionnement de la relation qui générerait l'évitement relationnel observé dans un second temps.

Comment étudier le coeur de l'interaction parents-bébé autiste ?

L'expérience du *partage* d'attention, de vocalisations et d'affects paraissant cruciale pour l'entrée dans l'intersubjectivité (Trevarthen & Aitken, 2001), l'étude non seulement des comportements du bébé, mais aussi et surtout l'étude de la contingence et de la *synchronie* entre les comportements du bébé et de la mère paraissent pertinente pour affiner l'étude dynamique et développementale des processus pathogéniques précocément en jeu dans l'autisme.

La question du rôle du partenaire de l'interaction doit aussi être étudiée: comment les parents réagissent-ils au manque d'intérêt manifesté précocément par le bébé ? La quasi-totalité des études de films familiaux se focalise sur le comportement du bébé futur autiste. Cependant, Massie a observé une difficulté d'attachement et de contact visuel de la part des parents (Massie, 1978), et plusieurs auteurs notent a contrario des tentatives de compensation de la part des parents: insistance et répétition des consignes, jeux physiques... qui semblent avoir une certaine efficacité (Baranek, 1999; Trevarthen & Daniel, 2005). Très récemment, Muratori a élaboré une grille spécifique visant à décrire les comportements intersubjectifs des bébés et prenant en compte les comportements des parents et a pu observer que dès le premier semestre, les parents des bébés autistes ont moins de comportements de "regulation down" (comportement visant à moduler l'éveil et l'humeur du bébé dans le sens de l'apaiser) que ceux des bébés avec retard mental (Muratori, Apicella, Muratori, & Maestro, 2011).

Pour affiner encore l'analyse de l'interaction, il conviendrait donc de prendre en compte les processus bidirectionnels, incluant les comportements des parents et surtout la façon dont parents et bébé s'articulent, avec des répercussions positives ou négatives sur l'autre partenaire (boucles interactives). Une étude de la dynamique développementale précoce prenant en compte la synchronie permettrait de suivre l'évolution de la dyade ou triade.

Particulièrement, comme nous avons vu que le fonctionnement interactif des bébés autistes est fluctuant, sporadique, il nous a paru intéressant du point de vue théorique comme du point de vue thérapeutique, de se pencher sur les séquences d'interaction réussie pour approfondir quel contexte, quelle situation, ou quelle stimulation peut provoquer une réponse de la part du bébé. Pour cela, la prise en compte de la synchronie dans l'interaction précoce est aussi essentielle.

1.2.4. Article publié (RASD)



Contents lists available at ScienceDirect

Research in Autism Spectrum Disorders

Journal homepage: <http://ees.elsevier.com/RASD/default.asp>

Review

What studies of family home movies can teach us about autistic infants: A literature review

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ARTICLE INFO

Article history:

Received 14 October 2009

Accepted 27 October 2009

Keywords:

Autism

Pervasive Developmental Disorder

Home movies

Early identification

Regression

ABSTRACT

The current study reviewed all prior studies conducted on family home movies of infants who would be later diagnosed with autism spectrum disorder (ASD). Out of 41 original reports found since 1975, we retained 18 studies (317 films, maximum), sorted according to their methodological design using a quality grid. In the first 2 years of life, signs that differentiated children with ASD from children with developmental delays were as follows: less of a response to their name, less looking at others, lower eye contact quality and quantity, less positive facial expression and intersubjective behaviors (e.g., showing shared attention). Studies focusing on regression confirmed the clinical validity of the phenomena. We conclude that findings from home movies studies along with prospective studies have created the bases for identification of infants and toddlers at risk of developing ASD before the 18–24-month period, despite early diagnosis of autism remains a complex challenge.

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1. Introduction

Autism spectrum disorders (ASD) disturb the development of interpersonal relationships and cooperative behavior. Although genetic factors are now well-established (Cohen et al., 2005), the causal processes that lead to the development of the condition remain unclear and poorly documented, especially during the first years of life. Indeed, diagnosis is rarely made before a child is between 2 and 3 years of age. Improved knowledge of the early developmental course of children who will be eventually diagnosed with ASD appears to be crucial. This knowledge is needed in order to better understand the complex pathogenic phenomena of autism and to improve the early screening and management of autism. Indeed, there is consensus that the earlier treatment begins, the better the child's prognosis is.

For more than 30 years, there has been a growing clinical interest in family home movies of infants who are subsequently diagnosed with ASD. Although numerous limitations have been described, studies of these films have proved to be of scientific merit. They show, in a non-invasive way, the early behaviors of these infants long before the time of clinical diagnosis. We propose here a review of this extensive literature, weighing the scientific quality of the various studies and emphasizing the consistency of the data. In particular, we aimed (a) to review signs in the first 2 years of life that may be useful for the early screening of autism; (b) to chart the phenomenon of regression using a developmental approach; and (c) to address in early-onset cases, beyond the issue of regression, whether competencies are lacking from birth, fail to emerge, or develop normally before stagnating or declining.

2. Methods

Utilizing the PubMed and PsycINFO databases, we screened the literature published from January 1975 to January 2008 with the following criteria: ("autistic" or "autism" or "pervasive developmental disorder" or "infantile psychosis" or "childhood psychosis") and ("home" or "family") and ("movies" or "films" or "videos" or "videotapes"). Out of the 93 articles found, we excluded 46 articles because they did not address home movies made during infancy before any diagnosis of Pervasive Developmental Disorders (PDD). Of those excluded, 22 dealt with experimental studies after the diagnosis was made, eight focused on videos as a tool for care, five focused on other disorders, five focused on early signs obtained by other methods, and six were irrelevant. We also screened the reference lists of the 47 relevant articles and found seven additional references. Out of the 54 articles retained, we excluded dissertation abstracts ($N=5$), papers on data already reported elsewhere ($N=3$: Bernabei, 1998; Massie, 1975, 1977), studies with roughly the same sample ($N=2$: Adrien, Perrot, et al., 1991; Adrien et al., 1992) keeping the larger one (Adrien et al., 1993), papers on preliminary results ($N=1$: Rosenfeld, Korolitski, Coyer, & Montes de Oca, 1990), and reviews ($N=2$: Malvy et al., 1999; Palomo, Belinchon, & Ozonoff, 2006). Thus, we listed 41 relevant studies for review.

Given the great number and variety of methodological designs, we constructed a quality grid to prioritize the studies with a quality coefficient that was estimated according to nine criteria: (a) *sample size* ($N < 10$ vs. 10–15 vs. >15), (b) *diagnostic criteria* (no criteria vs. diagnostic criteria of PDD vs. restricted diagnostic criteria and/or specific assessments scale: Childhood Autism Rating Scale (CARS), Autism Diagnostic Interview-Revised (ADI-R)), (c) *age range* (>1 year vs. 6–12 months vs. <6 months), (d) *IQ assessment* (no IQ vs. IQ assessed but lower than control), (e) *control group* (no control vs. normally developing control vs. delayed control), (f) *blindness* (no vs. yes), (g) use of *video coding tools* (no vs. yes), (h) *quotation reliability* (single quotation vs. double vs. double with interrater reliability or kappa), and (i) use of *data analysis* (no vs. yes). Each study received a score from 0 to 2 for each criterion. Dichotomous variables (no vs. yes) received a score 0 or 2. We then computed the "quality score" (from 0 to 18 points) for each study (see scores in Table 1).

To review the early characteristics of children with autism, we decided to keep only the more pertinent studies that received a quality score equal to or higher than 13 (out of 18 points). Then, when possible, we gathered the data and grouped them by age and by each pertinent field for autism. Next to the significant results, we also mentioned the non-significant results from all studies coding the same behavior frequencies. Because, according to Allison et al. (2008) skills are reduced rather than completely absent in infants with ASD, we kept only the significant results, and ignored the non-significant ones for two studies coding the presence/absence of specific behaviors instead of frequency (Maestro et al., 2001; some items in Clifford, Young, & Williamson, 2007). Given the limited number of longitudinal studies, all were kept for the developmental questions regardless of the quality score.

Table 1
Main methodological characteristics of home movie studies on infants who later exhibit ASD (1975–2008).

Studies	Team	Object studied	Age range ^a (months)	Sample size: index/controls ^b	Inclusion criteria	Control for IQ ^c	Blind	QS
Osterling et al. (2002)	Washington	Aut. signs, dev. skills	12	20/14 DD/20	PDD (D3R)	64/53 (DD)	Y	18
Clifford and Dissanayake (2007)	Adelaide	JA, gaze, affect	0–6–12–18–24	22/15 (DD+TD)	AD (D4)	65/83 (TD+DD)	Y	18
Clifford et al. (2007)	Adelaide	Developmental skills	12/24	15/15DD/15	AD (D4)	69/77 (DD)	Y	17
Maestro, Muratori, Cavallaro, et al. (2005)	Pisa	Social attention	0–6–12	15/13	AD (D4)	7 < 70; 7 > 70	Y	17
Maestro et al. (2002)	Pisa	Social attention	0–6	15/15	PDD (D4)	6 < 70; 7 > 70	Y	17
Baranek et al. (2005)	Chapel Hill	Object playing	9–12	11/10 DD/11	AD (D4)	56/65 (DD)	Y	17
Baranek (1999)	Chapel Hill	Aut. signs, dev. skills	9–12	11/10 DD/11	AD (D4)	56/65 (DD)	Y	17
Goldberg et al. (2008) ^d	Irvine	Regression reported	6; 12; 18; 24	56/14	ASD	66	Y	16
Colgan et al. (2006)	Chapel Hill	Gestures	9–12	21/14	AD (D3+4)	14 < 70, 7 > 70	Y	16
Receveur et al. (2005) ^d	Tours	Aut. signs, dev. skills	10–12; 16–18; 24–26; >48	18	AD (D4)	10 < 50/8 > 50	Y	16
Werner and Dawson (2005)	Washington	Aut. signs, dev. skills	12/24	15LOA/21EOA/20	PDD (D4)	55	Y	15
Osterling and Dawson (1994)	Washington	Aut. signs, dev. skills	12	11/11	PDD (D3R)	4 < 75, 6 > 75	Y	15
Werner (2000)	Washington	Aut. signs, dev. skills	8–10	15/15	PDD (D3R)	8 < 70, 4 > 85	N	14
Ozonoff et al. (2007)	Sacramento	Motor development	0–24	26EOA/28LOA/25DD/24	AD	61/55/64 (DD)	N	14
Zakian et al. (2000)	Tours	Autistic signs	0–8–17–24	14/10	AD (D4)	6 < 50; 8 > 50	Y	14
Adrien et al. (1993)	Tours	Autistic signs	0–12–24	12/12	AD (D3R)	7, 7–105	Y	14
Mars et al. (1998)	Philadelphia	Aut. signs, dev. skills	12–30	25/25	AD/PDD (D4)	55	Y	14
Maestro, Muratori, Cesari, et al. (2005) ^d	Pisa	Autistic signs	0–6–12	40	PDD (D4)	22 < 70, 18 > 70	N	14
Maestro et al. (2006)	Pisa	Social attention	0–6–12–18	15EOA/15LOA/15	AD (D4)	–	Y	13
Maestro et al. (2001)	Pisa	Developmental skills	0–6–12–18–24	15/15	AD (D4)	–	Y	13
Losche (1990)	Berlin	Cognition	4–12–21–30–42	8/8	AD (D3)	MR	Y	13
Bernabei et al. (1998) ^d	Roma	Developmental skills	0–6–12–18–24	10	PDD (D4)	9MR + 1HF	Y	13
Bernard et al. (2006) ^d	Tours	Gestures	12–18–24–30–36	8/8	AD	56	N	11
Bernard et al. (2002) ^d	Tours	Gestures	12–18–24–30–36	7	AD (D4)	37–131	N	10
Maestro et al. (1999) ^d	Pisa	Autistic signs	0–6–12–18–24–36	26/normal scores	PDD (D4)	–	N	10
Rosenthal et al. (1980) ^d	San Francisco	Cognition	0–36	14/14	PDD	–	N	9
Bernabei and Camaioni (2001) ^d	Roma	Developmental skills	0–36	1	AD (D4)	MR	N	NA
Eriksson and De Chateau (1992) ^d	Stockholm	Aut. signs, dev. skills	0–14	1	AD (D3R)	60	N	NA

JA = joint attention; aut. signs = autistic signs; dev. skills = developmental skills; DD = developmental delay; TD = typical development; EOA = early onset autism; LOA = late-onset autism; AD = autism disorder; ASD = autism spectrum disorder; PDDNOS = pervasive developmental disorder not otherwise specified; D3 = DSMIII; D3R = DSMIIIR; D4 = DSMIV; HF = high-functioning; MR = mental retardation; Qual. score = quality score; N.A. = not appropriate.

^a Indicating intermediate age, meaning that authors realized sub-analysis for each intermediate age range.

^b Unless specific indication (DD), control were normally developing children.

^c Mean IQ, or repartition of the autistic sample according to IQ, or IQ range/when indicated, mean IQ in DD sample.

^d Studies excluded from the review of early signs of autism and used in other analyses.

Table 2
Early signs of PDD in home movie studies ($N = 18$): significant differences for infants with ASD compared with typically developing children.

	First year	Second year	Study
Clifford and Dissanayake (2007)	Lower eye contact frequency and quality, less response to name, lower affect quality	Same findings as in the first year, and lower JA frequency (in initiation ++ and response too) and quality, lower requesting frequency (in initiation) and quality Less response to name, peer interest, positive affect, eye contact quality and frequency, declarative showing, nestling, conventional games, functional play, anticipatory postures, more gaze aversion.	1
Clifford et al. (2007)			2
Maestro, Muratori, Cavallaro, et al. (2005)	Less social attention in the first but not in the second semester.		3
Maestro et al. (2002)	0–6 months: less looking at, orienting toward, smiling at, vocalizing to . . . people; less seeking contact, anticipating the other's aim, attuning behaviors, exploration of object.		4
Baranek et al. (2005)	No significant difference across levels of play, or duration of object play.		5
Baranek (1999)	Unusual posturing, less response to name		6
Osterling et al. (2002)	Less orienting to name, looking at people, gesturing, looking at objects held by others, more repetitive actions.		7
Colgan et al. (2006)	Less <i>variety</i> in social gestures; no less <i>total</i> or <i>initiated</i> gestures (pointing was excluded).		8
Werner and Dawson (2005)	Less complex babble or words: EOA < TD < LOA. Less protodeclarative pointing (EOA).	Less words and sentences, declarative pointing, orienting, and gaze.	9
Osterling and Dawson (1994)	Less orienting to name, showing object, pointing (none), looking at face.		10
Werner et al. (2000)	8–10 months: less orienting to name after excluding the 3 LOA		11
Losche (1990)	Less "goal-directed actions"	Less goal-directed actions; sensorimotor development delayed from 13 to 21 months onward and then reduced.	12
Maestro et al. (2006)	EOA: less social attention at 0–6 months; LOA: more social and non-social attention at 6–12 months.	EOA and LOA: less social attention, and more non-social attention at 12–18 months.	13
Maestro et al. (2001)	0–6 months: less pointing comprehension, anticipation of other's aim.	Less communicative gestures, 18–24 months: less shared attention and meaning vocalization.	14
Zakian et al. (2000)	6–12 months: less declarative pointing, communicative gestures. 0–8 months: no significant item	9–17 months: ignores people, poor interaction, no smile, no expressive mimic, too calm, no expression of emotion. 18–24 months: same items and prefers aloneness, no vocal communication, no imitation, inappropriate use of objects, no differentiation of persons, unstable attention.	15
Mars et al. (1998)		Less following verbal directions, looking at faces, showing objects, alternating gaze, looking at people, pointing with gaze, expressing words, imitating vocalizations.	16
Adrien et al. (1993)	Poor interaction, no social smile, lack of appropriate facial expressions, hypotonia, unstable attention.	8 new items: ignores people, prefers solitude, no eye contact, lack of appropriate gestures and or expressive postures, excessively calm, unusual postures, hypoactivity, no expression of emotion.	17
Ozonoff et al. (2007)		Later motor maturity for DD and EOA, compared with TD	18

JA = joint attention; EOA/LOA = children with early-onset/late-onset autism; DD = children with developmental delay; TD = typically developing children.

3. Results

3.1. General comments

Out of the 41 studies gathered, about 70% ($N = 29$) came from five main research groups. The *San Francisco team* in 1975 was the pioneer in publishing studies ($N = 3$) of family home movies of infants who would later develop autism, focusing both on *mother–child interactions* and *early symptoms*. The *Tours team* conducted many studies ($N = 15$), first using a scale constructed to recognize the *early symptoms* of autism, and later, new tools to screen various *early skills* (e.g., gestures, imitation and joint attention). The *Washington team* ($N = 4$) tried to improve upon the methodology by standardizing age and context and comparing with a developmentally delayed sample. The *North Carolina team* conducted studies ($N = 3$) on roughly the same sample, coding first *social, affective and sensori-motor behaviors*, then *object playing* using computer-based coding, and finally *social interaction gestures*. Last, the *Pisa team* ($N = 6$) assessed the onset of symptoms (e.g., early attention to people vs. attention to objects; age of regression) through home movies on large samples with different control conditions, such as early signs from parental interviews and early signs from matched controls with typical development.

Most studies searched for statistically significant differences in autistic vs. control comparisons, whereas others described early signs, skills, or longitudinal development of autistic infants without statistical analysis (Adrien, Faure, et al., 1991; Adrien, Gattegno, Streri, Reynaud, & Barthélémy, 2005; Bernabei & Camaioni, 2001; Bernard, Guidetti, Adrien, & Barthélémy, 2002; Eriksson & De Château, 1992; Gattegno, Ionescu, Malvy, & Adrien, 1999; Massie, 1978a; Sauvage et al., 1988; Teitelbaum, Teitelbaum, Nye, Fryman, & Maurer, 1998; Trevarthen & Daniel, 2005). Finally, some studies aimed to compare different ages (Bernabei, Camaioni, & Levi, 1998; Maestro, Muratori, Cesari, et al., 2005) or different pathological groups (Dubois-Carmagnat et al., 1997; Goldberg, Thorsen, Osann, & Spence, 2008; Receveur et al., 2005). Comparisons with developmentally delayed (DD) children have enabled identification of the specific signs of ASD.

Study quality varied based on the various methodological variables taken into account by our quality grid; 22 studies obtained a score of 13 or more. With regard to early autistic signs, we also excluded four studies without comparisons to typical children (Bernabei et al., 1998; Goldberg et al., 2008; Maestro, Muratori, Cesari, et al., 2005; Receveur et al., 2005), resulting in 18 studies with an aggregate of a maximum of 317 films (perhaps less, since authors might have used the same films twice without mentioning it).

Regarding developmental issues, we found nine articles dealing with late-onset autism (Bernabei & Camaioni (2001); Eriksson & De Château (1992); Goldberg et al., 2008; Maestro, Casella, Milone, Muratori, & Palacio-Espasa, 1999; Maestro, Muratori, Cesari, et al., 2005; Maestro et al., 2006; Osterling, Dawson, & Munson, 2002; Werner & Dawson, 2005; Werner, Dawson, Osterling, & Dinno, 2000) and 11 longitudinal studies (Adrien et al., 1993; Bernabei et al., 1998; Bernard et al., 2002; Bernard, Adrien, Roux, & Barthélémy, 2005; Bernard, Adrien, Roux, & Barthélémy, 2006; Clifford & Dissanayake, 2007; Maestro et al., 1999, 2001; Malvy, Adrien, Roux, Lataste, & Sauvage, 1994; Receveur et al., 2005; Werner & Dawson, 2005). The methodology of all selected studies is summarized in Table 1.

3.2. Early signs of ASD during the first 2 years of life

We summarize the data of the 18 selected studies in Table 2 according to the first and second years of age. In this section and in the next sections, we report in parentheses the number we have given to each study in Table 2. Because for different reasons (see discussion of limitations) home movie studies did not always obtain the same results, we have also signaled conflicting results in parentheses. For the initial 6 months, significant signs were consistently observed only by the Pisa team: less social attention (Table 2: studies 3, 4, 13), anticipation of the other's aim, pointing comprehension and attuning behaviors (Table 2: studies 4, 14), and explorative activity (Table 2: study 4).

In the first year as a whole, signs were present in all major autistic domains: socialization, communication, intersubjectivity, and affect. ASD infants lacked social interest (especially in the first semester), interacted poorly (Table 2: studies 4, 15, 17), and looked at others less in six out of nine studies (Table 2: studies 1, 3, 4, 7, 10, 13; but not in studies 6, 9, 11), but inconsistently displayed qualitative gaze anomalies (Table 2: study 1; but not study 15). They displayed, however, higher non-social attention (Table 2: studies 3, 13). Affective behaviors were also reduced, with less appropriate facial expressions (Table 2: studies 15, 17), but an inconsistent reduction in social smiles (Table 2: studies 4, 15, 17; but not in studies 1, 9, 11) and inconsistent lower quality of affect in one out of two studies (Table 2: study 1; but not study 6). Greater levels of distress were not observed, however (Table 2: studies 6, 9, 10). Response to name was reduced in several studies (Table 2: studies 6, 7, 10, 11; but not study 9), as were communicative gestures (Table 2: studies 7, 14; but not studies 8, 10). Vocalization per se was not significantly reduced (Table 2: studies 7, 9, 10, 11); however, vocalizations *to people* (Table 2: studies 3, 4) were reduced. There was also a reduction in interactive behaviors, such as declarative pointing (Table 2: studies 9, 10, 14), showing (Table 2: study 10) and, in one out of two studies, looking at objects held by others (Table 2: study 7; but not study 9).

Regarding motor activity, results differed across studies, but when compared with DD infants, results were mostly non-specific. As ASD children often have cognitive delays, when an item discriminates ASD children from typical developing ones, we are unable to conclude that this item is specific to autism per se unless it discriminates ASD children from DD ones as well. There may be hypotonia (Table 2: study 17), hypoactivity (Table 2: studies 4, 12; but not studies 15, 17) and delayed motor maturity in both ASD and DD children, with only DD showing movement abnormalities (Table 2: study 18). Repetitive

behavior frequency was either non-significant (Table 2: studies 6, 9, 11) or non-specific compared with DD (Table 2: study 7). Likewise, unusual posturing was not significant (Table 2: studies 15, 17) or non-specific compared to DD (Table 2: study 6). Lastly, neither self-stimulation (Table 2: study 10) nor stereotypies (Table 2: studies 6, 15, 17) were significantly increased in the first year.

It is important to note that during the first year of life, numerous traits identifiable with ASD, such as rigid and repetitive object playing, unusual posturing, less gesturing, less looking at objects held by others, less looking at the camera, and perhaps visual fixation and lower affective expression (Table 2: studies 6, 7) were in fact not discriminated in the delayed infant/typical infant comparison. However, some items did discriminate autistic from DD children in the first year, specifically less frequent orientation to name, looking less at others and lower quality of affect (Table 2: studies 1, 6, 7).

In the second year, poor social interaction persisted, with less looking at people (Table 2: studies 1, 2, 9, 16, 17; but not study 15), decreased quality of eye contact (Table 2: studies 1, 2; but not study 15), and even gaze aversion (Table 2: study 2). New signs were also inconsistently reported, such as isolation (Table 2: studies 15, 17; but not study 16), less nestling (Table 2: study 2; but not study 16) and less imitation (Table 2: study 15; but not study 16). Lower mimicry and expression of emotions (Table 2: studies 15, 17) and positive affect quality (Table 2: studies 1, 2; but not study 16) persisted, with inconsistent reductions in social smiling (Table 2: studies 15, 17; but not studies 1, 2, 9, 16). Communicative gestures, expressive postures (Table 2: studies 14, 17; but not study 16), and response to name (Table 2: studies 1, 2, 9; but not study 16) were lower, as were the number of words and sentences. Autistic infants displayed more stereotyped vocalizations (Table 2: studies 9, 14, 15, 16) and followed verbal directions less (Table 2: study 16). Pointing (Table 2: studies 2, 9, 16), declarative showing, requesting, shared attention, and anticipatory postures (Table 2: studies 1, 2, 14, 16) were reduced, especially in initiation and quality (Table 2: study 1). Activity and cognition were also impaired, as evidenced by the observation of unstable attention (Table 2: studies 15, 17), hypoactivity, hypotonia, unusual postures (Table 2: studies 12, 17, 18; but not study 15), inappropriate use of objects (Table 2: study 15), and lower Piagetian sensorimotor stages (Table 2: study 12), as well as reduced amounts of functional play, symbolic play, and actions following a social script (Table 2: studies 2, 12).

Compared with DD, the signs specific to ASD seemed more numerous in the second year (eight significant items are reported for the second year vs. three in the first year): lower eye contact quality, gaze aversion, lower social peer interest, less positive affect, less nestling, less protodeclarative showing, less anticipatory postures and less conventional games (Clifford et al., 2007; Clifford and Dissanayake, 2007). Eye contact quality and affect quality were found to be the best predictors of a later diagnosis of autism (Clifford et al., 2007). However, regarding protodeclarative pointing, the delayed group fell between typical and autistic groups (Clifford et al., 2007), exhibiting a (slight) delay in joint attention behaviors that was less impaired than in the autistic sample (Clifford and Dissanayake, 2007). Thus, in the second year, pre-autistic signs (lack of social behavior and joint attention) became more obvious, allowing a distinction to be made between autistic and delayed children, whose cognitive delays also increased (Losche, 1990; Rosenthal, Massie, & Wulff, 1980).

3.3. Is autistic regression or late-onset autism (LOA) a valid concept?

Two single-case studies of autistic “regression” reported by parents supported the existence of this phenomenon. The first child waved good-bye, played peek-a-boo, babbled often, played normally and used protodeclarative pointing before the occurrence of an acute regression around 12 months. He then showed signs of withdrawal as well as both silent and repetitive behavior and play (Eriksson & De Chateau, 1992). The second child smiled, gazed, pointed, waved and played patty-cake, but from 22 months onward, the child began to show repetitive and stereotyped behavior, isolation, language stagnation, and decline of mental age (Bernabei & Camaioni, 2001). Until 12 months of age, he always turned when called; between 12 and 19 months of age, he then engaged in this behavior inconsistently, and after 22 months, the child no longer responded (Bernabei & Camaioni, 2001).

Goldberg et al. (2008) focused on the concordance between information derived from parental report and from the direct observation of home movies and reported better concordance for language loss than for other losses (e.g., pointing, showing, joint attention, social gaze, orienting to name, functional and symbolic play), which parents often failed to report. Furthermore, two studies focusing on the time of onset that included 40 and 26 cases, respectively (Maestro et al., 1999; Maestro, Muratori, Cesari, et al., 2005), showed that most cases began in the first semester, whereas other cases began within the second semester and a few cases after the first year (late-onset autism; LOA). However, even after a regression, islands of interaction and communication persisted for several months (Bernabei & Camaioni, 2001), and then disappeared completely. Only three studies directly compared infants with early-onset autism (EOA) and LOA, according to regression reported by parents on the ADI-R (Osterling et al., 2002; Werner & Dawson, 2005) or assessed in home movies (Maestro et al., 2006). At 1 year of age, infants with LOA did not differ from typical children; they gazed (Maestro et al., 2006; Osterling et al., 2002), smiled (Maestro et al., 2006), vocalized to people (Maestro et al., 2006; Werner & Dawson, 2005), pointed (Werner & Dawson, 2005), oriented to their name (Osterling et al., 2002) and paid attention to objects held by others (Osterling et al., 2002) as typical children did. This differed significantly from infants with EOA. However, there may be some slight signs of LOA in the second semester, such as higher scores on non-social competencies (Maestro et al., 2006).

In contrast, at 2 years of age, there were no differences between EOA and LOA in declarative pointing, social gaze, orienting to name, or language development (Werner & Dawson, 2005). Finally, in the light of this review, LOA appears to be a valid concept. A child from the LOA group may coarsely be defined as resembling a typical child at 1 year and then shifting to resemble an EOA child at 2 years.

3.4. Developmental course in early-onset autism

Although longitudinal studies show that every child's development is unique, we will describe a mean course. As seen above, in EOA, the core autistic symptomatology, lack of social and communicative activity, is present from the first year, and even from the first semester, but at a lower rate. This could explain why professionals do not detect it earlier. Thus, all children seem to have mutual attention and emotional reactions from the first months of life, and some of them show social interest, social turn-taking, and peek-a-boo (Bernabei et al., 1998). Therefore, social skills may be present at the beginning of life, though infants, who later go on to be diagnosed with ASD, rarely make use of them. Children then seem to progress in social (Bernabei et al., 1998) and communicative areas (Bernard et al., 2002) from the first to the second or third semester, before losing previously mastered behaviors, especially ones that are socio-interactive and associated with attachment (Bernabei et al., 1998; Bernard et al., 2002). In the second year, poorer social interest and reactivity change into aversion and avoidance, with a decrease in social activity (Adrien et al., 1993; Bernabei et al., 1998; Malvy et al., 1994; Receveur et al., 2005; Werner & Dawson, 2005) and communicative gestures (Adrien et al., 1993; Bernabei et al., 1998; Bernard et al., 2002; Malvy et al., 1994), making the pathology easier to detect. EOA and LOA showed, between 12 and 24 months, an absolute decrease of the same magnitude in social gaze (Werner & Dawson, 2005). Likewise, intersubjective skills (pointing, shared attention, anticipation, initiation of requests), though reduced early on in a child's development, may increase within the second year (Bernabei et al., 1998; Bernard et al., 2002; Clifford and Dissanayake, 2007; Maestro et al., 2001) before decreasing at the end of the second year (Bernabei et al., 1998; Bernard et al., 2002; Maestro et al., 2001). Also, vocalization to people decreased in the first semester (Maestro et al., 2002; Maestro, Muratori, Cavallaro, et al., 2005), increased within the second semester (Maestro, Muratori, Cavallaro, et al., 2005) and then stagnated within the second year (Werner & Dawson, 2005). This stagnation occurs at a time when, in typical children, there is a tremendous increase in expressive language. Nevertheless, some ASD children did produce words in the second year (Bernabei et al., 1998; Bernabei & Camaioni, 2001). With regards to verbal comprehension, although children with autism are usually less attentive to language and less responsive to name by the end of the second semester (Werner et al., 2000), some children do exhibit verbal comprehension in the first year and maybe more in the 2nd year (Bernabei et al., 1998).

As for autistic onset, several courses of cognitive development are observed (Rosenthal et al., 1980): cognitive delay appears to be both an early and dynamic phenomenon, with developmental alteration over time (Losche, 1990; Rosenthal et al., 1980) and perhaps even an *absolute* cognitive decline (Bernabei & Camaioni, 2001; Losche, 1990). This cognitive alteration goes along with autistic symptomatology: children who ignored people more in the third semester became more delayed later on (Receveur et al., 2005). Though reduced since the first months of life, many social, communicative and intersubjective skills are present and even *growing* during the first 2 years, before beginning to stagnate or even decrease in the second and/or third year.

4. Discussion

4.1. Comparing findings from home movie studies with those from prospective studies

Some limitations of home movie studies have been emphasized, such as the uncertainty concerning their representativeness, the lack of standardization, and the risk of selection by parents. Fortunately, recent prospective studies using high-risk samples (e.g., those with autistic siblings) confirm most home movie's results, validating their merit. Indeed, prospective studies showed an early lack of social engagement around the first birthday (Landa, Holman, & Garrett-Mayer, 2007; Zwaigenbaum et al., 2005) and even between 6 and 12 months (Bryzon et al., 2007). In prospective studies, communication skills were also impaired as early as 12–14 months, with a reduced response to name (Nadig et al., 2007; Zwaigenbaum et al., 2005), reduced phrases and/or vocabulary comprehension (Landa & Garrett-Mayer, 2006; Mitchell et al., 2006; Zwaigenbaum et al., 2005), reduced language production (Landa & Garrett-Mayer, 2006; Zwaigenbaum et al., 2005) and reduced gesture production (Mitchell et al., 2006; Zwaigenbaum et al., 2005), all predicting an outcome of autism spectrum disorder (ASD) at 2 or 3 years. Reduced intersubjective skills already described in clinical settings at 18 months (Baron-Cohen et al., 1996; Wetherby, Watt, & Morgan, 2007) have been found even at 14 months (Sullivan et al., 2007). Early affective impairments and irritability have also been found between 6 and 12 months (Bryzon et al., 2007), and more distressed reactions have been found at 12 months (Zwaigenbaum et al., 2005). Lastly, hypoactivity at 6 months (Zwaigenbaum et al., 2005) and more stereotyped behaviors as early as 12 months (Loh et al., 2007) were also found, but the latter study found sizeable overlap between the group of siblings who would become ASD, the group of siblings who would not, and the control group. Regarding specificity, a study comparing ASD, DD and TD communication in the 18–24-month period found impairments in the ASD group for social, intersubjective and communicative fields, with gaze shifts, gaze/point follow, acts for joint attention and the rate of communicating specifically impaired, when compared with the DD group (Wetherby et al., 2007).

Concerning the developmental course, prospective studies again converge with home movie studies, showing a great variability in the individual course of development (Bryzon et al., 2007). In particular, one prospective study has supported the validity of regression (Landa et al., 2007). Also, they suggest a dynamic alteration during development, with ASD infants showing a decrease in social engagement, concomitant with irritability and intolerance to intrusions (Bryzon et al., 2007), as well as a decrease in disengagement of visual attention skills (Zwaigenbaum et al., 2005) between 6 and 12 months. In the

second year, they showed a slower increase of development in all scores of the Mullen Scales of Early Learning with, at times, an absolute decrease in one or more scores (Landa & Garrett-Mayer, 2006), a frequent notable decrease in developmental quotient on either the Bailey or Mullen scales (Bryzon et al., 2007), and stagnation in response to joint attention (Sullivan et al., 2007). Thus, we can state that home movie studies provide reliable and naturalistic data about ASD infancy, which have useful and valuable clinical and theoretical implications.

4.2. What are the early warning signs for ASD that can be used in an early screening?

A large consensus exists in the literature for the idea that early treatment may positively influence the course of autism. Pursuing a thorough analysis of home movie findings could help to operationalize new tools for early screening, as has been done by the North Carolina group (Baranek et al., 2005; Reznick et al., 2007) with the First Year Inventory. With regards to developmental maturation, it appears that signs of risk during the first year are poorer social interest (e.g., poor interaction and not looking at others, especially in the face), poorer communication (e.g., vocal and gestures expression and reception, especially response to name), poorer intersubjective skills, and poorer affective expression. Lastly, detection of at-risk infants becomes easier in the second year, because early social signs are intensifying; expressive and receptive language fails to develop (and is often the first sign reported by parents), while the lack of intersubjective skills and affective expression persists. We have summarized this developmental view in Fig. 1.

Because there are numerous early warning signs, should there be a preference for which one to use? Some authors used a discriminant analysis technique to estimate the discriminant power of potential markers (Baranek, 1999; Clifford et al., 2007; Maestro, Muratori, Cavallaro, et al., 2005; Mars, Mauk, & Dowrick, 1998; Osterling et al., 2002; Osterling and Dawson, 1994; Werner et al., 2000). The most reproducible discriminant criteria may be “response to name” (Baranek, 1999; Clifford et al., 2007; Osterling et al., 2002; Osterling and Dawson, 1994; Werner et al., 2000) as soon as the end of the first year of life, “looking at faces” or “eye contact” (Clifford et al., 2007; Mars et al., 1998), and “pointing” or “showing” (Mars et al., 1998; Osterling and Dawson, 1994). In regards to specificity, “quality of eye contact” and “quality of affect” were the best predictors of autism in a previous study, allowing, with peer interest and response to name, a correct classification of 79% of children with autism among three populations (AD/DD/TD) in the second year (Clifford et al., 2007).

Indeed, specificity and sensitivity also must be accounted for. First, regarding specificity, delays in verbal expression and comprehension are not specific to ASD; given their great developmental variability, they can also belie a developmental delay, a specific language disorder, or can even be seen in a typical developing child. Furthermore, although they may not be specific to autism, delays in the use and understanding of language used in combination with social and communication deficits can be extremely useful for identifying children with ASD. Second, dealing with cognitive impairment in children with autism is a critical issue. Most studies controlled mean QD of their autistic sample in retrospective measures, always finding a lower QD than in the control sample. The question arises as to whether the QD (or IQ) at the age of diagnostic and

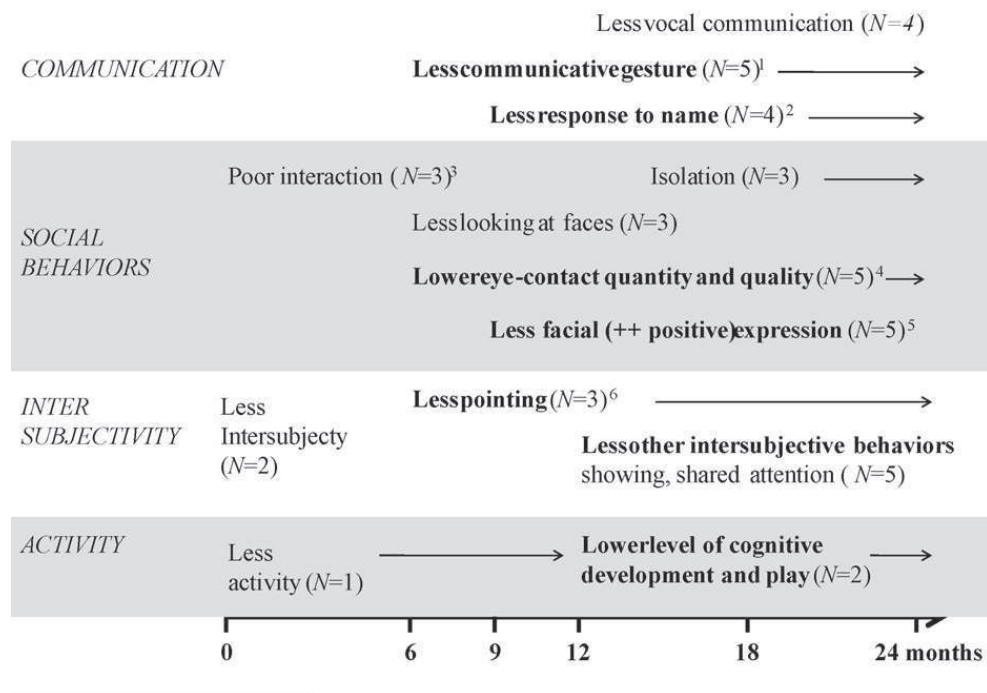


Fig. 1. Early signs of autism according to age and main developmental domain from home movie studies. Signs that are more specific to autism (compared to children with developmental delays) appear in bold. N indicates the number of studies reporting the corresponding item. ¹significant in the 6–12-month period in 1 study; ²significant in the last months of the first year in 3 studies; ³significant in the 0–6-month period in 1 study; ⁴significant in the 6–12-month period in 2 studies; ⁵significant in the last months of the first year in 2 studies; ⁶significant in the 6–12-month period in 1 study.

evaluation (often between 3 and 6 years of age) is the same as in infancy, before the full installation of autistic symptoms. Studies focusing on the cognitive development of children with autism (Losche, 1990; Rosenthal et al., 1980) showed that their development was often impaired very early. Thus, some early signs found in the autistic vs. typical infants' comparison could prove to be signs of delayed development. Comparisons with delayed children are thus very valuable to highlight the signs that are more specific to autistic disorders. Unfortunately, only a few studies compared these three samples: autistic vs. delayed vs. typical children (Baranek et al., 2005; Baranek, 1999; Clifford et al., 2007; Clifford and Dissanayake, 2007; Osterling et al., 2002; Ozonoff et al., 2007). They showed that some early signs are related to delay rather than to autism itself. Even though autistic and delayed children have similar repetitive behaviors, cognitive delays and even more or less delay in the emergence of intersubjective skills, children with autism differ from delayed ones in socialization, affect quality, and to a certain extent, intersubjective skills. In order to further extend our knowledge as to which signs are specific to autism, another focus of interest should be home movie studies of high-functioning autistic cases.

With regard to sensitivity, as seen above, longitudinal studies have shown a great variability in the developmental profiles within the ASD group. Variability includes not only late-onset cases, but also early-onset cases, where there can be a possible decrease in skills throughout the second year and fluctuating cases with persisting islands of good interaction before the full installation of the autistic state. Moreover, babies who have become autistic can look and smile at others, look back during protoconversation, and have eye contact and warm connections with others, even if these behaviors are less frequent than in typical babies and need to be provoked by others in order to surface. Essentially, infants with autism fail to transform simple social behaviors into a series of successively more complex interpersonal relationships (Muratori & Maestro, 2007). For this reason, the risk of false negatives is great with regards to basic signs, suggesting that a good screening should search for more complex intersubjective impairments, such as initiation of interaction. Screening may be conducted twice to enhance the chances of detecting fluctuating and LOA cases. On the basis of the Pisa team's work (Maestro et al., 2001, 2002, 2006; Maestro, Muratori, Cavallaro, et al., 2005) that found early reduction of social and intersubjective manifestations, we can expect very early detection, as soon as 6 months of age. The French prospective "Preaut" study, currently ongoing, is attempting to detect signs as early as 4 and 9 months of life on the basis of dynamic intersubjective signs, like the manifestations of the desire to raise pleasure (to be a source of joy) in others (Cullere-Crespin, 2007; Laznik, 2007).

In summary, which warning signs should be preferentially used for an early screening? While pointing is an easy potential early marker, as it appears as soon as the beginning of the second year, it may lack specificity. In contrast, decreases in orienting to name, looking at others and affect quality can distinguish autistic from delayed and typical children, especially in the first year. While failure to look at faces may not be sensitive enough, and lower affect quality may be difficult to

Table 3
Early screening for risk of autism according to prospective and home movie studies.

	Signs	Sensitivity		Specificity
		Prospective studies	Home movie studies	
First semester	Less social attention and activity		3/3	
	Less intersubjectivity		2/2	
	Hypoactivity/hypotonia	1/2	1/1	
End of the first year	Less looking at/less orienting toward others	2/3	6/9	++
	Poor interaction		3/3	
	Less facial expression	1/2	2/2	-
	Less social smile		3/6	
	Less affect quality		1/2	++
	Less communicative gestures	3/3 (S = 0.33)	2/4	-
	Less social vocalization		2/2	
	Poor response to name	2/2 (S = 0.5)	4/5	++
	Less pointing	1/1	3/3	+/-
	Less other intersubjective behaviors	2/2	5/6	-
Second year (18–24 months)	Less looking at people	3	5/6	++
	Lower eye contact quality		2/3	++
	Less positive affect		1/2	++
	Less communicative gestures/postures	3/3	2/3	
	Less vocal communication	4/4	4/4	
	Language comprehension	3/3	1/1	
	Less response to name	2/2	3/4	
	Less pointing	2/2	3/3	+/-
	Other ISB: showing, RJA, anticipatory postures	5/5	4/4	+++

ISB: intersubjective behaviors; RJA: response to joint attention.

Specificity in autistic/delayed comparison: (-) not specific in home movie studies; (+/-) partially specific in home movie studies; (++) specific in home movie studies; (+++) specific in home movies + prospective studies.

Sensitivity: rate of studies that found significance for this item; S = sensitivity as calculated in one study. Most pertinent items (as regards sensitivity, reproducibility and specificity) appear in bold.

operationalize for screening purposes, the failure to respond to name appears to be an early, easy, discriminant and reproducible sign of ASD. On the basis of both home movies and prospective studies, we gathered early signs that could be used for early screening of infants at risk for ASD, shown in Table 3.

4.3. Developmental issues

Home movie studies validate the existence of LOA cases, reported and described by parents as a “regression”. These infants seem to develop normally during the first year, even showing social and communicative skills, which later disappear during the second year. Furthermore, the developmental course of autism seems to be very different from one child to another, and even sometimes fluctuates for the same child. Thus, in the first few years, it might be useful to classify children according to the type of onset (previously assessed through home movies) before practicing statistical measures on any particular symptom. For example, it appears useful to study late and early onsets separately.

The early dynamic course of skills and autistic signs raises a more theoretical issue: are social skills a primary disorder or a downstream effect of another primary phenomenon? Mundy and Crowson (1997) proposed a cybernetic model in which a primary deficit in social attention (or Trevarthen's primary innate intersubjectivity, 1979), and especially a difficulty in eye contact, causes a scarcity in social information and a subsequent difficulty in joint attention skills. Likewise, according to Hobson's theory (1993), the difficulty in affective expression at a dyadic level causes subsequent difficulty in joint attention skills. More recently, Pelphrey and Carter (2008) have proposed that social deficits are central to autism in the sense that early failures in social engagement play a causal role in the emergence of the communication deficits and repetitive, stereotyped behaviors and interests. Our review, showing very early social signs, and a secondary *decrease of communicative skills*, lends support to these hypotheses. In dealing with language acquisition, the fact that some autistic infants were able to listen and understand language early on, and even produce words, but with an early decrease observed in gestural communication and intersubjectivity, suggests the existence of dysfunction located upstream of language treatment. Thus, instead of a perceptive impairment, failure in language acquisition appears as a lack of interest in humans. However, an alternative hypothesis may be that there is a failure in neural commitment to language processing that occurs around the first year of life (Kuhl, 2004).

However, given that we know now that social anomalies of the autistic infant are present very early in life, a further issue will be to consider how these early anomalies modify parental attachment and behaviors. From the first months, Massie (1978b) found a significant lack of attachment behaviors (visual-touch-holding) from the mothers, often with gaze aversion, which contrasts with the good attachment behaviors made toward the next-born child (Massie, 1978a). On the other hand, unconscious compensatory behaviors from parents were also observed from the first months: attempts to establish communication, increasing the saliency of a given stimulus (Doussard-Roosevelt, Joe, & Bazhenova, 2003) through repetitive cuing, with for example repeated prompting (Adrien, Faure, et al., 1991; Adrien et al., 1992; Baranek, 1999; Trevarthen & Daniel, 2005). Under certain conditions like physical games (Trevarthen & Daniel, 2005), repeated prompting (Baranek, 1999), and motherese (Laznik, 2007), the child become able to respond. Thus, the interactions appear to be amended in a complex way that may imply bidirectional processes.

5. Conclusions

We conclude that home movie studies converge with the findings of prospective studies on early signs of ASD and should be considered as interesting tools for study of the first months of life. However, early diagnosis of ASD remains a complex challenge. The home movie studies may also be promising for future research by creating and using computerized methods of study for specific markers that could dramatically reduce the time needed for “manual” investigations (Mahdhaoui et al., *in press*). Other methodological perspectives include studies of high-functioning autistic infants, development of longitudinal studies, and separate studies of early- and late-onset cases. Lastly, considering the early lack of social interest and the sporadic use of social skills, further research should focus on interactive sequences, exploring what context allows an autistic infant to engage in a dyadic exchange and communication. This last point seems to be of seminal importance from both theoretical and therapeutic perspectives.

Acknowledgements

The current study was supported by a grant (no. 2008005170) from the *Fondation de France* given to MC and DC and by grants PRIN 2003–2005 and PRIN 2005–2007 from the Italian Ministry of Instruction, University, and Research (MIUR) given to PM.

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2. Etude des interactions synchrones et réciproques chez le bébé à devenir autistique

2.1. Importance de la synchronie

2.1.1. Définition

Pour Feldman, la synchronie dans l'interaction parent-bébé intègre la co-occurrence de comportements, d'états affectifs et de rythmes biologiques entre parents et bébé qui forment ainsi ensemble une unité fonctionnelle (Feldman, 2007). Elle souligne l'importance de la synchronie dans la communication émotionnelle et la maturation du cerveau social, son insertion dans des processus somatiques impliquant des rythmes physiologiques et des facteurs hormonaux et elle propose d'en faire un modèle de l'intersubjectivité. La synchronie commence donc dès la vie prénatale (échanges neuro-endocriniens, sensoriels) et continue après la naissance à travers l'interaction (échanges émotionnels et sensoriels : voix, regards, odeur...).

2.1.2. La synchronie dans les interactions en face à face

De nombreux auteurs se sont intéressés aux micro-analyses d'interactions parents-bébé en face à face, montrant que la communication passe par la synchronie, qui repose sur les compétences précoces du bébé et les capacités d'accordage des parents. Ainsi Condon et Sander ont montré que le nouveau-né est d'emblée dans une synchronie avec le rythme de la voix de sa mère (Condon & Sander, 1974). Les nouveaux-nés sont capables de se synchroniser avec la « narration émotionnelle » de l'adulte par des gestes ou par des émissions vocales en miroir (Malloch, 1999/2000). Stern a aussi étudié l'articulation et la synchronie des comportements dans les interactions mère-bébé (D. N. Stern, Jaffe, Beebe, & Bennett, 1975). Trevarthen a souligné que le rythme constitue un premier mode de communication entre le bébé et sa mère: protoconversation, orchestrée par la synchronie et qui préfigure le tour de parole (Trevarthen & Daniel, 2005). Crown également a montré l'accordage des rythmes des regards du bébé avec celui des vocalisations maternelles (Crown, Feldstein, Jasnow, Beebe, & Jaffe, 2002).

Mais les parents s'adaptent encore plus au bébé. Interrogeant la prédictibilité des comportements de sourire et de regard de chaque partenaire, Messinger a montré que le comportement de la dyade obéit à des règles : le parent est

assez prédictible en s'adaptant à l'enfant et au début c'est lui qui est à l'initiative du sourire, et il répond toujours lui-même au sourire de l'enfant. En revanche, l'enfant ne répond pas toujours et est donc moins prédictible, surtout au début, mais le devient de plus en plus au fil du temps (Messinger, Ruvolo, Ekas, & Fogel, 2010). Messinger évoque aussi la notion « d'états dyadiques » quand il y a co-occurrence de sourire par exemple. Le bébé perçoit la réponse accordée, synchronisée de l'adulte et de nombreux travaux ont montré qu'il est déstabilisé par le défaut de synchronie.

2.1.3. La rupture de synchronie : effets à court terme

Brazelton a constaté les effets négatifs d'un visage figé sur des bébés de 3 semaines (Brazelton, Tronick, Adamson, Als, & Wise, 1975). Le paradigme du **still face** a été développé par Tronick (Tronick, Als, Adamson, Wise, & Brazelton, 1978) et on a pu envisager la dépression comme un modèle naturel de still-face et d'asynchronie (Stanley 2004). L'importance de la synchronie dans les interactions mère-bébé a aussi été étudiée dans des expériences de **déphasage**, en double circuit audio-vidéo. Les premiers, Murray et Trevarthen (Murray & Trevarthen, 1985) ont conçu un schéma en 2 temps : en direct puis en déphasé (le bébé reçoit en différé l'enregistrement de la mère). Ils ont montré que les bébés de 6 semaines sont perturbés par un délai de transmission du comportement maternel (dyssynchronie). Nadel (Nadel, Carchon, Kervella, Marcelli, & Réserbat-Plantey, 1999) a repris cette expérience sur des bébés de 2 mois avec leur mère, mais cette fois en 3 temps (direct/déphasé/direct), pour vérifier que la perturbation observée lors du déphasage n'est pas liée simplement à la fatigue du bébé. Lors du déphasage, les bébés arrêtent de sourire, de regarder, de donner des signaux communicatifs. Il y a un désintéressement de la communication, puis ils ont un regain d'intérêt pour la communication lorsqu'elle redevient synchronisée. Henning a étudié la réciproque sur le même principe expérimental : dans un double circuit vidéo, un délai de 3 secondes perturbe le comportement du bébé de 3 et 6 mois mais pas celui de la mère (Henning & Striano, 2011).

2.1.4. Rôle de la synchronie : effets à long terme

Feldman a souligné l'importance de la synchronie entre parents et bébé dans la co-construction progressive de l'interaction sociale (Feldman, 2003). En effet, la synchronie de la mère vis-à-vis de l'affect du bébé à 3 mois et la synchronie mutuelle mère-enfant à 9 mois sont des prédicteurs du self-contrôle de l'enfant à 2 ans (Feldman, Greenbaum, & Yirmiya, 1999).

De plus, la synchronie joue un rôle dans le développement cognitif, comme la capacité à détecter des relations de contingence en rapport avec ses actions, ou encore l'acquisition du langage. Dans un travail sur la prise en

compte des contingences sociales et non-sociales, Lohaus montre une relation entre l'expérience de réponses sociales contingentes de la part de ses parents (index de «responsiveness» sur la base d'une latence de 1 seconde) et la capacité du bébé de 3 mois à détecter des contingences non-sociales dans lesquelles il est impliqué (Lohaus et al., 2005). Et Goldstein a montré l'importance de l'interaction en direct (et donc synchrone) dans des processus cognitifs comme l'acquisition du langage : la maturation des vocalisations du bébé avec sa mère ne survient que si celle-ci fournit des réponses contingentes aux vocalisations du bébé et pas lorsque le bébé reçoit la même quantité de réponses mais non-contingentes (Goldstein, King, & West, 2003).

L'attention conjointe, fonction pivot du développement de la communication et de l'intersubjectivité, est reconnue pour être défaillante chez l'enfant autiste (Charman, 2003) et l'étude des films familiaux nous a montré qu'elle semble l'être très précocément (au 2^e semestre). Or l'attention conjointe implique évidemment la synchronie. De façon intéressante, Siller a montré que même si les parents d'autistes font preuve d'autant de synchronie et d'attention partagée que les autres, à l'intérieur du groupe des parents d'autiste, leur taux de synchronie et d'attention partagée aux intérêts du bébé est corrélé au développement ultérieur du langage et de l'attention conjointe (Siller & Sigman, 2002).

2.1.5. L'imitation immédiate, une forme parfaite de synchronie ?

Dès la naissance, le bébé est préparé à entrer en contact par l'imitation (Nagy). Dès 2 semaines, le bébé est capable d'imiter des expressions faciales (Meltzoff & Moore, 1977), et dès 6 semaines, il détecte qu'il est imité par l'adulte et préfère cela à une réponse contingente mais désaccordée (Meltzoff, 1990). Les allers-retours de l'imitation sont une forme particulière de synchronie qui suscite un plaisir interactif et favorise sans doute la prise de conscience de soi en tant qu'agent semblable et en interaction avec un autre et donc le développement de l'intersubjectivité. Nadel (Nadel, 2011) a en effet montré que l'imitation a une fonction de communication préverbale chez l'enfant (particulièrement entre 2 et 4 ans, mais aussi dès la première année), et que cette communication possède les caractéristiques de synchronie, de tour de rôle et d'attention conjointe inhérentes à toute communication. Les jeunes enfants aiment beaucoup imiter et être imités et s'en servent entre eux pour entrer en contact et se « parler » sans mot. La reconnaissance du fait d'être imité par l'autre crée un intérêt envers l'autre, et pousse à imiter l'autre (cf a contrario les protocoles d'interaction déphasée où le bébé se désintéresse de sa mère qui n'est plus synchrone, et cesse de l'imiter). L'imitation apparaît aussi comme un soutien probable au

phénomène d'attention conjointe (l'imitation médiée par un objet crée une situation d'attention conjointe sur l'objet). De plus, l'imitation agit comme précurseur de la reconnaissance par le bébé de l'intentionnalité de l'autre (l'imitateur), ouvrant finalement l'accès à l'intersubjectivité (si l'autre m'imité, c'est qu'il a une *intention* de m'imiter d'une part, et quand il m'imité, il ressent la même chose que moi, d'autre part). Enfin, il a été montré que chez l'autiste, comme chez l'enfant préverbal, l'imitation favorise l'interaction, mieux que d'autres interventions interactives (Nadel, 2011). L'imitation synchrone apparaît donc comme un moyen privilégié d'entrer en communication avant l'utilisation du langage.

Par ailleurs, la synchronie interpersonnelle a un support neuronal démontré dans un travail récemment publié : la synchronie dans l'imitation libre entre deux personnes est corrélée à l'émergence d'une synchronisation des cerveaux dans la bande alpha-mu (une zone impliquée dans l'interaction sociale) (Dumas, Nadel, Soussignan, Martinerie, & Garnero, 2010). En conclusion, la prise en compte de la synchronie apparaît nécessaire à l'étude de l'interaction fine parents-bébé, et nous intéresse d'autant plus qu'elle semble au cœur de processus liés à l'intersubjectivité, que les films familiaux nous ont montré très tôt défaillante.

2.2. Approche méthodologique

Afin d'étudier l'interaction parents-bébé autiste, nous avons repris des films familiaux de bébés autistes déjà analysés et cotés par l'équipe de Pise dans un travail récemment publié (Muratori et al., 2011) et utilisant une grille avec des items pour le bébé et des items pour le care-giver. Ce premier travail avait montré, dès le premier semestre, une moindre durée des moments d'échange et de partage affectif ("syntonie") du bébé autiste avec ses parents. On retrouve là l'idée d'un manque très précoce d'intérêt et de réactivité à autrui. Au 2e semestre, on observe une diminution de comportements plus élaborés (mettant probablement en jeu des mécanismes en lien avec l'intersubjectivité secondaire): entretenir et maintenir l'interaction, répondre à une invitation, répondre à l'appel du prénom. Au 3e semestre, d'autres diminutions de comportements intersubjectifs viennent s'ajouter (regard référentiel, vocalisations significatives) et on observe en plus un manque de recherche active de l'autre (soliciting).

Comment prendre en compte plus avant la qualité de l'interaction et la réciprocité au sein de l'interaction ? Comment capter des indices de la dynamique interactive, voire des boucles interactives ? Quels comportements du care-giver influent sur le comportement du bébé et comment le bébé impacte-t-il en retour les interactions du care-giver ?

Dans une approche multidisciplinaire (psychopathologie-ingénierie), nous avons envisagé l'étude de la synchronie, traduite en co-occurrence des comportements du bébé et du care-giver dans une même fenêtre temporelle, comme indice des interactions réussies. L'étude bidirectionnelle de l'interaction est fournie par le sens de la succession temporelle (sens parent→bébé ou sens bébé→parent). Ainsi, nous avons utilisé et développé des méthodes computationnelles pour extraire et analyser les moments de comportement interactif synchrone entre parents et bébé (filtrage des interactions "réussies"). Nous y avons adjoint l'étude développementale (longitudinale) pour tenter de rendre compte de l'évolution et des processus d'ajustement dans la diade et la triade.

L'étude porte sur un échantillon index de 15 enfants diagnostiqués "Trouble autistique". Le groupe contrôle comprend d'une part 15 enfants normaux et d'autre part 12 enfants avec retard mental. L'ensemble des films tournés par les parents les 18 premiers mois de la vie a été analysé pour en extraire toutes les séquences d'interaction potentielle c'est-à-dire avec le bébé en présence d'un care-giver. Les scènes, d'une durée de 1 à 4 minutes, ont été datées par semestre (1^{er}, 2^e ou 3^e semestre), découpées et mélangées pour être cotées en aveugle. La grille de cotation regroupe des items comportementaux, concernant d'une part le bébé (29 comportements en direction d'autrui ou d'un objet), et d'autre part le care-giver (8 comportements "relationnels" en direction du bébé, à l'exclusion des comportements directement en relation avec les soins maternels). La grille a été entrée dans le logiciel Observer, prévu pour faciliter et accélérer la cotation manuelle. Celle-ci a été réalisée par des cotateurs entraînés, la fidélité interjuge étant vérifiée par une double cotation sur une partie des scènes. Tout ce travail a été réalisé en amont par l'équipe de Pise (Muratori et al., 2011).

Nous avons ensuite repris l'ensemble de ces cotations. La méthodologie permettant de prendre en compte la synchronie et la réciprocité dans les interactions est résumée sur la figure 2. De façon à simplifier l'analyse ultérieure des données, nous avons défini des méta-comportements, à partir de considérations cliniques et théoriques, et regroupé ainsi les 29 comportements du bébé en 6 "méta-comportements" et les 8 comportements du care-giver en 5 "méta-comportements". Les cooccurrences ont alors été modélisées par des modèles de Markov, extrayant donc les comportements du bébé suivis d'un comportement relationnel du care-giver dans les 3 secondes (considéré comme une réponse)= interaction bébé→care-giver d'une part, et d'autre part les comportements relationnels du care-giver suivis d'un comportement du bébé dans les 3 secondes (considéré comme une réponse du bébé) = interaction care-giver→bébé. Les principaux modes interactifs entre parents et bébé ont été décrits, par groupe et par semestre, dans les 2 sens de l'interaction, à l'aide d'un modèle probabiliste d'interaction (diagramme Markov). Un modèle statistique mixte linéaire généralisé (prenant en compte l'effet sujet)

nous a ensuite permis de comparer les 3 groupes, globalement, par semestre, et aussi dans une dynamique développementale (modifications significatives au fil des semestres) pour chaque groupe.

Enfin nous avons utilisé une méthode de factorisation en matrices non-négatives (NMF), permettant une modélisation intégrative prenant en compte l'ensemble des dyades comportementales, et une décomposition en clusters (clustering) sur la base de la variance. Le nombre de clusters traduit la richesse de l'interaction. Nous avons analysé les similarités développementales des groupes pathologiques avec le groupe typique à l'aide du calcul d'information mutuelle normalisée (NMI) (Mahdhaoui, 2010).

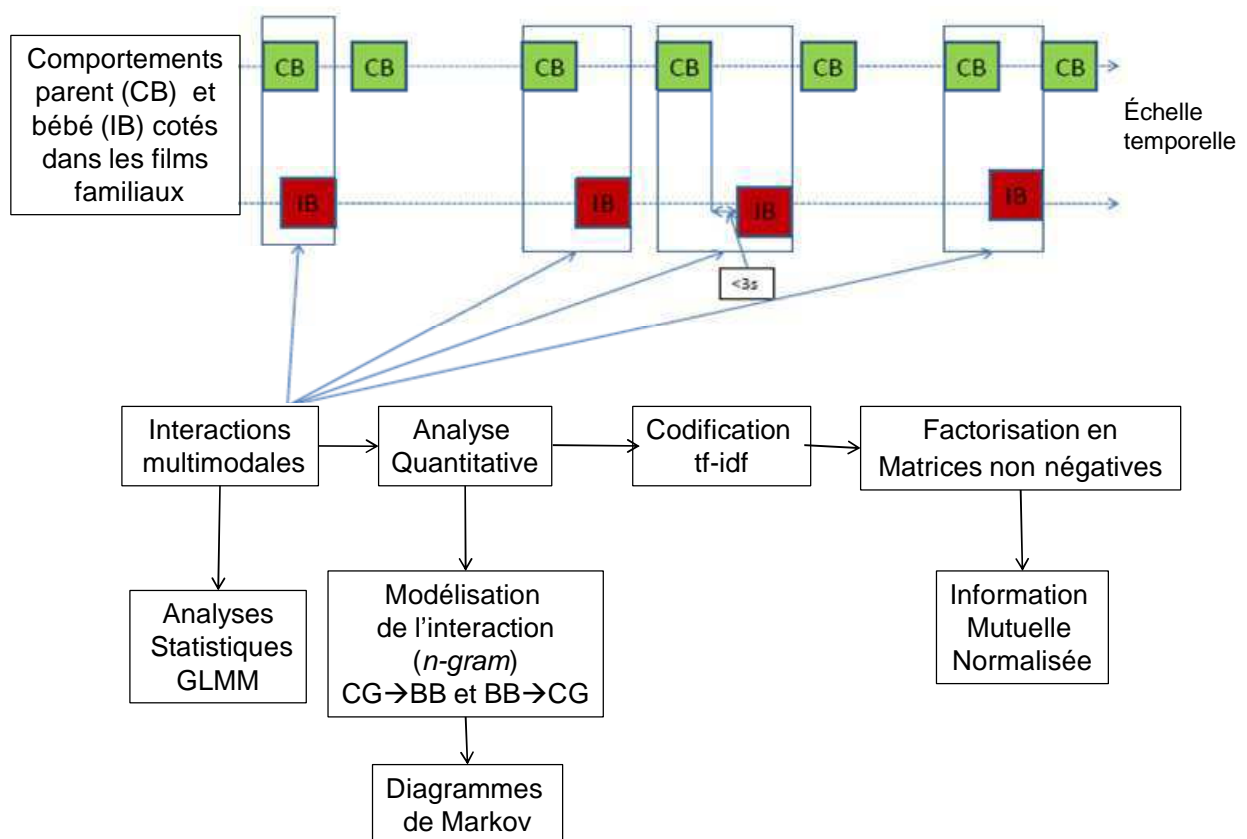


Figure 2. Analyse de l'interaction parent-bébé: principes généraux.

{CG→BB} ensemble des patterns interactifs du caregiver (CG) vers le bébé (BB)

(Saint-Georges et al., in press) ensemble des patterns interactifs du bébé (BB) vers le caregiver (CG)

GLMM=Modèle Mixte Linéaire Généralisé

2.3. Principaux résultats

2.3.1. Etude développementale des interactions synchrones du bébé typique

Nous considèrerons simultanément dans le pool des interactions réussies, d'une part l'évolution au fil des semestres de la répartition relative des divers comportements du care-giver et du bébé (selon le diagramme de Markov), et d'autre part, en valeur absolue, les variations statistiquement significatives des comportements d'un semestre à l'autre (d'après le modèle mixte linéaire généralisé). La figure 3 présente une synthèse des résultats.

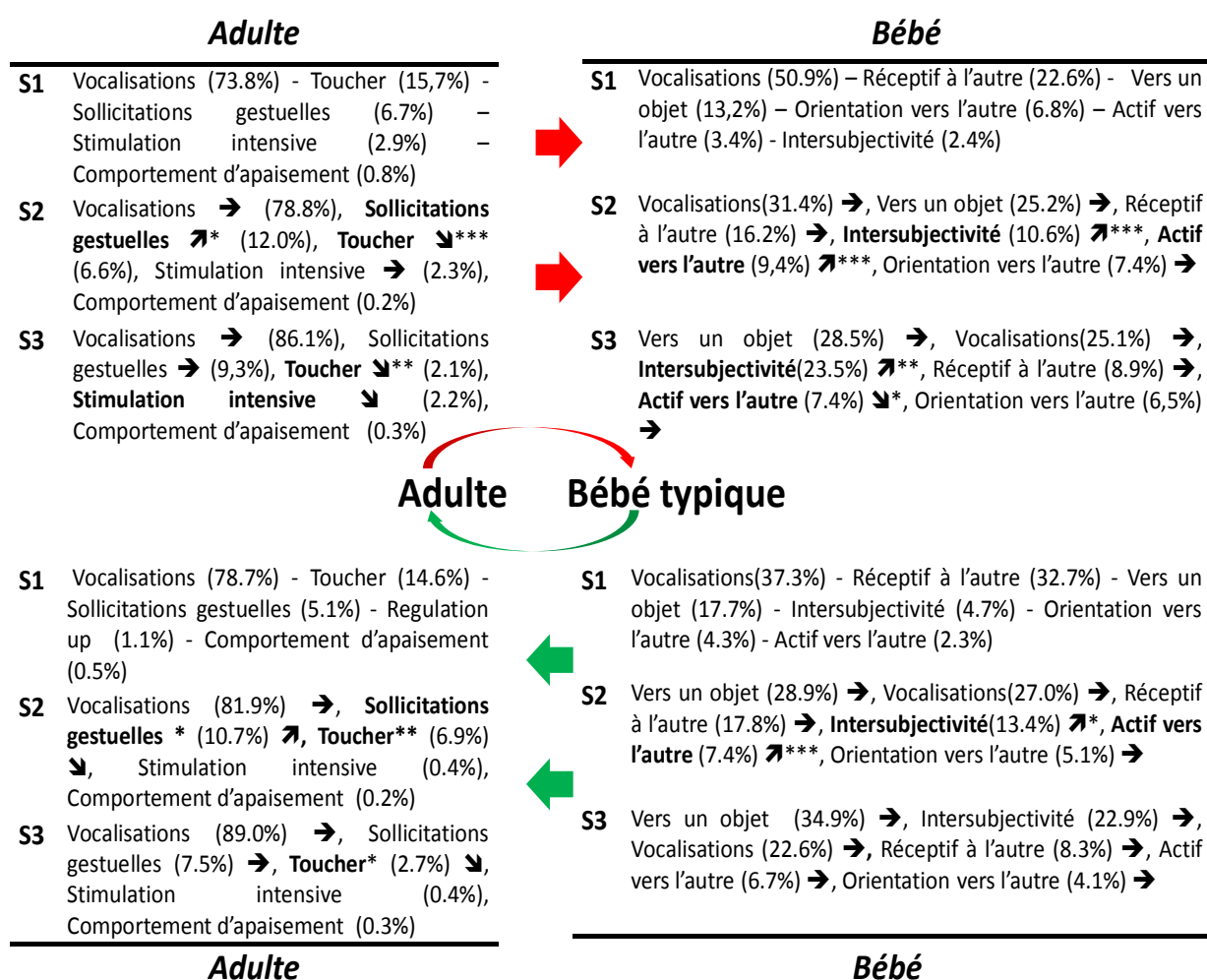


Figure 3: Représentation développementale des principaux modes d'interaction du bébé typique

En haut: sens adulte→bébé/ En bas: sens bébé→adulte. S1, 2, 3 = Semestre 1, 2, 3.

Entre parenthèses: % du comportement au sein de l'ensemble des interactions du groupe pour ce semestre.

Les flèches indiquent la stabilité (→) ou les variations significatives par rapport au semestre précédent: en hausse (↗) ou en baisse (↘) (*p< 0.05; **p<0.01; ***p<0.001)

Du côté du bébé, la part des **comportements actifs de recherche de l'autre** ("seeking people") dans les interactions réussies augmente nettement du 1er au 2e semestre, puis diminue au 3e (en valeur absolue, on retrouve les mêmes variations, qui sont significatives). La part des **comportements intersubjectifs** au cours des interactions réussies croît régulièrement au fil des semestres, représentant 1/5e des interactions au 3e semestre (en valeur absolue, cette augmentation est continûment significative, surtout en réponse). La part des **comportements avec un objet** dans l'interaction (pouvant donc entrer dans le cadre de l'attention conjointe) augmente régulièrement pour devenir prépondérante au 3e semestre, avoisinant 1/3 des comportements initiateurs d'interaction (à l'intérieur de ce méta-comportement, l'augmentation de certains items individuels est significative: "contact object" au 2e semestre et "exploring object" aux 2e et 3e semestres).

Ainsi, au 2e semestre, le bébé normal se tourne activement vers l'autre (seeking people), développant progressivement, notamment avec le début de l'attention conjointe, des compétences intersubjectives (y compris l'entrée dans le langage verbal), conformément à la littérature (Trevarthen & Aitken, 2001). Au 3e semestre, alors que la simple recherche d'autrui diminue, l'intérêt du bébé, au coeur même de l'interaction, se tourne de plus en plus et de façon prépondérante vers les objets, en intrication avec la mise en place de l'intersubjectivité. Nous reconnaissons là le développement croissant de l'attention conjointe (Striano & Stahl, 2005)(Kawai et al.).

Parmi les actions de care-giver qui déclenchent une réponse du bébé ou qui répondent au bébé, les **vocalisations** sont largement prédominantes et ceci de façon croissante au fil des semestres. La part du **toucher** est bien moindre et diminue rapidement au fil des semestres (en valeur absolue, cette baisse est significative à chaque semestre). En fait, les parts du toucher et du gestuel s'inversent au 2e semestre, les **incitations gestuelles** augmentant significativement en valeur absolue au 2e semestre. La part des actions de **stimulation intensive** ("reg-up"), naturellement plus importante en sollicitation qu'en réponse, est quoiqu'il en soit très basse (en valeur absolue, ce comportement diminue significativement au 3e semestre).

Ainsi, la large prédominance des stimulations vocales dans les interactions réussies montre, en concordance avec la littérature (Trevarthen, 1999), l'attraction qu'exerce la voix des parents sur le bébé, dès le premier semestre, et ce pouvoir s'accroîtra encore par la suite (au fil de l'entrée progressive du bébé dans la compréhension du langage). Parallèlement, les stimulations gestuelles augmentent, venant probablement soutenir la communication globale et illustrer le verbe (Gogate, Bahrick, & Watson, 2000; McGregor, 2008). Inversement, le toucher est progressivement abandonné comme le bébé entre pleinement dans la relation active et dans l'intersubjectivité. De même, la stimulation intensive (reg-up) n'a plus lieu d'être.

2.3.2. Etude comparée des interactions synchrones des bébés autistes

Dans un souci de concision et de clarté, nous ne développerons ici que les résultats concernant les bébés autistes (figure 4) et non les résultats concernant les bébés à retard mental, à moins qu'ils ne viennent éclairer notre discussion des résultats concernant les bébés autistes.

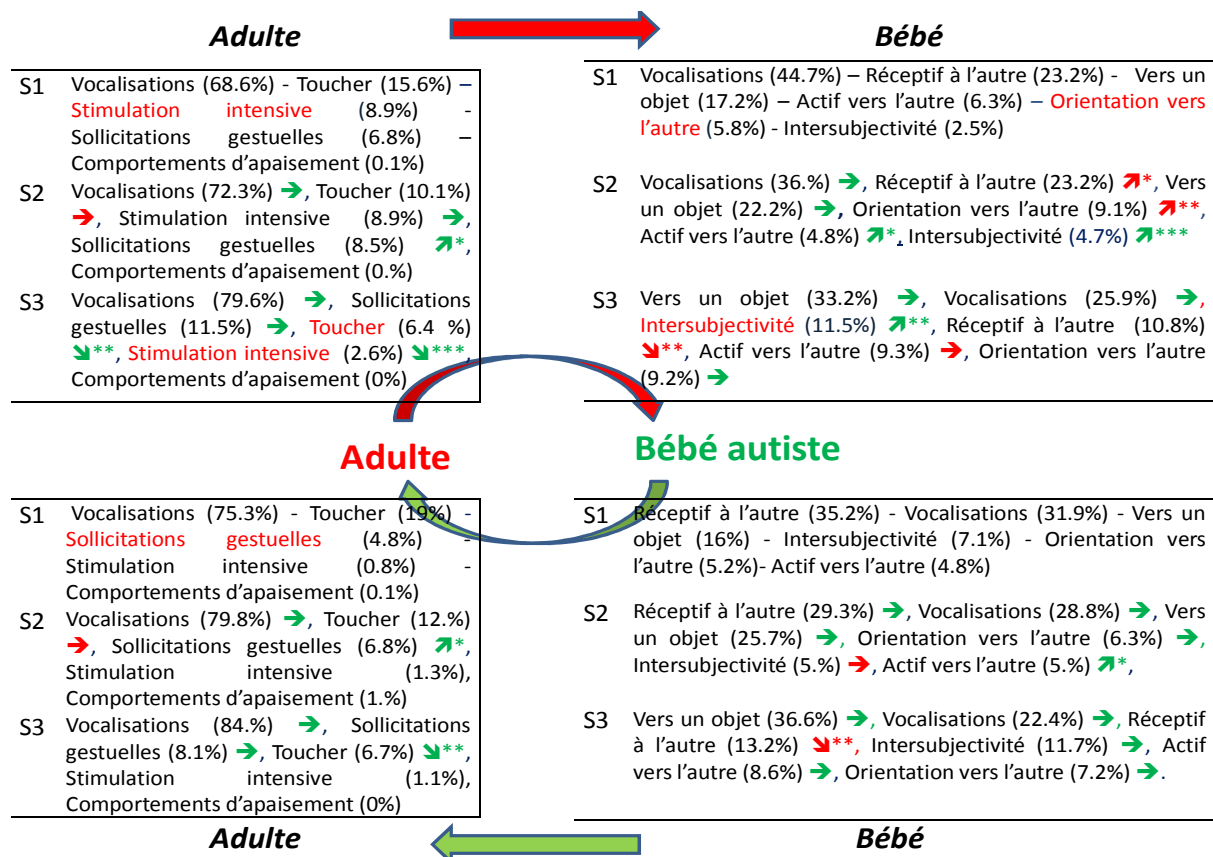


Figure 4 : représentation développementale des principaux modes d'interaction du bébé à devenir autistique

En haut: sens adulte→bébé/ En bas: sens bébé→adulte. S1, 2, 3: Semestres 1, 2, 3.

Entre parenthèses: % du comportement au sein de l'ensemble des interactions du groupe pour ce semestre.

Les flèches indiquent la stabilité (→) ou les variations significatives par rapport au semestre précédent: en hausse (↗) ou en baisse (↘) (*p< 0.05; **p<0.01; ***p<0.001)

La couleur rouge indique une différence significative du groupe autiste comparé au groupe typique; un comportement en rouge traduit une différence dans la comparaison transversale entre les 2 groupes à un semestre donné; une flèche en rouge traduit une différence dans la progression développementale (la direction de la flèche diffère entre les 2 groupes). Les valeurs de p concernant la comparaison avec le groupe typique sont données dans le texte de l'article.

Du côté des bébés autistes, comme pour les bébés normaux, les réponses par des **comportements d'intersubjectivité** croissent significativement de semestre en semestre, mais restent, globalement et plus spécialement au 3e semestre, inférieurs à ceux des bébés normaux (figure 5). Réciproquement, les réponses des parents aux comportements intersubjectifs de leur bébé n'augmentent pas au 2e semestre, contrairement à ce qui se passe pour les bébés normaux.

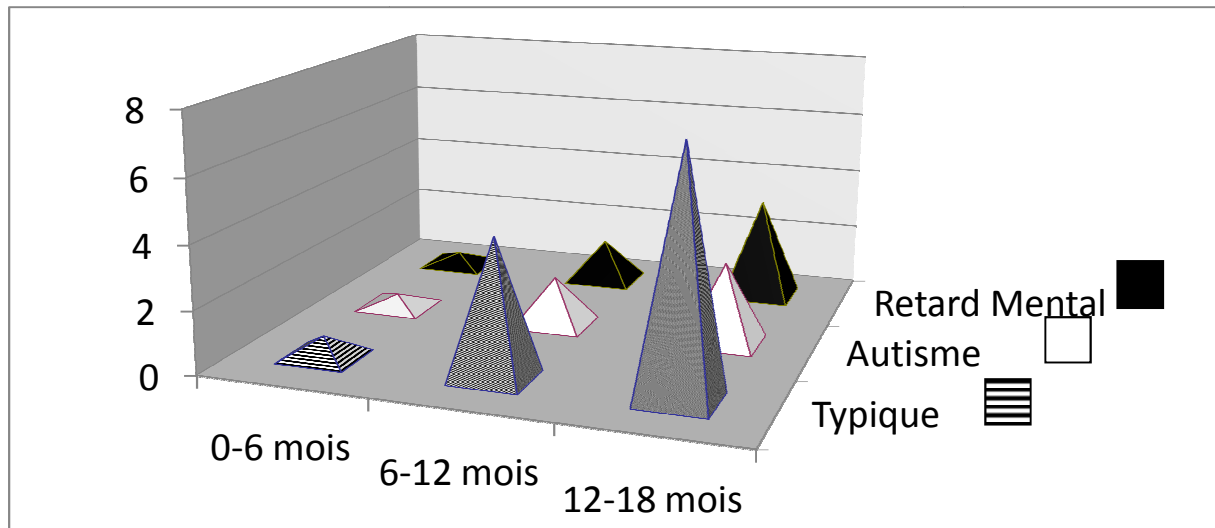


Figure 5 : Comportements intersubjectifs du bébé répondant à une interaction

Concernant les autres "méta-comportements", au 1er semestre, les bébés autistes répondent moins que les autres par une **orientation vers l'autre**. Cependant, à la différence des bébés normaux, ils présentent au 2e semestre une augmentation significative des **comportements réceptifs** à l'autre (passifs) tandis que les comportements actifs augmentent trop peu. Il y a donc une ouverture vers l'autre, mais préférentiellement sur un mode passif. Au 3e semestre, les comportements réceptifs décroissent uniquement chez le bébé autiste, ce qui traduit une phase de fermeture vis-à-vis de l'autre. Au sein des **comportements vis-à-vis des objets**, l'exploration d'objet est significativement moindre chez les autistes, globalement et aux 2e et 3e semestres.

Ainsi, contrairement aux bébés avec retard mental, les bébés autistes présentent un développement atypique et déviant. Dès le premier semestre, ils ne se tournent pas assez vers autrui; au deuxième semestre, ils s'ouvrent à l'autre, mais sur un mode qui reste plutôt passif; de plus, ils partagent trop peu d'intérêt pour les objets dans le cadre de la relation, alors que l'exploration de l'objet était intacte en soi dans l'étude précédente sur les mêmes données; cela semble indiquer un déficit de la mise en place de l'attention conjointe, bien connue chez des enfants autistes plus âgés (Colombi et al., 2009). Au 3e semestre, ce déficit persiste, s'accompagne d'un déficit croissant du comportement intersubjectif, et d'une fermeture à autrui. Tous ces résultats s'accordent avec l'hypothèse développée plus haut (chapitre

1.3.4) selon laquelle un déficit quantitatif initial de l'intérêt primaire pour autrui débouche secondairement sur un déficit quantitatif en expériences d'attention conjointe et par la suite sur un déficit des compétences intersubjectives avec un dysfonctionnement de la communication et une tendance à l'évitement relationnel.

Du côté des comportements du care-giver, on note que dans le sens bébé→care-giver, la seule chose qui distingue les parents d'autistes des typiques est une réponse gestuelle plus faible chez les parents de bébés autistes au 1er semestre (est-ce lié à l'expérience que feraient les parents d'un manque d'effet de ce type de stimulus sur leur bébé ?). Ainsi, alors que les comportements intersubjectifs des bébés sont diminués, les réponses des parents d'autistes diffèrent peu de celles des typiques, ainsi qu'on peut le voir sur la partie inférieure de la figure 4 (le haut de la figure montre comment le bébé répond aux parents, alors que le bas de la figure montre comment les parents répondent au bébé). Cela signifie que globalement les parents d'autistes se comportent normalement dans leurs réponses à leur bébé.

En revanche, du côté des stimulations par le care-giver (partie supérieure de la figure 4), on assiste à une **stimulation intensive** plus fréquente et prolongée (durée cumulée de "regulation-up") de la part des parents d'autistes que ce qui est observé chez un bébé typique, dès le 1er semestre et jusqu'au 3e, malgré une décroissance au fil du temps (figure 6). L'augmentation de la durée de reg-up n'était pas observée dans l'étude précédente ne tenant pas compte de l'interaction, ce qui montre que les bébés autistes répondent préférentiellement à ce type de sollicitation et que c'est à ce prix qu'a lieu la réussite de l'interaction.

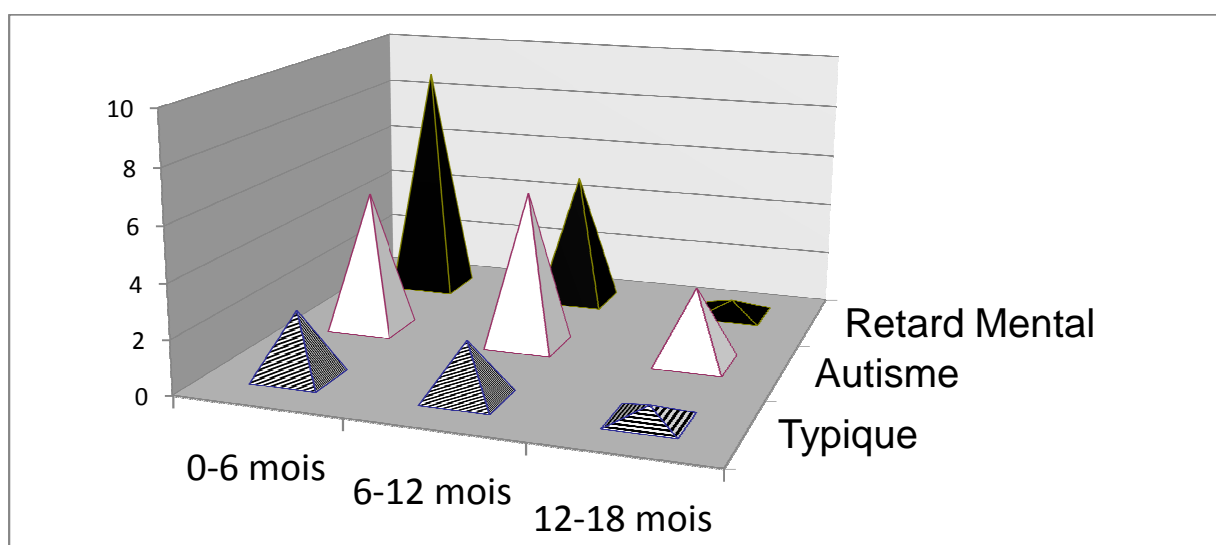


Figure 6. Comportements de stimulation intensive des parents pour initier une interaction

Cependant, l'efficacité du comportement de regulation up (figure 7), d'abord très forte chez nos bébés autistes, chute considérablement par la suite, si bien qu'au 3e semestre, l'élévation des interactions initiées par reg-up semble à mettre sur le compte d'un recours plus important des parents à ce type de stimulation plutôt qu'à une plus grande réactivité du bébé.

En ce qui concerne les **incitations tactiles**, nous retrouvons un profil proche de celui des stimulations intensives. En effet, contrairement à ce qui se passe chez les bébés typiques, où la diminution du toucher était très significative dès le 2e semestre, les incitations tactiles envers les bébés autistes ne diminuent qu'au 3e semestre, et restent néanmoins significativement supérieures à celles prodiguées par les parents de bébés normaux.

Ainsi, les parents d'autistes ne répondent pas à leur bébé différemment des parents normaux; de plus, au fil du développement, ils semblent s'adapter à leur bébé autiste, qui dès le 1er semestre a besoin d'être plus stimulé, puis par la suite continue à avoir besoin de stimulation de type "primaire" (toucher, reg-up) pour être dans la relation, alors que le bébé normal répond à des sollicitations plus élaborées, notamment verbales.

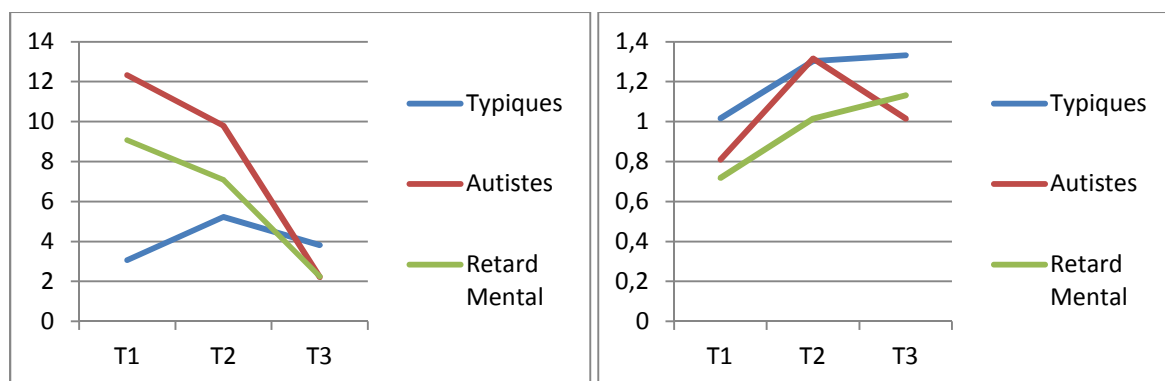


Figure 7: Index d'efficacité des comportements parentaux pour obtenir une réponse du bébé :

1) comportement de regulation-up (à gauche),

2) vocalisations parentales (à droite).

(Les comportements pouvant donner plusieurs réponses, l'index d'efficacité peut être supérieur à 1)

Les vocalisations parentales ne distinguent pas significativement les 2 groupes et leur évolution ne subit pas non plus de changement significatif au fil du temps. Cependant, comme il s'agit de la stimulation parentale largement la plus fréquente, nous avons tenté d'établir son efficacité sur le bébé au fil du temps et dans chaque groupe (figure 7). Si l'efficacité des vocalisations parentales pour obtenir une réponse du bébé semble suivre une courbe ascendante, chez le bébé autiste, on observe au 3e semestre une cassure

atypique de la courbe d'efficacité, qui fait suite à un rattrapage au 2e semestre. Notons que le bébé à retard mental semble suivre une évolution similaire à celle du bébé normal. Cependant, nous ne pouvons parler que de tendance car nous n'avons pas actuellement recherché la significativité statistique de ces variations.

Enfin, le calcul de l'information mutuelle normalisée après clustering des comportements (figure 8), montre un éloignement progressif des interactions parents-bébé autiste par rapport à la normalité (alors que l'écart entre les interactions des bébés à retard mental et celles des bébés normaux reste stable). Rapporté à ce que nous avons observé précédemment dans l'analyse longitudinale du développement autistique à travers les films familiaux (les aléas de l'évolution, son caractère parfois fluctuant), cela concoure à montrer que l'autisme n'est pas là d'emblée mais qu'il s'installe selon une certaine dynamique.

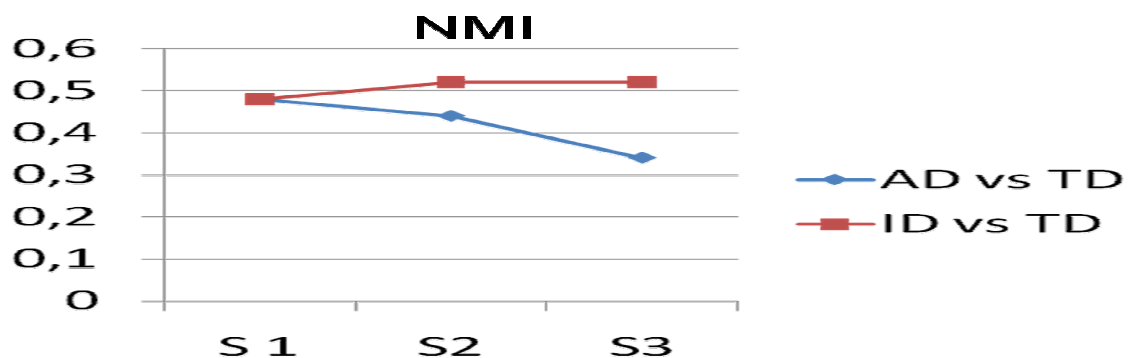


Figure 8. Similarité développementale utilisant l'information mutuelle normalisée (NMI) après factorisation en matrices non-négatives. :

1) entre bébés typiques (TD) et bébés à retard mental (ID): en rouge ; 2) entre bébés typiques et bébés à développement autistique (AD) : en bleu, S=semestre.

2.4. Discussion

2.4.1. Dynamique interactive

L'étude des interactions "réussies" suggère que le bébé futur autiste présente, en réponse aux sollicitations de l'adulte, un déficit précoce de l'intérêt porté à autrui et des compétences intersubjectives, avec une évolution non linéaire et déviante de ses capacités relationnelles aboutissant à une phase de fermeture. De plus, les parents répondent normalement à leur bébé et même s'adaptent à lui par une hyperstimulation dès le premier semestre, et un

maintien de modalités “archaïques” de stimulation qui devraient normalement, dans le développement typique, être abandonnées aux 2^e et 3^e semestres pour laisser la place à une communication plus élaborée. Nos résultats concordent ainsi avec ceux de Watson et de Siller qui ont montré que les parents d'autiste font preuve d'autant d'attention et de synchronie vis-à-vis de leur bébé que les normaux et les retard mentaux (Siller & Sigman, 2002; Watson, 1998).

2.4.2. Dépistage de l'autisme

En concordance avec les résultats de l'analyse de la littérature sous l'angle développemental (Maestro et al., 2001; Saint-Georges et al., 2010), nous avons observé une évolution fluctuante, le deuxième semestre apparaissant comme une période d'ouverture, malgré un manque d'élan vers l'autre, avant la fermeture qui s'installe au cours de la deuxième année. Une campagne de dépistage systématique devrait donc peut-être tenir compte de ces fenêtres et éviter la période du 2^e semestre, sauf à y rechercher plus spécifiquement un manque de recherche active de l'autre, ou un déficit de compétences plus élaborées (intersubjectives).

Le dépistage précoce reste donc délicat en raison du caractère discret et éventuellement fluctuant des dysfonctionnements “pré-autistiques” précoces. Cependant, dans notre étude, l'analyse ciblée des interactions réussies semble permettre la mise en évidence de certaines particularités du fonctionnement interactif de la dyade ou triade. Il serait donc utile de prêter attention, lors du dépistage, aux dimensions de synchronie, de contingence et d'adaptation réciproque, car les difficultés interactives du bébé ont des répercussions sur la façon dont les parents tentent d'entrer en contact avec lui (Trevarthen & Daniel, 2005). En particulier, nous avons observé une adaptation des parents sous la forme d'une hyperstimulation de leur bébé, qui renvoie à un savoir, conscient ou inconscient, des parents sur les difficultés relationnelles de leur bébé. Cela doit nous conduire, pour le dépistage, à être particulièrement attentif à ce type de comportement car il peut masquer le manque de réactivité ou d'initiative d'un bébé, mais aussi en être finalement l'indice, si on y prête attention. De plus, ces données suggèrent que les inquiétudes parentales (De Giacomo & Fombonne, 1998) devraient être prises en compte. D'autant plus que certaines différences entre les groupes normaux et autistes n'apparaissent significatives que dans l'approche longitudinale (le comportement réceptif n'est pas significativement inférieur chez les autistes comparés aux typiques; ce qui est significatif est la décroissance de ce type de comportement du 2^e au 3^e semestre). Dans ce cas, seuls les proches du bébé peuvent percevoir cette évolution comme inquiétante.

2.4.3. Limites et perspectives

Certaines limites pourraient déboucher sur des études complémentaires. D'abord, notre étude est limitée par la taille de l'échantillon et il est probable que certains résultats non significatifs auraient pu le devenir sur un échantillon plus large. Ensuite, le focus porté sur les interactions réussies montre une dynamique de la dyade dans sa globalité mais ne précise pas la part du bébé et du care-giver dans les différences observées. Il serait intéressant d'approfondir par des analyses supplémentaires telles que l'index d'efficacité d'une stimulation donnée pour obtenir une réponse du partenaire. De plus, il pourrait paraître pertinent, dans la mesure où l'on s'intéresse au comportement du care-giver, de différencier celui du père de celui de la mère, puisque la place et la dynamique en sont sans doute différentes. Par ailleurs, nous savons que la population autiste constitue probablement un groupe hétérogène; l'étude de la dynamique développementale de groupe est nécessaire pour obtenir des résultats significatifs mais elle présente l'inconvénient de peut-être moyenniser d'importantes variations individuelles; des études individuelles longitudinales sur les mêmes sujets seraient utiles pour préciser le degré de cette variation interindividuelle, voire distinguer plusieurs profils développementaux. Enfin, en l'absence d'indices sur l'expression faciale des parents (généralement peu accessible sur les films familiaux) la description comportementale de l'interaction rend mal compte de la dimension subjective, affective et émotionnelle. En complément de l'étude quantitative des vocalisations parentales réalisée ici, leur étude qualitative (la prosodie) pourrait permettre d'apporter cet aspect affectif et venir enrichir l'étude comportementale de la dynamique interactive, en l'ancrant dans la subjectivité et l'émotion (Fernald & Kuhl, 1987).

2.5. Article publié (PLoS ONE)

Do Parents Recognize Autistic Deviant Behavior Long before Diagnosis? Taking into Account Interaction Using Computational Methods

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Abstract

Background: To assess whether taking into account interaction synchrony would help to better differentiate autism (AD) from intellectual disability (ID) and typical development (TD) in family home movies of infants aged less than 18 months, we used computational methods.

Methodology and Principal Findings: First, we analyzed interactive sequences extracted from home movies of children with AD (N = 15), ID (N = 12), or TD (N = 15) through the Infant and Caregiver Behavior Scale (ICBS). Second, discrete behaviors between baby (BB) and Care Giver (CG) co-occurring in less than 3 seconds were selected as single interactive patterns (or dyadic events) for analysis of the two directions of interaction (CG→BB and BB→CG) by group and semester. To do so, we used a Markov assumption, a Generalized Linear Mixed Model, and non negative matrix factorization. Compared to TD children, BBs with AD exhibit a growing deviant development of interactive patterns whereas those with ID rather show an initial delay of development. Parents of AD and ID do not differ very much from parents of TD when responding to their child. However, when initiating interaction, parents use more touching and regulation up behaviors as early as the first semester.

Conclusion: When studying interactive patterns, deviant autistic behaviors appear before 18 months. Parents seem to feel the lack of interactive initiative and responsiveness of their babies and try to increasingly supply soliciting behaviors. Thus we stress that credence should be given to parents' intuition as they recognize, long before diagnosis, the pathological process through the interactive pattern with their child.

Citation: Saint-Georges C, Mahdhaoui A, Chetouani M, Cassel RS, Laznik M-C, et al. (2011) Do Parents Recognize Autistic Deviant Behavior Long before Diagnosis? Taking into Account Interaction Using Computational Methods. PLoS ONE 6(7): e22393. doi:10.1371/journal.pone.0022393

Editor: James G. Scott, The University of Queensland, Australia

Received: February 14, 2011; **Accepted:** June 21, 2011; **Published:** July 27, 2011

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Funding: This study was supported by the Fondation de France and the Université Pierre et Marie Curie. The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Competing Interests: The authors have declared that no competing interests exist.

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Introduction

Early signs of autism

Autism is a severe psychiatric syndrome characterized by the presence of abnormalities in reciprocal social interactions, abnormal patterns of communication, and restricted and stereotyped behaviours starting before age 3 [1]. Autism is now a well-defined clinical syndrome after the third year of life, and considerable progress in understanding its emergence in the first two years of life has been achieved [2,3]. Although there have been significant advances in describing single or multiple early signs, our ability to detect autism during early age is still challenging. Home movies (ie., naturalistic films recorded by parents during the first years of life) and direct observations of at risk infants are the two most important sources of information for overcoming this problem. They have both described children with autism disorder (AD) during the first 18 months as not displaying the rigid patterns described in older children. In particular, AD

children can gaze at people, turn toward voices and express interest in communication as typically developing (TD) infants do [4,5]. However, in several studies, children who later develop AD show as early as the first year less social behavior (e.g., looking at others, especially at the face), communication skills (e.g., responding to name), inter-subjective initiative, and emotion expression than TD infants. In the second year, early social signs intensify; expressive and receptive language fails to develop, while the lack of inter-subjective skills and of emotional expression persists [4,5]. These insights from home movies have been confirmed in studies of at risk children [6,7,8,9] and in studies using retrospective data from parental interviews to assess early signs of AD (Guinchat et al., in revision). As regards specificity, signs that differentiate AD children from children with intellectual disability (ID) are limited to the second year: fewer responses to name, fewer glances to others, lower eye contact quality and quantity, less positive facial expression and fewer inter-subjective behaviors (e.g., showing shared attention) [4,5]. To further

investigate early signs in the interactive field, Muratori et al. [10] studied home movies of the first three semesters of life from AD, ID and TD children with independent scoring of both baby (BB) and caregiver (CG) behaviors and timing. AD infants displayed impairments in “syntony”, “maintaining social engagement”, “accepting invitation” and in “orienting to their name” (definitions are given in Table 1) as early as the first year of life in comparison with TD children. At semester 3, some items differentiated AD from TD while for other items AD showed significantly lower scores compared to ID. In addition, they noted

that AD babies received less action than ID from their CG to regulate down their arousal and mood.

Taking into account interaction

One of the main limitations of these studies is that they have not or only poorly taken into account the importance of BB/CG synchrony and reciprocity in the early interactions [11]. As it is of seminal importance to have more insight not only into early social competencies of infants who are developing autism but also into interactive situations where they preferentially

Table 1. Infant’s and caregiver’s behaviors and meta-behaviors from the infant caregiver behavior scale (ICSB).

Meta-behavior	Item Behavior	Glossary
<i>Child Behaviors (N = 29)</i>		
Behavior with object	Orienting toward object	The child directs his/her gaze towards a source of new sensory stimulation coming from an object
	Gaze Following an object	The child shifts his/her gaze to follow the trajectory of an object.
	Explorative activity with object	The child touches something by hands, mouth or other sensory-motor actions, to find out what it feels like.
	Looking at object/around	The child directs his/her eyes towards an object, or simply looks around.
	Smiling at object	The child intentionally smiles at object.
	Enjoying with object	The child finds pleasure and satisfaction experiencing a physical or visual contact with an object.
Vocali-zations	Seeking contact with object	The child employs spontaneous and intentional movements to reach contact with an object.
	Simple Vocalisation	The child produces sounds towards people or objects.
Crying	Crying	The child starts crying after a specific/non specific event.
	Orienting toward people	The child directs his/her gaze towards a source of new sensory stimulation coming from a people
Gaze Following a person	Gaze Following a person	The child shifts his/her gaze to follow the trajectory of another person.
	Explorative activity with person	The child touches a person to find out what it feels like (by hands, mouth or other sensory-motor actions).
Receptive to people	Looking at people	The child directs his/her eyes towards a human face.
	Smiling at people	The child intentionally smiles at a person.
	Enjoying with person	The child finds pleasure and satisfaction experiencing a physical or visual contact with a person.
	Sintony *	The child shows signs of congruous expressions to affective solicitations, to the other’s mood.
Seeking people	Seeking contact with person	The child employs spontaneous and intentional movements to reach contact with a person.
	Soliciting	The child displays a vocal or tactile action to attract the partner’s attention or to elicit another response.
Inter-subjective behavior	Anticipation of other’s intention	The child makes anticipatory movements predicting the other’s action.
	Communicative gestures	The child displays use of social gestures.
	Referential gaze	The child shifts his/her gaze towards the caregiver to look for consultation in a specific situation.
	Gaze following gaze	The child shifts his/her gaze to follow the gaze of another person.
	Accept Invitation	The child’s behavior is attuned to the person’s solicitation within 3 seconds.
	Orienting to name prompt	The child assumes a gaze direction towards the person who calls him/her by the name.
	Imitation	The child repeats, after a short delay, another person’s action.
	Pointing comprehensive/ declarative/ requestive	The child a) shifts his/her gaze towards the direction pointed by a person; b) points something in order to share an experience; c) in order to obtain an object.
	Maintaining social engagement *	The child takes up an active role within a two-way interaction in order to keep the other person involved. The child interacts, vocalises and maintains turn taking.
	Meaningful Vocalisation	The child intentionally produces sounds with a stable semantic meaning
<i>Caregiver’s Behaviors (N = 8)</i>		
Reg-up/down	Regulation up * /down	Modulates the child’s arousal and mood, to either excite (reg-up) or calm (reg-down).
Touching	Touching	Stimulates the child requesting attention by touching him/her.
Vocalization	Vocalizing/naming/behavior request	Stimulates the child requesting attention by vocalizing, naming
Gesturing-showing	Gesturing/showing object	Stimulates the child requesting attention by gesturing or showing him object

doi:10.1371/journal.pone.0022393.t001

emerge, we tried to overcome these caveats by using for previous data [10] new engineering techniques of interaction analysis focusing on reciprocity and synchrony between BB and CG. Recently, applying machine learning methods to explore TD infant and mother behavior during interaction, Messinger et al. [12] showed that developmental changes were most evident when the probability of specific behaviors was examined in specific interactive contexts. The aims of the current study were to assess early social interactions of infants with TD, ID and AD taking into account simultaneously: CG behavior, BB behavior, synchrony of the interaction partners, and finally, the two directions of interaction (from CG to BB and from BB to CG). Among others, we hypothesized that (1) infants with AD should exhibit a growing deviant social development whereas those with ID should rather show an initial delay of development; (2) CG of babies with atypical development should feel very early the initial pathological process and this feeling could be expressed through atypical/unusual interactive patterns.

Materials and Methods

General view of the study

The diagram-flow of the study is summarized in Figure 1. Forty-two children were randomly selected inside the Pisa Home Movie database, with the following criteria: 15 who will be diagnosed with AD, 12 with ID and 15 who will develop normally (step 1). All scenes showing a situation in which social interaction could occur (i.e. all scenes with an infant and an adult) were extracted and, if necessary, segmented in short sequences in order to be scored (step 2). CG and BB behaviors were rated independently within each interaction sequence according to a grid with a specific part for each partner (step 3). An interaction database was created by extracting [CG→BB] or [BB→CG] signals occurring “simultaneously”, that is within a time window of 3 seconds (step 4). A computational model using Markov assumption of interaction was performed to describe the interaction (step 5). Quantitative statistics were performed to assess and compare emergence of interactive patterns by time and by group (step 6). To study these interactive patterns with an integrative perspective, Non-negative Matrix Factorization (NMF) were performed (step 7). Steps 1, 2, and 3 have been described in a previous report where a full description is available [10]. Here we only summarize them.

Participants (Step 1)

The study has been approved by the Ethical Committee of the Stella Maris Institute/University of Pisa, Italy [13]. The Pisa Home Movie data base includes three groups of children matched for gender and socio-economic status, with home movies (HM) running for a minimum of 10 minutes for each of the first 3 semesters of life. Group 1 includes 15 children (M/F: 10/5) with a diagnosis of AD without any sign of regression confirmed with the Autism Diagnostic Interview Revised [13]. Group 2 includes 12 children (M/F: 7/5) diagnosed with ID according to the DSM-IV criteria and a Childhood Autism Rating Scale (CARS) [14] total score under 25. The composite IQ score was below 70 for both AD and MR (figure 1). Group 3 includes 15 children (M/F: 9/6) with a history of typical development confirmed by non pathological scores at the Child Behavior Check List [15].

Extraction of CG-BB interaction situations (Step 2)

An editor, blind to children diagnoses, selected from among the HM of each child all segments running for at least 40” where the infant was visible and could be involved in human interaction

(standard situations). For each infant, the sequences were organized in three periods of 6 months of age (≤ 6 month; $6 < \text{age} \leq 12$ months; > 12 months). Sequences were randomly selected by group and by semester. Preliminary t-test analysis showed that chosen video material was comparable across groups and for each range of age, in length and number of standard situations.

Computer-based coding system (Step 3)

The Observer 4.0[®] was configured for the application of the Infant Caregiver Behavior Scale (ICBS) to the video media file-material. The ICBS (Table 1) is composed of 29 items referring to the ability of the BB to engage in interactions and 8 items describing CG solicitation or stimulation toward the infant to obtain his attention. All target behaviors were described as Events which take an instant of time. Caregiver regulation up caregiver regulation down were described as events and also states which take a period of time and have a distinct start and an end.

Four coders were trained to use the computer-based coding system until they achieve a satisfactory agreement (Cohen’s Kappa ≥ 0.7). The standard situations derived from the HM of the three groups of children (AD, ID and TD) were mixed, and each one was rated by one trained coder blind to which group they belonged. For a continuous verification of inter-rater agreement, 25% of standard situations were randomized and rated by two coders independently. The final inter-rater reliability, calculated directly by the Observer, showed a satisfactory Cohen-k mean value ranging from 0.75 to 0.77.

Creation of the interaction database (step 4)

We first created an interaction data base (Step 4) by extracting all interactive events defined as sequences of caregiver behavior and infant behavior co-occurring within a time window of 3 seconds. The whole interaction database was divided into two sets: (1) CG→BB interactions, i.e. any child behaviors occurring within the 3 seconds following any caregiver behavior (including events that occur within the same second); (2) BBCG interactions, i.e. any caregiver behaviors occurring within the 3 seconds following any child behavior (again including concomitant events). The 3 second window was based on available literature on synchrony ([11]). Interactive events that occurred at the same second were integrated in the two sets of the interaction database because it was too difficult to assume who was primary or secondary in the interaction. Extraction was performed using Linux based script. The sequence of n interactive patterns is termed n-gram as usually done in natural language processing or gene analysis. In this study, we only focused on bi-gram modeling. Given the large number of possible types of interaction ([CG item x BB item] combinations = 8×29), and the low frequency of several items in the data base, we created five CG meta-behaviors (Vocal solicitation, Touching, Gestural solicitation, Regulation up, Regulation down) and six BB meta-behaviors (Vocalizations, Inter-subjective behavior, Seeking people, Receptive to people, Orienting toward people, Behavior with object) by grouping ICBS items. Meta behaviors are shown in the left column of Table 1. Then we repeated the process of extraction to obtain finally, for each standard situation, all sequences of caregiver meta-behavior and infant meta-behavior occurring within a time window of 3 seconds.

Characterization of infant-caregiver interactive patterns (Step 5)

General principles of the analysis we used to investigate interactive patterns by group and by time are summarized in figure 2. First, we aimed to describe infant-caregiver interaction by

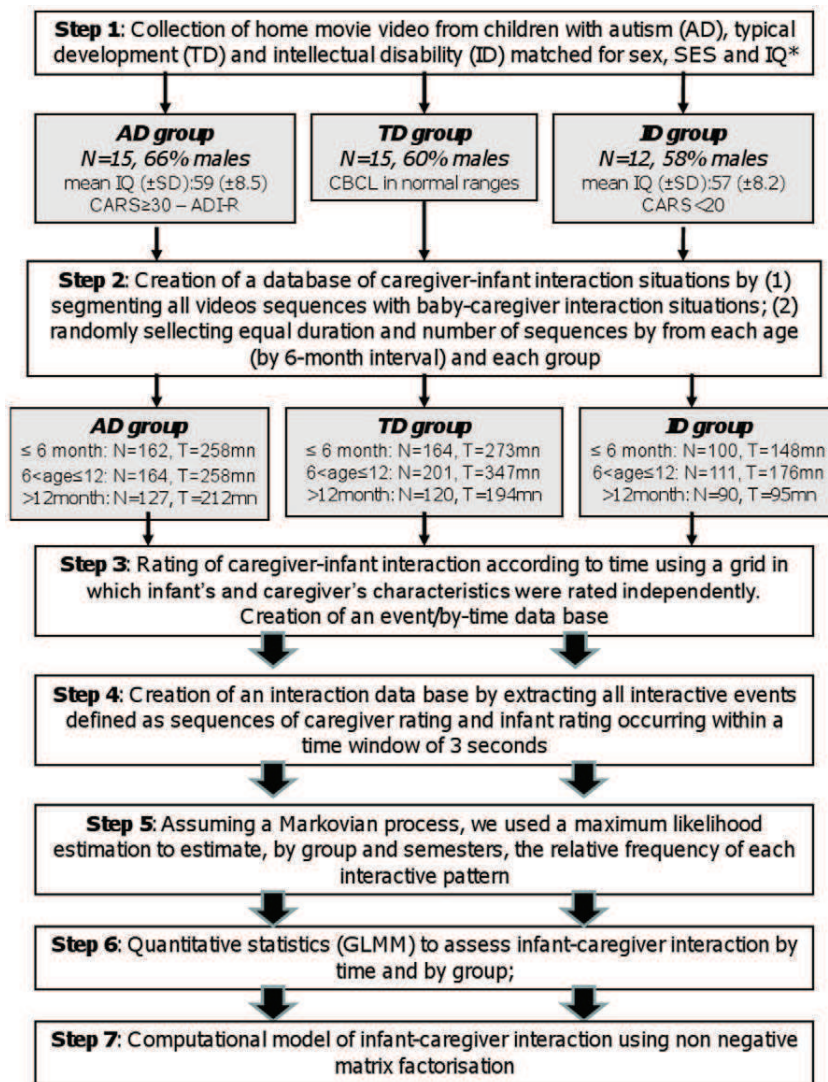


Figure 1. Diagram flow of the study. SES = Socio Economic Status; IQ = Intellectual quotient; CARS = Children Autism Rating Scale; CBCL = Child Behavior Check List; SD = Standard Deviation; GLMM = Generalized Linear Mixed Model; *IQ matching only between ID and AD children and based on Griffiths Mental Developmental Scale or Wechsler Intelligent Scale.
doi:10.1371/journal.pone.0022393.g001

time and by group and assess emergence of language and social engagement by time and by group as they are core issues of autism. For each of the two sets of the database (ie., the two directions of interaction), assuming a Markovian process, we used a maximum likelihood estimation to estimate, by group and semesters, the probability (relative frequency) of each interactive pattern or bi-gram (couple of CG and BB items) using meta behaviors only (6×5 for BB→CG and 5×6 for CG→BB). Grouping all the more frequent (>1%) interactive patterns (or bi-grams) allows designing Markov chains representing the parent-infant interaction. Markov diagrams were performed using Graphviz (see <http://www.graphviz.org/>).

Quantitative statistics (Step 6)

Statistical analyses were performed using R Software, Version 2.7 (The R Foundation for Statistical Computing). Analyses were conducted separately on each of the two sets of the data base (CG→BB and BB→CG). We computed descriptive statistics of

each CG and BB interactive behavior and meta-behavior, by group and by semester. To assess by group and/or by time significant associations, we used a generalized linear mixed model (GLMM). Using this model, we performed a linear regression that was generalized to the variable distribution (here a quasi Poisson distribution) and with a random effect to take into account patients' auto correlations [16]. The distribution of each item behaviors and meta-behaviors was studied in order to compute statistics with GLMM. All BB and CG meta behaviors, 6 CG items (Gesturing, Showing object, Vocalizing, Request Behavior, Naming) and 9 BB items (Orienting to name, Exploring object, Looking at object, Looking around, Looking at People, Contact Object, Orienting to People, Simple Vocalizations, Smiling at People) satisfied a "quasi-Poisson" law. Several other items occurring with a low frequency were not statistically usable because their distribution did not satisfy any known law. All BB and CG items and meta behavior responding to a quasi Poisson distribution were included in the model.

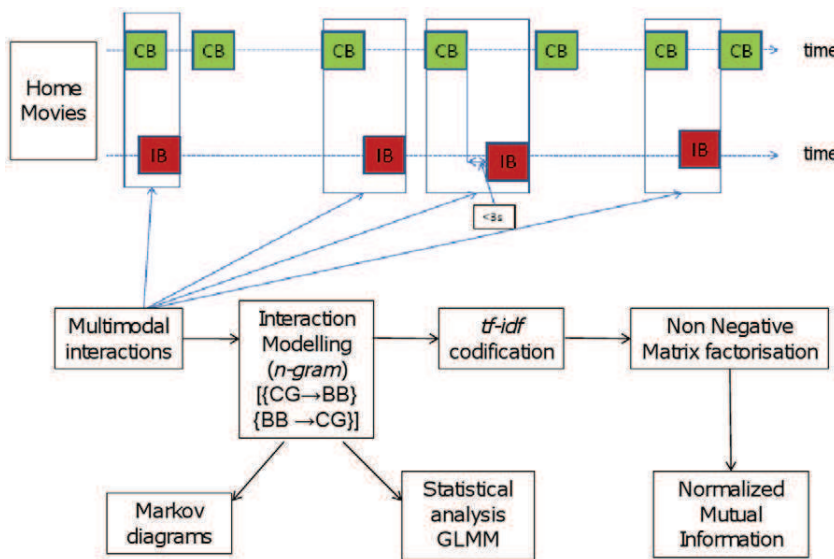


Figure 2. Analysis of parent-infant interaction: general principals. {CG->BB} ensemble of interactive patterns from caregiver (CG) to baby (BB); {BB->CG} ensemble of interactive patterns from baby (BB) to caregiver (CG); GLMM=Generalized Linear Mixed Model. doi:10.1371/journal.pone.0022393.g002

We conducted two univariate analyses first with Group as independent variable for a given semester, and then Time (semester) as independent variable within the same group. Then a multivariate analysis with both Time and Group was performed. As we knew that (1) AD and ID children would not behave better in interaction than TD and that (2) interactive behaviors change with time in pathological and typical children, we used a one-tail threshold of significance ($t=1.645$ for $p=0.05$) for each calculation of p .

Computational model of infant-caregiver interaction (Step 7)

Modeling and analyses done by Markov chains and GLMM provide useful insights on dynamic and relevance of individual interactive patterns. In order to study these interactive patterns with an integrative perspective, we proposed to employ a more global approach using Non-negative Matrix Factorization (NMF) [17]. All the m interactive patterns among the n movies have been grouped into a matrix V .

NMF is an unsupervised feature extraction method involving the decomposition of a non-negative matrix V (dimension $n \times m$) into two non-negative matrices W ($n \times k$) and H ($k \times m$) by multiplicative updates algorithm:

$$V \approx WH$$

The non-negativity constraints are relevant for the analysis of human behaviors since they allow only additive, not subtractive, combinations (part-based representation). The rank k of the factorization represents the number of latent factors and is usually chosen such that $(n+m)k < nm$. The rank k is interpreted as the number of clusters resulting in groups of interactive behaviors. Indeed, rows or columns of the decomposed matrices (H and W) are usually considered to be the membership degree to a cluster. NMF has been successfully used in various applications including interpretation of social behaviors [18] and computational biology [19]. Most of the studies have pointed important requirements

such as the pre-processing of the data, optimization of the rank of factorization (the number of clusters) and also the initialization.

Regarding the pre-processing, we used a method usually employed in document analysis: tf-idf (term frequency-inverse document frequency) [20]. This approach is based on the fact that a query term that occurs in many documents may not be discriminant and consequently should be given less weight than one that occurs in few documents. In our work, terms refer to interactive patterns while documents refer to home movies. The key idea is to give more importance to an interactive pattern in a given home movie if 1) the interactive behavior appears frequently in the home movie and 2) the interactive behavior does not appear frequently in other home movies. For a given interactive behavior t_i within a movie d_j , we estimated the term-frequency tf_{ij} :

$$tf_{ij} = \frac{n_{ij}}{\sum_l n_{lj}}$$

where n_{ij} is the number of occurrences of the considered interactive pattern (t_i) in the movie d_j , and the denominator refers to the total of occurrences of all the interactive patterns in the movie d_j .

The inverse document frequency is a measure of the general importance of the interactive pattern (a measure of informativeness) defined as the logarithm of the ratio of documents (movies) to the number of documents containing a given term (interactive patterns):

$$idf_i = \log \frac{|D|}{|\{d : t_i \in d\}|}$$

where $|D|$ is the total number of movies in the database and $|\{d : t_i \in d\}|$ is the number of movies containing the interaction pattern t_i . Finally, the tf-idf representation is obtained by multiplying the weights: $(tf-idf)_{ij} = tf_{ij} \times idf_i$.

The number of clusters is an important issue in the current work since it will provide insights on the combination of interactive patterns among groups and semesters. To determine the optimal k

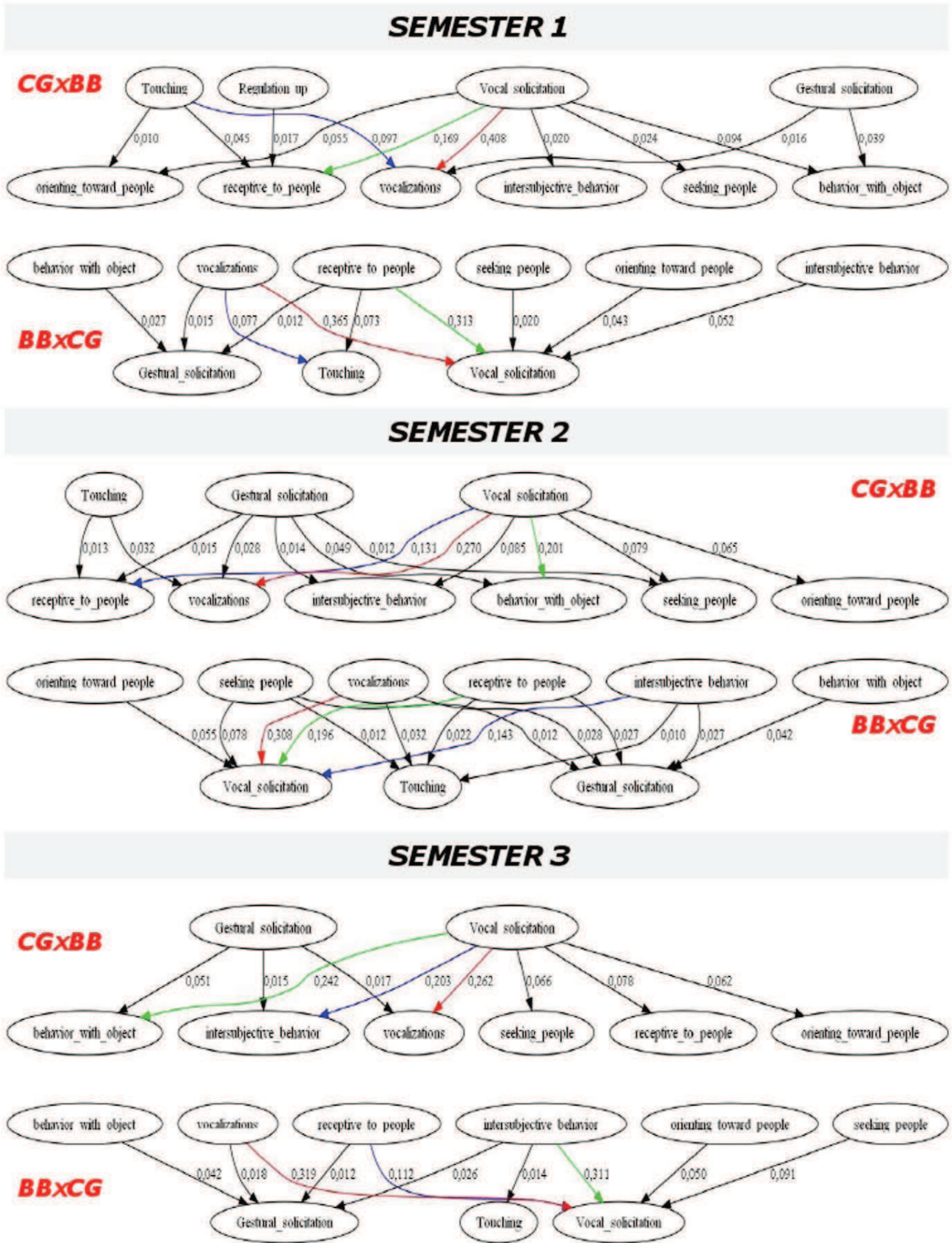


Figure 3. Markov diagram of the main early interactive patterns in typical developing children according to time and interaction direction.

doi:10.1371/journal.pone.0022393.g003

which decomposes the samples into ‘meaningful’ clusters, we investigated ‘Homogeneity-Separation’ since the standard definition of a good clustering is that of ‘Homogeneity-Separation’: every element in a cluster must be highly similar (homogeneous) to the other elements in the same cluster and highly dissimilar (separation) to elements outside its own cluster.

The stochastic nature of NMF requires strategies to obtain stable and reliable results that also depend on the initialization process. In the current work we use a recent method proposed by Boutsidis and Gallopoulos [21] termed Nonnegative Double Singular Value Decomposition (NDSVD), which is based on Singular Value Decomposition (SVD) but with non-negative constraints. Unlike random approaches, NDSVD guarantees stable results but not necessarily efficient ones; for this purpose multiple runs of NDSVD have been carried out.

In order to understand the developmental similarity of AD children towards TD, and ID children towards TD, we calculated the value of the Normalized Mutual Information (NMI) as proposed by Strehl and Ghosh [22]. The NMI of two different clustering measures the agreement between the two clustering:

$$NMI(y^1, y^2) = \frac{\sum_{i=1}^k \sum_{j=1}^k n_{ij}^{1,2} \log \left(\frac{n \times n_{ij}^{1,2}}{n_i^1 \times n_j^2} \right)}{\sqrt{\left(\sum_{i=1}^k n_i^1 \log \frac{n_i^1}{n} \right) \left(\sum_{i=1}^k n_i^2 \log \frac{n_i^2}{n} \right)}}$$

where n_i^1 is the number of interactive patterns belonging to cluster c_i using clustering y^1 , n_j^2 is the number of interactive patterns belonging to cluster c_j , using clustering y^2 , and $n_{ij}^{1,2}$ is the number of interactive patterns belonging to cluster c_i , using clustering y^1 and belonging to the cluster c_j using y^2 . One should note that $NMI(y^1, y^1) = 1$ indicating same clustering and consequently same interactive behaviors.

Results

Early interaction in TD children and significant developmental changes

Figure 3 summarizes the Markov diagram of all interactive patterns in TD children (at the meta-behavior level) occurring with a frequency higher than 1% according to both interaction direction [CG→BB] or [BB→CG] and semester. The diagram estimates 93.6% to 96% of the total interaction patterns according to semester and direction of interaction. When CG starts interaction, he/she predominantly uses vocal solicitation at all semesters. BB responds with vocalization (38.6%), being receptive to people (16%) and with object behaviors (8.9%) during the first semester (S1). BB responds with vocalization (25.4%), with object behaviors (18.8%) and being receptive to people (12.4%) during S2. BB responds with vocalization (24.6%), with object behaviors (22.9%) and intersubjective behaviors (19.1%) during S3. When BB starts interaction he uses preferentially vocalizations and being receptive to people during S1, to which CG answers with vocalizations (54.8%) and touching (12.1%). During S2, BB uses behavior with object (28.8%), vocalizations (26.9%), being receptive to people (17.8%) and intersubjective behaviors (12.4%). CG answers predominantly with vocal solicitation. During S3, patterns are similar but BB intersubjective behaviors (21.9%) are much more frequent than being receptive to people (7.3%).

For each interaction direction, figure 4 shows the relative distribution of meta-behaviors by semester, and summarizes the

GLMM model in TD children. Significant developmental changes are indicated by an arrow (↗ or ↘ according to a significant increase or decrease). They are as follows: BB intersubjective behaviors and seeking people behaviors, both as interaction initiation [BB→CG] and response [CG→BB] increase from S1 to S2. The increase continues from S2 to S3 as response [CG→BB] for BB intersubjective meta-behavior whereas BB seeking people behaviors decrease (only as response, too). However, during S3, BB intersubjective behaviors become the second child solicitation for CG. BB behavior with object becomes the first solicitation from the BB as soon as S2, and also the first response of the BB at S3. CG touching behaviors decrease in both directions from S1 to S2, and from S2 to S3. CG gestural solicitation increases from S1 to S2. CG vocal solicitation is predominant in all semesters. CG regulation up/down are very low in TD children during interactive patterns.

For the meta-behaviors that showed significant changes during early development, we also tested the corresponding CGBB individual items included in the model (see methods). Significant results are as follows: BB orienting to name increases ($p < 0.001$) from S1 to S2 and decreases from S2 to S3 ($p < 0.001$); BB contact object increases ($p < 0.05$) from S1 to S2; BB exploring object increases ($p < 0.001$) from S1 to S2 and again from S2 to S3 ($p < 0.001$); BB looking around ($p < 0.05$) and BB smiling at people ($p < 0.05$) decrease from S2 to S3. CG gesturing increases ($p < 0.001$) from S1 to S2 and then decreases ($p < 0.001$) from S2 to S3; CG request behavior ($p < 0.05$) and CG naming ($p < 0.01$) increase from S1 to S2.

Early interaction in AD and ID infants compared to that in TD infants

Figure 5 and figure 6 summarize the significant developmental changes over time (represented by an arrow) and the significant differences in the multivariate analysis (by group and by time comparison) using the GLMM model in AD and ID children, respectively.

Considering first child behavior, when CG starts interaction [CG→BB], BB inter-subjective behaviors grow every semester ($p < 0.01$) whatever the group, but they are lower for ID than TD ($p < 0.01$) at S1. In contrast, for AD it is lower ($p < 0.05$) globally (all semesters combined) and tend to be significantly lower ($p < 0.1$) at S3. When BB starts interaction [BBCG], BB inter-subjective behavior is again significantly lower ($p < 0.05$) for ID than TD at S1. From S1 to S2, unlike for TD, BB inter-subjective behavior does not increase in both pathological groups, but only children with ID exhibit a significant increase of inter-subjective behavior from S2 to S3. BB orienting toward people is lower ($p < 0.05$) in response at S1 for AD than TD. However, it significantly increases ($p < 0.01$) from S1 to S2 for AD (whereas TD keep stable). Other BB meta-behaviors (vocalizations, seeking people, being receptive to people, behavior with object) show no significant differences between groups.

From a developmental point of view, AD children, unlike TD children, show a significant increase ($p < 0.05$) of receptive behaviors from S1 to S2, and conversely, a much smaller increase of seeking people behaviors ($p < 0.05$) than TD ($p < 0.001$). In summary, from S1 to S2, AD children become more “open” (receptive) and interested in an exchange (orienting toward people) but only in a passive way (not seeking people); moreover at S3, the decrease of BB receptive behaviors is striking in AD ($p < 0.01$) whereas this is not significant for TD children.

ID children do not show any increase of BB seeking people over time but have high rates at S1. Like TD children but unlike AD children, ID children don’t exhibit significant changes over time

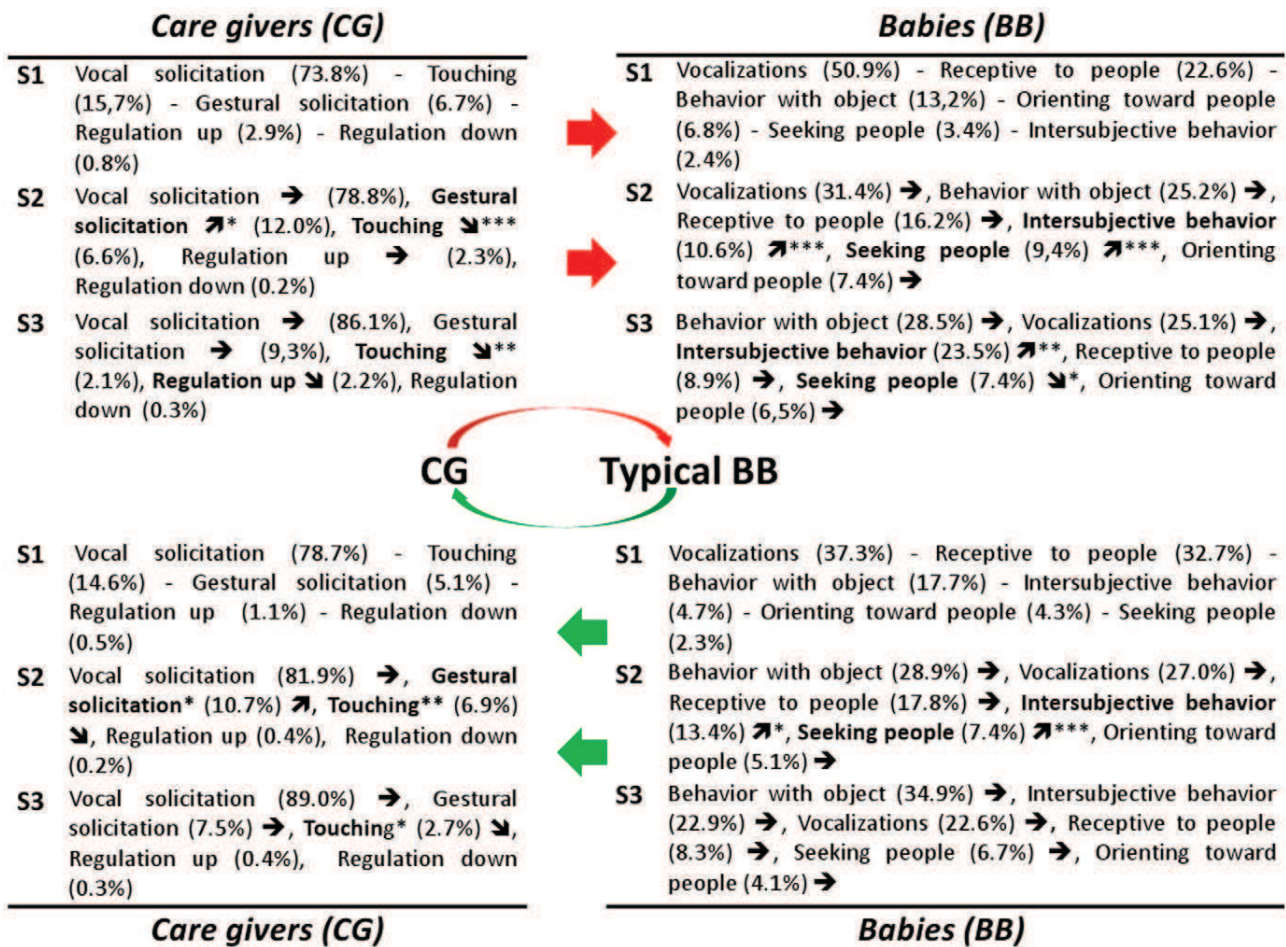


Figure 4. Developmental view of meta-behaviors for typical infants. Top: Care-Givers towards Babies/Down: Babies towards Care-Givers. S = Semester; See Table 1 for a brief description of cited infant's or care-giver's behaviors and meta-behaviors. In brackets: % of this behavior inside the whole interactions of the group in the semester. The arrow indicates behaviors that significantly grow (↗) or decrease (↘) compared with the previous semester (*p<0.05; **p<0.01; ***p<0.001). doi:10.1371/journal.pone.0022393.g004

either in BB receptive behaviors or in BB orienting toward people. Unlike AD and TD children, ID children exhibit a significant increase of BB behaviors with object from S1 to S2, but whatever the semester they stay (but not significantly) below TD and AD.

Considering now CG behavior, CG vocal solicitation is always higher for parents of TD children, but it never reaches significance between groups nor over time. CG gestural solicitation is lower at S1 in the two pathological groups reaching significance for parents of ID children only in initiation [CG→BB] (p<0.05) and for parents of AD children only in response [BB→CG] (p=0.01). However, for the three groups it increases significantly from S1 to S2 in both ways of interaction, except in response for parents of ID children. CG touching behavior does not change in CG of AD and ID children from S1 to S2, while it decreases for parents of TD children (p<0.001). Then from S2 to S3, it decreases in parents of AD children as it does for parents of TD children. However at S3, CG touching is higher for parents of AD and ID children compared with TD children, in initiation [CG→BB] (p<0.05) and with a tendency (p<0.05 for ID and p<0.1 for AD) in response [BB→CG]. Finally, CG regulation-up duration is higher for parents of ID and AD children (p<0.05) at S1. Then it decreases (p<0.05) from S2 to S3 in all groups. However, at S3, it remains higher (p<0.05) for parents of AD children.

For item behaviors included in the model (see methods), all semesters together (in the multivariate analysis), BB orienting to name and BB exploring object appear lower in the AD group than in TD (p<0.01 and p<0.001 respectively). With regards to the ID group, BB looking object, BB looking around and CG gesturing appear lower than in the TD group (p<0.05). BB exploring object, at S2 and S3, was lower for AD children (p<0.05 and p<0.01 respectively). As for other developmental changes for AD children, from S1 to S2, unlike for TD, BB orienting toward people and BB smiling to people are growing (p<0.01 and p<0.05 respectively). From S2 to S3, unlike for TD children, BB exploring object and BB looking around don't increase, and BB looking at people decreases (p<0.05). From S1 to S2, CG touching increases non-significantly (while there is a significant decrease in TD group: p<0.001) and from S2 to S3, CG gesturing doesn't decrease, and CG naming decreases (p<0.05). For other items, AD group follows a development similar to that of typical.

Developmental similarity between AD vs TD and ID vs TD using Non negative Matrix Factorization

To give a more general view of interactive patterns during infancy, we also used non-negative matrix factorization. First, we applied a tf-idf (term frequency-inverse document frequency) to

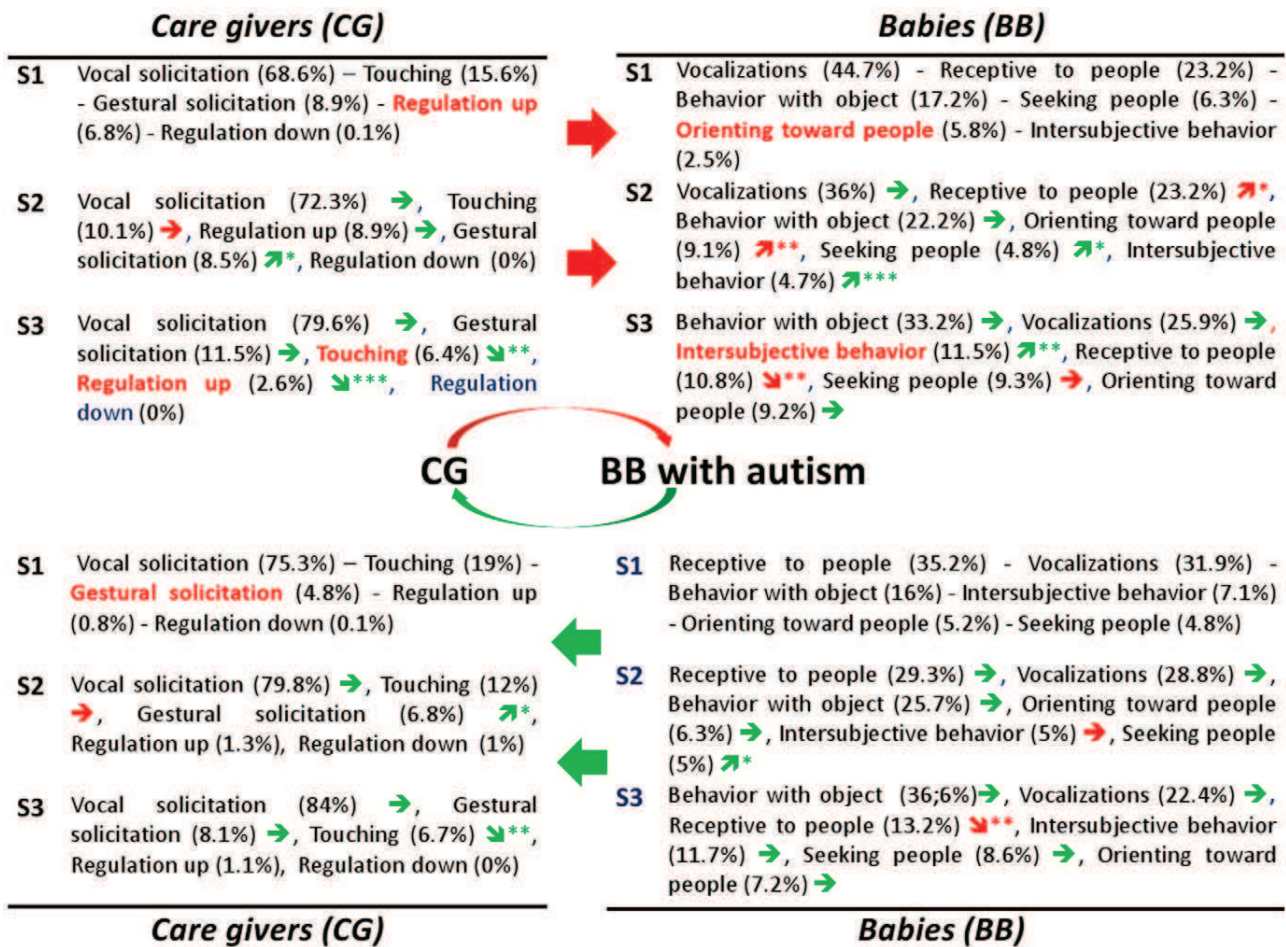


Figure 5. Developmental view of main interactive behaviors for infants with autism. Top: Care-Givers towards Babies/Down: Babies towards Care-Givers. S = Semester; See Table 1 for a brief description of cited infant’s or care-giver’s behaviors and meta-behaviors. In brackets: % of this behavior inside the whole interactions of the group in the semester. The arrow indicates behaviors that significantly grow (↗) or decrease (↘) compared with the previous semester (*p<0.05; **p<0.01; ***p<0.001). The red color indicates a significant difference when compared with TD: behavior in red color means that it differs in a group comparison (inside a given semester); arrow in red color means that the progression over time differs from that of the TD children (meaning the arrow has not the same direction). Significant p values are given in the text. doi:10.1371/journal.pone.0022393.g005

transform the scenes annotations into a representation suitable for the clustering task. The best solutions of behavior signals clustering for the ‘Homogeneity-Separation’ method yielded the following number of clusters according to semester (S1, S2, S3): 11, 14 and 9 for TD; 5, 11, 14 for ID; 12, 8, 10 for AD.

To illustrate the developmental similarity of AD children towards TD, and ID children towards TD, we calculated Normalized Mutual Information (NMI) values between the clustering results of TD/AD at each semester (0.48, 0.44, 0.37 for S1, S2, S3 respectively) and NMI values between the clustering results of TD/ID at each semester (0.48, 0.50, 0.47 for S1, S2, S3 respectively). Figure 7 shows that NMI values between the clustering results of TD/AD decrease over time, whereas NMI values between the clustering results of TD/ID show stability over time (see figure 7).

Discussion

As opposed to all previous home movies studies, the use of engineering methods related to social signal processing allowed focusing on dynamic parent↔infant interaction instead of single behaviors of the baby or of the parent. The focus on interaction

has many advantages. First, it allows to maintain attention on antecedents and consequences of interactive behaviors; second it allows to point out significant sequences that could be able to prompt or inhibit social interaction in a naturalistic and spontaneous way; third, it could produce insights for treatments based on parent-infant engagement that are now considered to be a fundamental part of many types of treatment. We discuss our results separately with regard to typical and atypical developments of interactive patterns. Throughout the discussion we put a series of comparisons with results described in a previous paper on the same subjects with the objective to demonstrate the added value of a research on autism using engineering methods which has its focus on interactive social sequences and not just on simple, or even complex, behaviors.

Summarizing CG↔BB interactive patterns in typically developing babies

Among BB behaviors vocalizations are predominant from birth, and exploring object grows significantly every semester until behaviors with object become the first BB meta-behavior in the second year. While seeking people peaks significantly at second

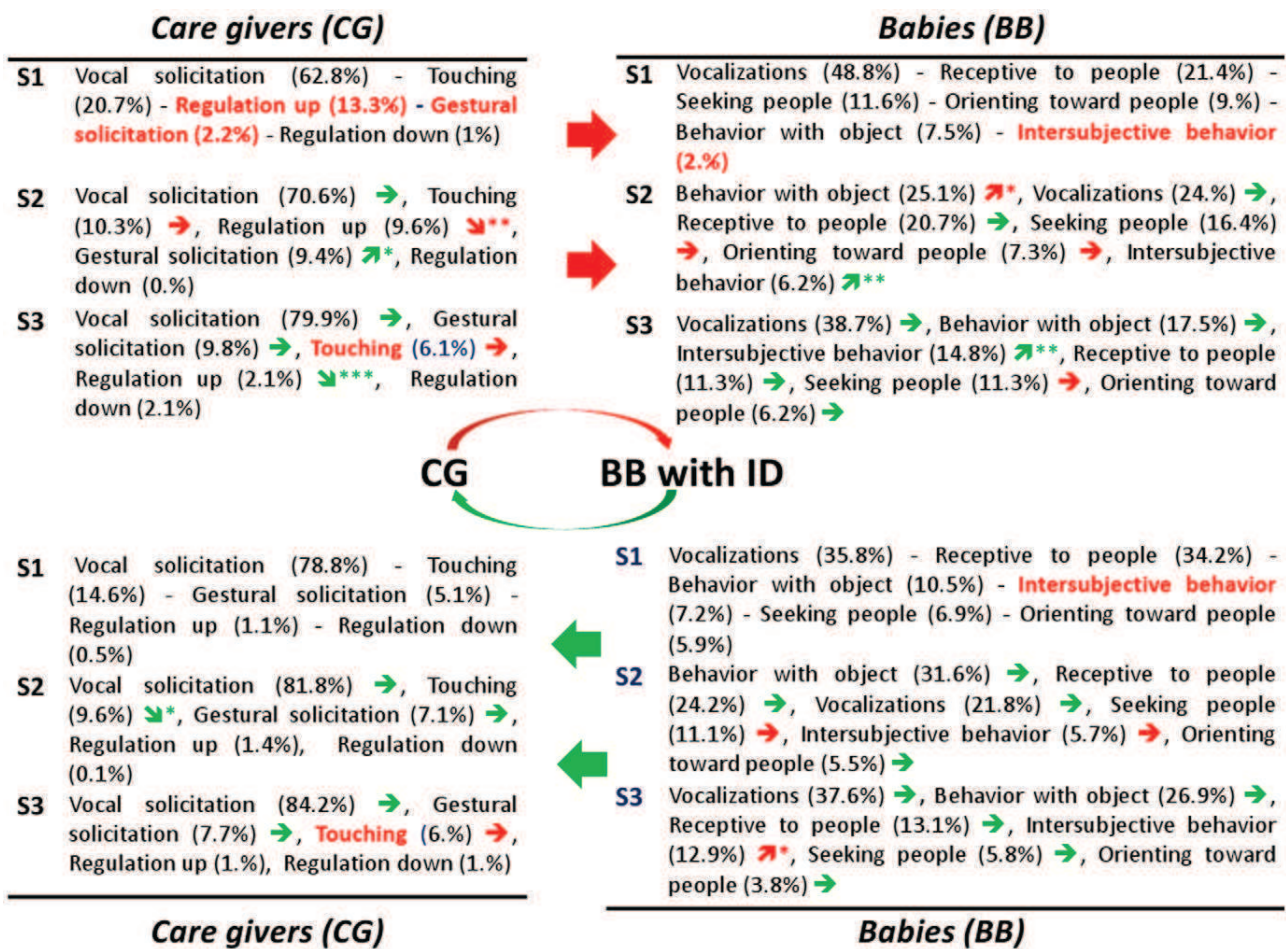


Figure 6. Developmental view of main interactive behaviors for infants with intellectual disability (ID). Top: Care-Givers towards Babies/Down: Babies towards Care-Givers. S=Semester; See Table 1 for a brief description of cited infant’s or care-giver’s behaviors and meta-behaviors. In brackets: % of this behavior inside the whole interactions of the group in the semester. The arrow indicates behaviors that significantly grow (↗) or decrease (↘) compared with the previous semester (*p<0.05; **p<0.01; ***p<0.001). The red color indicates a significant difference when compared with TD: behavior in red color means that it differs in a group comparison (inside a given semester); arrow in red color means that the progression over time differs from that of the TD children (meaning the arrow has not the same direction). Significant p values of group comparisons are given in the text. doi:10.1371/journal.pone.0022393.g006

semester compared with next and previous semesters, intersubjective behavior continues to grow significantly over the semesters. Thus in the second semester, a typical child is rather seeking and attending to his care-giver and little by little turns to objects, even inside the interaction (since our “filter” keeps only behaviors that are included in an interactive dynamic). This pattern describes the typical development of shared or joint attention [23,24] and points out how this phenomenon is entangled with both the simultaneous increase of inter-subjectivity and with vocalizations.

Also among CG behaviors, vocalizations are predominant from birth. We can assume that this type of stimulation which has its roots in animal communication is the more powerful way to strengthen child attention and affective communication. Probably it happens thanks to prosodic cues specific of infant directed speech [25,26] that are the object of a parallel paper where we have proposed a specific technological analysis of motherese [27]. Moreover, vocalizations pose the basics of language acquisition along with gestures [28,29]. Indeed, CG gestural solicitations increase during the first year. In contrast, touching decreases every

semester so that as the child becomes gradually more active (seeking people) and conscious (intersubjective acts) in the relationship, parents follow suit by leaving their touching behavior but not their vocalizations and increasing their gestural communication [30]. Indeed, the literature shows that mothers tailored their communication to infants’ level of lexical-mapping development [28].

What differs in AD and ID developments of interactive patterns?

While ID infants seem to show an initial delay, they more or less follow the developmental path of TD infants. Namely, after an initial delay in inter-subjective behavior they increase as do TD but a semester later. In the same way, ID children exhibit a significant increase of behaviors with objects during the first year, moving to catch up to the TD functioning. In contrast, AD children seem to develop otherwise. Especially, AD children show less orienting toward people in the first semester, and thereafter they exhibit a much smaller increase of seeking people behaviors than TD (whose score is multiplied by 4). As already described in a

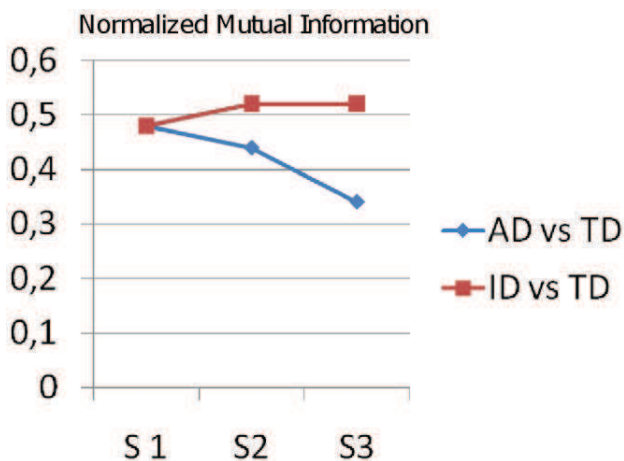


Figure 7. Developmental similarity between intellectual disability (ID) and typical development (TD) (red line) and between autism disorder (AD) and typical development (TD) (blue line) using Normalized Mutual Information (NMI) after non negative matrix factorization (S = semester). doi:10.1371/journal.pone.0022393.g007

previous study [31], during the second semester there is an increase of orienting toward people and in receptive behaviors, especially smiling to people. But this increasing pattern, from an interactive point of view, appears to be *passive*, and after the first birthday these receptive behaviors dramatically decrease (to note that receptive behaviors remain stable both in TD and in ID children). Thus, it seems that the real marker for atypical social development is the weakness in initiating a social interaction: without the increase of social initiative the ability to be receptive and responding to others also becomes more scarce. Moreover, inter-subjective behaviors, even if globally lower, become specifically lower after the first birthday.

All these results are consistent with the hypothesis of a growing deviant development in AD [1] whereas children with ID show just a delay of social development, as illustrated in figure 7 summarizing the NMI values of non negative matrix factorization. This deviant development concerns also BB exploring object, which we did not find significant in the previous paper whose focus was on behaviors not on interaction context. Indeed, in the present study exploring object appears significantly reduced in the AD group as soon as the second half of the first year. This means that AD babies have less exploration of object inside the early interactive context, and that, unlike for TD (and ID), exploring object doesn't increase for AD after the first birthday. Thus the child does explore object but outside a real social interaction: we suggest that this pattern could be the expression of an early (and growing) lack of joint attention in AD. Joint attention is known to be deficient in older children with autism [32], and early lack of joint attention is correlated with a poor social interaction [33].

With regards to CG behaviors there are both differences and similarities as far as initiative and response. First of all, caregivers have toward their babies longer regulation up interaction and less gestural solicitation. We imagine that gestural solicitation becomes reduced because it fails to get a response; as a confirmation, in the previous paper [10] we described how CG soliciting by name decreases as a matter of the reduced orienting to name by AD babies. On the other hand, the high regulation up has a different meaning. First, CG Regulation up duration appears higher, in the first 6 months and in both pathological groups, only in the interactive context (it was not significant without the filter of

interaction): that means that interactive moments are sustained both in AD and in ID by CG Regulation up; TD babies do not need a large amount of these CG behavior to express their sociality. Second, after the first birthday, regulation up remains significantly higher only for AD. We can hypothesize that while parents of both AD and ID feel from the first 6 months that their baby needs to be more stimulated, afterwards only parents of AD are confronted with a lack of social interest in their baby as he/she appears to enter into a clearer pathological process in the third semester. Indeed, AD children showed a lack of interest in people from the first 6 months, an increase of engagement (even if more passive) in the second semester, and then, after the first birthday, also a sharp decline of receptive meta-behaviors. Third, this special pattern of CG regulation up is associated, in the second semester, with the fact that parents go on touching their child to obtain a response (unlike TD children, there's no decrease of touching). The pattern composed of higher touching and longer regulation up still remains present in the second year when parents become more conscious of the difficulties to obtain a response.

In contrast, parental responses to inter-subjective behaviors do not differ from parents of TD babies. The few differences in quantity of CG responses in the first semester can be put down to lower babies' inter-subjective behaviors as far as a parental response needs a soliciting child. In sum, it seems that, except feeling that their baby needs to be stimulated, parents respond globally in the same way to their babies when he/she starts an interaction.

Clinical implication for early detection of autism

Over the past 20 years much attention has been dedicated to behavioral indicators that will be present very early in life, certainly in infancy. Nevertheless, prospective (such as siblings studies) and retrospective (such as home videos studies) studies have not yet identified a clear prodrome that is a constellation of unfailing early warning signs indicating the development of a disease up to the time in which the clinical symptoms fulfill the required criteria for a diagnosis [3]. Our study adds some general lines useful to reach the objective of identifying prodrome of autism.

First, our interaction data base (i.e. extracting all sequences of caregiver behavior and infant behavior occurring within a time window of 3 seconds) has provided some significant findings which are detectable only during parent-infant interaction. Thus, we propose that the best way to study the emergence of autism should be based on interaction rather than on behaviors of each part of the dyad. Concepts such as synchrony [11], closely-fitting match [34] and mutual adaptation could provide a great deal of help to workers in the field of early detection of autism [35].

Second, our study shows a course of autism characterized by a decreasing atypical pattern in the second semester of life and afterwards an increasing loss of contact. This pattern, that we have named 'fluctuating type of onset' [36], does not seem unusual in non regressive autism as in our sample. This finding could be of seminal importance for both individualization of the right windows in screening programs (first six months of life or after the first birthday) and implementation of timely effective parent-infant training in a sensible period as the second semester of life does appear.

Third, we can confirm that much credence should be given to parents when they entrust their concerns to professionals (as shown by retrospective parental questionnaires [37,38]). Moreover our research shows that parent listening can be implemented by some specific question and/or observation about the hyper-stimulating style of parent interaction toward their baby; in fact, we suggest

that this particular attitude betrays the presence of an under-active baby (lack of initiative, inability to provoke or to anticipate other's aims, hypo-activity) which need to be stimulated. Thus through this pattern of interaction parents seem to feel very early that something is wrong in their baby - long before diagnosis. Although, even if the BB intergroup differences do not reach significance and then are not detectable for a stranger (i.e. the pediatrician), some dynamic changes like the significant longitudinal decrease of "receptive" meta-behavior after the first birthday should presumably be detectable for the child's relatives.

Limits of this study

The first limitation is the sample size. As we used rigorous statistical methods taking into account the random subject effect and autocorrelation, we did not always obtain an analyzable, known distribution, and as scenes were very variable for a given infant (due to the great variability among scenes), some strong tendencies did not reach statistical significance; a larger sample would probably have allowed us more analyzable and/or significant results. Second, the analysis currently performed with our interactive filter highlighted the interactive dynamics without specifying the part played by each partner in the interaction. This would require additional analysis (e.g. response rate to a given stimulation) to determine this with accuracy and probably a larger sample. And last, only behavioral aspects of the stimulations were taken into account here, but qualitative emotional investment should be assessed as well, for example with the analysis of prosody (e.g., motherese); further research will focus on this question as we

recently developed an algorithmic tool to assess motherese in home movies [27].

We conclude that using engineering methods to study social interaction in home movies has improved our understanding of early interactions. We can assume that, even if most BB behavior intergroup differences do not reach statistical significance and then are not detectable for a stranger [10], some interactive/dynamic changes should be detectable for the child's relatives. Here, the results suggest that deviant autistic behaviors appear before 18 months when studying interactive pattern. Furthermore, parents of AD and ID children feel (consciously or not) the lack of interactive initiative and responsiveness of their babies and try to increasingly supply soliciting behaviors. Thus we stress that credence should be given to parents' feeling as they recognize, long before diagnosis, the pathological process through the interactive pattern with their child. These findings could help early identification of AD by encouraging professionals to provide more attention to parents concerns and ways of coping with their child.

Author Contributions

Conceived and designed the experiments: DC MC FM MCL SM. Analyzed the data: CSG AM MC DC. Contributed reagents/materials/analysis tools: DC FM CSG MC. Wrote the paper: CSG AM MC RC MCL FA PM SM FM DC. Performed the clinical experiments: FA PM SM. Performed the computational experiments: AM CSG RC. Wrote the first draft of the manuscript: DC FM CSG MC AM.

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3. Le mamananais peut-il nous aider à affiner l'analyse de l'interaction précoce ?

3.1. Introduction et méthodologie

Nous avons vu dans notre étude précédente (Saint-Georges et al., in press) que les stimulations vocales parentales jouent un rôle majeur et croissant dans les interactions précoces avec le bébé. Cependant le style et la qualité de ces vocalisations sont susceptibles de variations importantes, tant au niveau de leur production par les parents qu'au niveau de leurs effets sur les bébés. En effet, nous savons que les parents infléchissent leurs vocalisations lorsqu'ils parlent à leur bébé: ces particularités ont été largement étudiées sous le terme de mamananais (motherese ou infant-directed speech en anglais) (Fernald & Kuhl, 1987). Celui-ci a cette particularité intéressante d'être impliqué à la fois dans l'engagement relationnel et l'acquisition du langage, tous deux défaillants chez l'enfant autiste. Cependant, une étude exploratoire suggère que les bébés à risque autistique seraient eux aussi sensibles à cette prosodie pour entrer en relation (Laznik, 2007). L'étude de ces variations sur notre population de parents de bébés normaux, et de bébés autistes devrait permettre d'enrichir et d'approfondir l'étude fine des interactions précoces réciproques. Notamment l'étude de la dimension prosodique doit nous aider à mieux cerner les corrélats affectifs des stimulations vocales parentales et leurs effets sur les bébés typiques et autistiques.

Dans cette intention, et pour mieux connaître le rôle du mamananais dans les interactions normales, nous avons analysé la littérature actuellement disponible. Ainsi, à partir des moteurs de recherche Pubmed et PsycInfo, nous avons répertorié toutes les études publiées depuis 45 ans et jusqu'en 2011, et avons recensé 165 articles, desquels nous avons retenu 136 pertinents quant à notre recherche sur les conditions d'apparition chez les parents et les effets du mamananais sur le bébé. Nous y avons rajouté 30 articles trouvés dans les références bibliographiques ou bien dont nous avons eu connaissance par ailleurs. Nous avons travaillé sur la base des 166 articles pertinents pour réaliser une présentation argumentée d'une part sur les conditions d'émergence de ce type de langage, ses caractéristiques et ses variations; d'autre part, sur les effets observés chez l'enfant.

3.2. Principaux résultats

3.2.1. Caractéristiques générales du mamanais

Le mamanais est universel et transculturel. Il concerne non seulement les mères mais aussi les pères, les grands-parents, et finalement tout adulte en position de prendre soin d'un bébé (Fernald, Taeschner, Dunn, Papoušek, de Boysson-Bardies, et al., 1989). Il comprend des caractéristiques linguistiques, para-linguistiques et phonétiques, et même visuelles. Parmi les caractéristiques linguistiques, on recense une simplification du vocabulaire et de la syntaxe, avec des phrases courtes, des phrases ou des mots isolés, des répétitions, l'usage de diminutifs, de questions... Parmi les caractéristiques prosodiques, on observe une élévation de la fréquence fondamentale (tonalité) moyenne, une élévation de l'amplitude des variations de la fréquence fondamentale (variations prosodiques), avec des pics et des courbes caractéristiques, des répétitions prosodiques, un ralentissement du tempo et des pauses plus longues. La prosodie fournit aussi des indices syntaxiques en soulignant certains mots et la segmentation des mots et de la phrase. Enfin l'articulation des phonèmes est elle aussi modifiée (par exemple exagération de la durée des voyelles, hyperarticulation)(Ferguson, 1964; Newman & Hussain, 2006).

3.2.2. Variations des caractéristiques ou de la qualité du mamanais

Certaines caractéristiques du mamanais varient selon la langue et le sexe du locuteur, mais aussi le statut socio-économique, la fratrie, et enfin des pathologies psychiatriques perturbant l'affect telles que la dépression non traitée (Bettes, 1988; Kaplan, Bachorowski, Smoski, & Zinser, 2001) et la schizophrénie. On observe aussi des corrélats neuronaux et hormonaux (ocytocine) du mamanais (Gordon, Zagoory-Sharon, Leckman, & Feldman, 2010).

Le mamanais, quoique présent dès la naissance, varie également avec l'âge (il culmine vers 6 mois) (Kitamura & Burnham, 2003; Stern, Spieker, Barnett, & MacKain, 1983) et le sexe de l'enfant. Les contours prosodiques (qui varient aussi avec l'âge) traduisent souvent des intentions et des affects relatifs au bébé (Fernald, 1989; Papoušek, Papoušek, & Symmes, 1991), et en réalité, les courbes prosodiques caractéristiques du mamanais sont directement liées à l'intensité de l'affect (Trainor, Austin, & Desjardins, 2000). De plus elles sont influencées par la dynamique de l'interaction. Ainsi le mamanais varie avec la réponse synchrone de l'enfant (Braarud & Stormark, 2008; Smith & Trainor,

2008), ou même sa simple présence (Newman & Hussain, 2006), et aussi la tonalité de ses vocalisations (harmonisation). Si on constate une amélioration de la qualité du mamanais directement liée à la qualité de la réponse du bébé, on observe aussi, inversement, une accentuation du mamanais dans diverses situations où le bébé réagit trop peu (prématurité par exemple)(Niwano & Sugai, 2003; Reissland & Stephenson, 1999). De façon similaire, les mères s'adaptent au développement lexical de leur enfant, notamment en soutenant leurs vocalisations par une communication synchrone multimodale lorsque cela est nécessaire et en l'abandonnant lorsque cela est devenu inutile au stade de développement de leur enfant (Gogate et al., 2000). Dans le cas de nos bébés autistes que nous savons peu réactifs, on pourra donc s'attendre soit à un affaiblissement du mamanais par manque de feed-back du bébé, soit au contraire à une "activation" du mamanais pour compenser le manque de réactivité du bébé.

3.2.3. Effets du mamanais sur le bébé

Les contours prosodiques véhiculent l'affect et l'intention communicative, certains stimulant notamment la réactivité du bébé (Papoušek, Bornstein, Nuzzo, & Papoušek, 1990). De plus, le mamanais, par sa tonalité aiguë et ses grandes variations tonales, attire et maintient l'attention du bébé, favorisant l'apprentissage et l'engagement affectif (Fernald & Kuhl, 1987; Santarcangelo & Dyer, 1988). Cette "préférence" pour le mamanais, qui est corrélée à l'émotion véhiculée (Singh, Morgan, & Best, 2002), existe dès la naissance mais évolue avec le temps et en fonction de l'expérience vécue, puisqu'elle est compromise par l'existence d'une dépression maternelle. En effet le mamanais d'une mère déprimée perd de son pouvoir à éveiller l'attention et stimuler l'apprentissage, avec des effets qui peuvent même s'étendre à l'ensemble du mamanais produit par des femmes, alors que celui des pères reste "efficace" (Kaplan, Dungan, & Zinser, 2004).

Outre la stimulation de l'interaction, dont on sait qu'elle favorise l'apprentissage du langage, le mamanais joue un rôle majeur et multiple dans l'acquisition du langage: l'exagération des contours prosodiques, l'accent mis sur certains mots, les modifications phonétiques oeuvrent dans le sens de la catégorisation phonétique, de la reconnaissance et de la segmentation des mots et de la phrase, de l'acquisition de la syntaxe et finalement du langage (D'Odorico & Jacob, 2006; Kemler Nelson, Hirsh-Pasek, Jusczyk, & Cassidy, 1989; Morgan, 1996).

3.3. Synthèse et discussion

Le mamanaï s'inscrit au cœur de la relation dynamique mère-enfant.

D'abord, l'émotion ressentie de part et d'autre est fondamentale dans le phénomène de production et de maintien du mamanaï, qui apparaît alors comme un corrélat et un vecteur de la qualité de l'interaction mère-enfant (ou care-giver-enfant). La prosodie du mamanaï traduit en effet l'intensité émotionnelle de l'adulte (Trainor et al., 2000), qui est justement ce qui suscite l'intérêt et la préférence du bébé (Singh et al., 2002). Lorsque la qualité émotionnelle est perturbée par une pathologie maternelle, le mamanaï se détériore et perd sa capacité à promouvoir l'apprentissage chez le bébé (Kaplan, Bachorowski, Smoski, & Hudenko, 2002). Réciproquement, le bébé s'engage affectivement en réponse au mamanaï, ce qui le rend alors plus réactif et plus attractif pour un adulte (Werker & McLeod, 1989). De plus, les réponses du bébé vont à leur tour stimuler la mère et la qualité de son mamanaï (Braarud & Stormark, 2008). Nous aboutissons ainsi à la description d'une boucle interactive complète, dont chaque étape a été expérimentalement démontrée, et qui constitue finalement un modèle de l'interaction mère-bébé, potentiellement extensible à d'autres modalités et vecteurs relationnels.

D'ailleurs, le mamanaï dépasse les frontières de la communication verbale et s'intègre dans une communication multimodale (notamment visuelle et tactile). En effet, les gestes et expressions adressés aux enfants accompagnent le mamanaï et en partagent certaines caractéristiques (exagération, répétition, enthousiasme...) (Brand, Baldwin, & Ashburn, 2002). Cette communication multimodale vise à stimuler l'interaction et à soutenir la compréhension, et le message verbal, en fonction des besoins et de l'âge du bébé, en le contextualisant pour en lever l'ambiguïté (par exemple par le pointage) (Iverson, Capirci, Longobardi, & Caselli, 1999). En effet, la communication très précoce s'appuie sur le contexte concret et l'attention conjointe (Fernald, 2000).

La mère adapte ainsi en permanence sa communication à l'âge, au niveau de développement cognitif et verbal du bébé, donc à ses capacités de compréhension et à ses préférences (Kavanaugh & Jirkovsky, 1982). Le mamanaï s'appuie aussi en continu sur le feed-back du bébé (Bohannon & Marquis, 1977). D'ailleurs, la réceptivité et la sensibilité maternelles conditionnent la capacité du mamanaï à stimuler l'apprentissage (Kaplan, Burgess, Slifer, & Moreno, 2009). La synchronie joue donc un rôle essentiel dans l'émergence et le maintien du mamanaï au travers de la multimodalité, de l'ajustement mère-enfant et de la réciprocité.

Le mamanaïs signale une intention communicative adressée à l'enfant et donc, articulé au regard et ou au pointage, est probablement un vecteur puissant de l'attention conjointe (Senju & Csibra, 2008). En plus de révéler une certaine disposition émotionnelle et réceptive de l'adulte, le mamanaïs signale donc un message "sur mesure", "à la portée" du bébé, ce qui justifie qu'il s'attire la préférence de celui-ci.

En conclusion, le mamanaïs, lié à l'émotion et la réceptivité maternelle, est inséré au coeur de la dynamique d'ajustement affectif et cognitif continu de la mère et de son bébé (Reissland, Shepherd, & Cowie, 2002). C'est à la fois un témoin et un vecteur de la qualité de l'interaction, voire de la connexion mère-enfant, jouant vraisemblablement un rôle majeur dans le développement cognitif et social du bébé, comme le suggérait Papousek (Papousek & Papousek, 1983) en promouvant le partage d'affect (accordage), l'attention conjointe, l'apprentissage et l'entrée dans le langage. Cela va dans le sens des travaux de Hobson qui montrent que le bébé a besoin d'une connexion émotionnelle pour entrer dans des apprentissages intersubjectifs (Hobson, 2004).

Ainsi, chez nos bébés futurs autistes, nous faisons l'hypothèse que le mamanaïs joue un rôle important en stimulant leur engagement relationnel, compensant partiellement leur manque de réactivité au premier semestre, et favorisant la possibilité de l'attention conjointe, mais nous faisons aussi l'hypothèse que, sensible à la qualité et la réciprocité de la relation, ce mamanaïs décroîtra au fil du temps faute d'une stimulation suffisante des parents par le bébé et témoignant de la perturbation consécutive de la relation.

3.4. Article soumis (Child Development)

Motherese, an emotion and interaction based process, impacts infant's cognitive development

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Abstract

We reviewed all experimental studies published since 1966 on motherese or infant-directed speech (IDS). General linguistic and prosodic characteristics of IDS are universal across various languages and IDS is not restricted to mothers. However, IDS varies both with care-giver (cultural, psychological and physiological) and infant (reactivity, interactive feedback) factors. During interaction, (1) IDS meets infant's preference; (2) mother-infant contingency and synchrony are crucial in IDS production and prolongation. Thus, IDS plays a large role in infant's cognitive and social development, promoting infant's sharing of affect, attention and language learning.

Keywords: infant-directed speech – language acquisition – mother-infant interaction – prosody - emotion

Introduction

Motherese, also referred to as infant-directed speech (IDS) or baby talk, is a spontaneous way mothers, fathers, and caregivers talk to infants and young children. Reviewing the variety of terms used to denote the language environment of the young child, Saxton suggested the preferential use of "infant- or child-directed speech" (Saxton, 2008). As early as 1964, a linguist (Ferguson, 1964) had defined baby talk as "a linguistic subsystem regarded by a speech community as being primarily appropriate for talking to young children". He reported "baby talk" to be a well-known, special form of speech occurring in a number of languages and including 3 characteristics: (1) intonational and paralinguistic phenomena (higher overall pitch, preference for certain contours, and special features such as labialization), (2) words and constructions derived from the normal language (simplification of consonant clusters; some kind of interchange among sibilants, affricates and stops; frequent occurrence of diminutives; greater use of nouns rather than pronouns; and use of third person constructions to replace first and second

person ones), and (3) a set of lexical items peculiar to baby talk. He provided a precise and documented study of IDS in several varied languages. Since then, infant-directed talk has been studied extensively in normal mothers as well as those with various pathologies. Here, we aim to review the literature relevant to motherese and examine (1) which factors are associated with its productions and variations and (2) what are its known effects on the child and its suspected functions aside from language acquisition.

Method

We searched PubMed and PsycInfo databases from 1966 to March 2011 with the following criteria: journal article or book chapter with "motherese" or "infant-directed speech" within the title or abstract, published in the English language, excluding essays, and limited to humans. A diagram summarizing the literature search process is provided in figure 1. We found 90 papers using PubMed and 75 more using PsycInfo. Of the 165 documents found, we excluded 29 because they did not aim to improve knowledge on IDS but instead addressed others' aims (see Annex). Of those excluded, 1 paper reviewed infants' early perceptual processing of speech (Robin P. Cooper & Aslin, 1989); 1 study addressed infants' discrimination of adult-directed speech (ADS) dysfluency (Soderstrom & Morgan, 2007); 5 articles studied global caregiver-child interactions (Eckerman, Oehler, Hannan, & Molitor, 1995; Eckerman, Oehler, Medvin, & Hannan, 1994; Jones, 2003; Nakata & Trehub, 2004; Rivero, 2010); 1 study investigated not the form but the thematic properties of the speech mothers address to infants (Rabain-Jamin & Sabeau-Jouannet, 1997); 11 studies used IDS as a stimulus or a reference while addressing other questions (Rebecca J. Brand & Tapscott, 2007; Kaplan, Zarlengo-Strouse, Kirk, & Angel, 1997; Kuhl, Coffey-Corina, Padden, & Dawson, 2005; McCartney & Panneton, 2005; M. Monnot, Orbelo, Riccardo, Sikka, & Rossa, 2003; Pena et al., 2003; Shinozaki, Ostendorf, & Atlas, 2009; Wagner, Greene-Havas, & Gillespie, 2010; Ward & Cooper, 1999; Waxman, 1999; Zentner & Eerola, 2010); 3 studies addressed, across different languages, the influence of ambient language or IDS on newborn cries (Mampe, Friederici, Christophe, & Wermke, 2009) or infant babbling (Chen & Kent, 2010; S. A. Lee, Davis, & Macneilage, 2010); and 1 study focused on the speech of children with autism spectrum disorders (Sharda et al., 2010). Finally, we excluded 6 papers that belonged to a corpus of literature using IDS samples or IDS properties to better understand language acquisition (word segmentation, acquisition of syntax, grammatical categories, phonetic categories, and similar topics) (C. Fisher & Tokura, 1996; Lebedeva & Kuhl, 2010; S. Lee, Davis, & MacNeilage, 2007; Pelucchi, Hay, & Saffran, 2009; Shi, Morgan, & Allopenna, 1998; Werker et al., 2007).

We also screened the reference lists of the 136 relevant papers and found 30 additional relevant references (Bunce & Harrison, 1991; Burnham, Kitamura, & Vollmer-Conna, 2002; Curtin, Mintz, & Christiansen, 2005; D'Odorico & Jacob, 2006; Ferguson, 1964; Fernald & Hurtado, 2006; Herrera, Reissland, & Shepherd, 2004; Kathy

Hirsh-Pasek, Kemler Nelson, Jusczyk, Cassidy, et al., 1987; Hoff & Tian, 2005; Hoff-Ginsberg, 1991; Kajikawa, Amano, & Kondo, 2004; Kaplan, Bachorowski, & Zarlengo-Strouse, 1999; Kaplan, Danko, & Diaz, 2010; Kempe, Brooks, & Gillis, 2005; Kempe, Brooks, Gillis, & Samson, 2007; Kempe, Brooks, Mironova, & Fedorova, 2003; A. Mahdhaoui et al.; Newport, Gleitman, & Gleitman, 1977; Ogle & Maidment, 1993; Onnis, Waterfall, & Edelman, 2008; Nadja Reissland et al., 2002; Rowe, 2008; Segal, Nir-Sagiv, Kishon-Rabin, & Ravid, 2009; Seva et al., 2007; Leher Singh et al., 2002; D. N. Stern et al., 1983; Daniel N. Stern, Spieker, & MacKain, 1982; Swanson & Leonard, 1994; Swanson, Leonard, & Gandour, 1992; Waterfall, Sandbank, Onnis, & Edelman, 2010). Thus we had a total of 166 relevant papers.

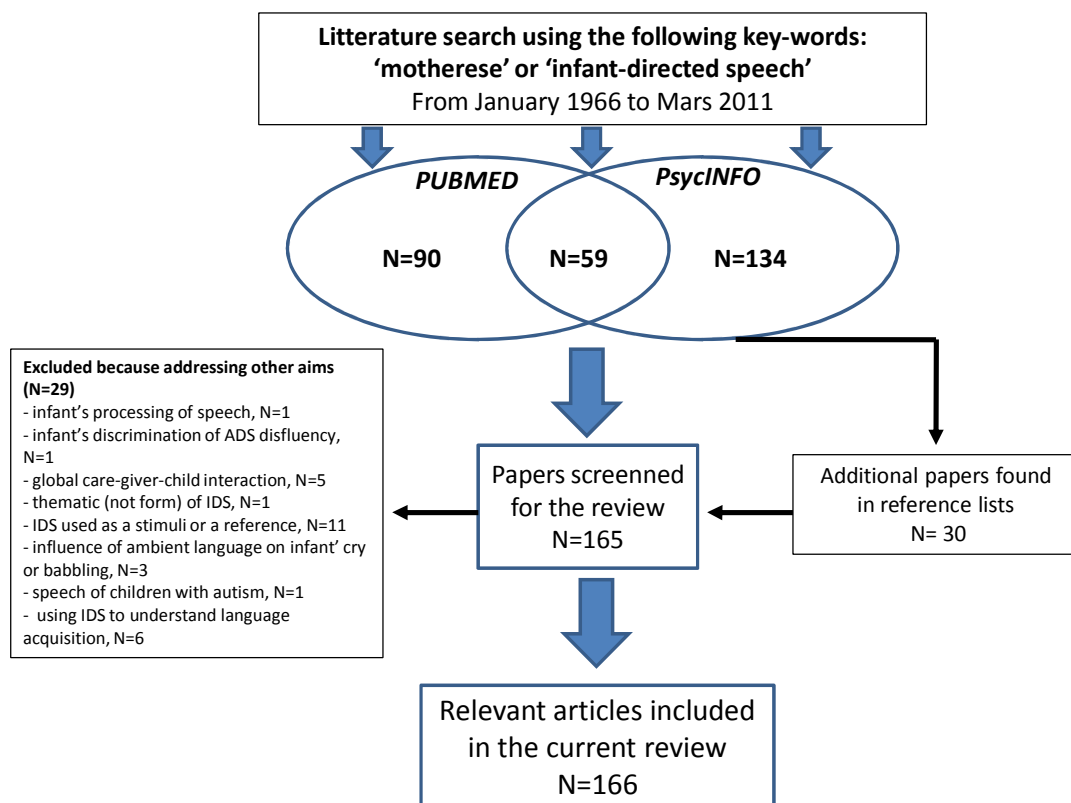


Figure 1: diagramm-flow of the review

Results are presented in several sections, as follows. Concerning IDS production, we reviewed first its general characteristics, then its variations according to maternal language; infant age and gender; infant vocalizations, ability and reactivity; and parental peculiarities. Concerning IDS effects on infants, we listed 4 main functions of IDS: communicating affect, facilitation of social interaction through infant preference, engaging and maintaining infant attention, and facilitating language acquisition. Some articles dealing with theoretical considerations, or including the boundaries of the concept of motherese, are integrated into the discussion.

Results

Motherese characteristics

General linguistic and paralinguistic characteristics of motherese have been described in several works. Motherese is characterized by shorter, linguistically simpler, and redundant utterances, isolated words and phrases, large numbers of questions, a frequent use of proper names, longer pauses, slower tempo, more prosodic repetition, wider tone range, and higher pitch (higher mean f_0) compared with ADS (Durkin, Rutter, & Tucker, 1982; Fernald & Simon, 1984; Cynthia Fisher & Tokura, 1995; Grieser & Kuhl, 1988; Soderstrom, Blossom, Foygel, & Morgan, 2008). Prosody also marks linguistic cues: telling a story to their 14-month-old infants, mothers consistently positioned target words on exaggerated pitch peaks in the utterance-final position, whereas in ADS their prosodic emphasis was more variable (Fernald & Mazzie, 1991). Using electro-laryngography, measures of the central tendency of fundamental frequency (f_0) were higher in mothers' IDS versus ADS, and the range of f_0 was greater, due to an increase in the upper limit of the range (Ogle & Maidment, 1993). The same pattern was found for fathers in up to 6 languages, although only mothers used a wider f_0 -range in IDS (Fernald, Taeschner, Dunn, Papousek, de Boysson-Bardies, et al., 1989; Katsuko Niwano & Kuniaki Sugai, 2003; Brenda Shute & Wheldall, 1999), and grandmothers also showed raised pitch and slower tempo when interacting with their grandchildren (Brenda Shute & Wheldall, 2001).

Prosodic contours vary according to mother's intention, and the prosodic patterns of IDS are more informative than those of ADS, providing the infant with reliable cues to the communicative intent of the speaker. Hearing content-filtered ADS and IDS in 5 interactive contexts (Attention-bid, Approval, Prohibition, Comfort, and Game/Telephone), adults were able to use intonation to identify the mother's intent with higher accuracy in IDS than in ADS (Fernald, 1989). Even South American adults listening to English-speaking mothers producing either prohibition, approval, comfort, or attention distinguished IDS from ADS and were better able to recognize the intention categories with IDS (Bryant & Barrett, 2007). Indeed, when mothers were instructed to use their voice to get their infant's attention, show approval, or provide comfort, dynamic (f_0 contour shape) and summary (f_0 mean, standard deviation, and duration) features discriminated between each of the pragmatic categories (Katz, Cohn, & Moore, 1996). Two contours are context-specific for all mothers in their IDS to 2- to 6-month-olds: mothers use rising contours when wanting attention and eye contact, whereas they use sinusoidal and bell-shaped contours when wanting to maintain the positive affect and gaze of an infant who is already gazing and smiling. They also use specific contours for specific types of sentences: rise contours for yes-no questions, fall contours for "wh" questions and commands, and sinusoidal-bell contours for declarative sentences (Daniel N. Stern et al., 1982). Moreover, across different languages, the same kinds of contours convey the same kinds of meanings in the majority of contexts: arousing/soothing, turn-opening/turn-closing, approving/disapproving, and didactic modeling (Papoušek et al., 1991). Using pitch

and broad spectral-shape measures, a multidimensional Gaussian mixture-model discriminator, designed to track affect in speech, classified ADS (neutral affect) versus IDS correctly more than 80% of the time, and classified the affective message of IDS correctly nearly 70% of the time (Slaney & McRoberts, 2003). Indeed, prosodic features of IDS are related to the widespread expression of emotion toward infants compared with the more inhibited expression of emotion in typical adult interactions: there are few acoustic differences between IDS and ADS when expressing love-comfort, fear, and surprise, but robust differences across these emotions (L. J. Trainor et al., 2000). Moreover, in contrast with ADS, speech and laughter often co-occur in IDS (Nwokah, Hsu, Davies, & Fogel, 1999). Finally, IDS and pet-directed speech (PDS) are similar in terms of heightened pitch and greater affect (intonation and rhythm in low-pass-filtered speech), although only IDS contains hyper-articulated vowels (Burnham et al., 2002).

Whereas IDS analyses generally focus on supra-segmental prosodic cues, recent works aiming to computerize the recognition of motherese also show that segmental characteristics of IDS are entangled with prosodic ones (Inoue, Nakagawa, Kondou, Koga, & Shinohara, 2011; Ammar Mahdhaoui et al., 2011). Even after controlling for typical IDS prosodic characteristics, vocalic categories as well as consonantal categories are enhanced (Cristia, 2010). In motherese, prosodic and phonetic cues also serve to highlight syntax and lexical units. Prosodic information, in maternal IDS to 6- to 10-month-old infants, provides cues to grammatical units not only at utterance boundaries, but also at utterance-internal clause boundaries (Soderstrom et al., 2008). Lengthening of final syllables is particularly exaggerated, even in utterance-internal positions (Albin & Echols, 1996). Reading experimental stories to their child (2 years old) and to adults, mothers lengthen vowels more in IDS than in ADS for content words (Swanson et al., 1992), and for function words only when they appear in a final position (Swanson & Leonard, 1994). Likewise, throughout the first 6 months, back vowel space is shifted upwards, vowel space is smaller and vowel duration is longer (though decreasing over time during months 3 and 4). Fricative /s/ duration is longer, and voice onset time is longer for alveolar and velar stops, as well as for /b/, but not for /p/; all this may enhance both auditory and visual aspects of speech (K. Englund & Behne, 2006; Kjellrun T. Englund, 2005; K. T. Englund & Behne, 2005). Indeed, along with acoustic characteristics, visual cues seem to be part of motherese, suggesting that hyper-articulation in natural IDS may visually as well as acoustically enhance speech. Indeed, lip movements are larger during IDS than ADS (Green, Nip, Wilson, Mefferd, & Yunusova, 2010).

Variations in motherese characteristics

According to language

Specific forms of IDS, as compared with ADS, have been found in various languages, including Western European languages (Fernald, Taeschner, Dunn, Papousek, de Boysson-Bardies, et al., 1989; S. A. Lee & Davis, 2010; B. Shute & Wheldall, 1989),

Hebrew (Segal et al., 2009), Korean (S. Lee, Davis, & Macneilage, 2008), Mandarin (Grieser & Kuhl, 1988; Liu, Tsao, & Kuhl, 2007), Japanese (Fais, Kajikawa, Amano, & Werker, 2010) and even in ASL between deaf mothers and their deaf children (Nobuo Masataka, 1992; N. Masataka, 1998; Reilly & Bellugi, 1996). Yet general trends in the form of IDS exist, and they seem to be mediated by linguistic and cultural factors. French, Italian, German, Japanese, British English and American English IDS share some general features (higher mean f_0 , greater f_0 variability, shorter utterances, and longer pauses) but with specificities across languages. For example, American English parents show the most extreme prosodic modifications (Fernald, Taeschner, Dunn, Papousek, de Boysson-Bardies, et al., 1989). Indeed, British IDS shows smaller increases in vocal pitch compared to American IDS (B. Shute & Wheldall, 1989). Compared to Korean IDS, British IDS also shows language-specific segmental distribution patterns (S. A. Lee & Davis, 2010). However, a conflict may sometimes arise between motherese features and language specificities: some IDS features may disturb the salience of the language. In this case, IDS generally preserves the cues that are essential in ADS; for example, in Mandarin (which is a “tone language”) IDS prosody does not distort the acoustic cues essential to word meaning at the syllable level (Liu et al., 2007), and the same is true for Japanese vowel devoicing (Fais et al., 2010). Regarding the potential conflict between grammatical and affective facial expression in ASL IDS, mothers shift from affect to grammar at about the child's second birthday (Reilly & Bellugi, 1996).

According to infant age and gender

IDS mean f_0 seems to increase from birth, peak around 4 to 6 months, and decrease slowly until the age of two years or more (Christine Kitamura & Burnham, 2003; D. N. Stern et al., 1983), and the extent of acoustic exaggeration is smaller in child-directed speech (CDS) toward 5-year-olds than it is in IDS (Liu, Tsao, & Kuhl, 2009). Also, prosodic contours vary with infant age (Katsuko Niwano & Kuniaki Sugai, 2002), “comforting” being most apparent at 0 and 3 months and then decreasing across age, “expressing affection” and “approval” peaking at 6 months and being least evident at 9 months, and “directive” utterances being most evident at 9 months and least evident at birth (Christine Kitamura & Burnham, 2003). Mothers also adjust their IDS as a function of the child's language ability. Indeed, around the two-word utterance period, an adult-like conversational style with frequent overlaps emerges in Japanese IDS (Kajikawa et al., 2004), and mean f_0 reaches almost the same value as in ADS (Amano, Nakatani, & Kondo, 2006).

Infant gender may also modify IDS characteristics: in their IDS to their 0- to 12-month-old infants, Australian mothers used higher mean f_0 , higher pitch range, and more rising utterances for girls than for boys, but Thai mothers used more subdued mean f_0 and more falling utterances for girls than for boys (C. Kitamura, Thanavishuth, Burnham, & Luksaneeyanawin, 2002).

According to infant vocalizations, ability and reactivity

The infant's presence facilitates IDS production, as shown by Fernald (Fernald & Simon, 1984), who compared IDS, simulated IDS (mother being asked to make a recording for her absent baby) and ADS. In simulated IDS, mean f_0 did not rise significantly compared with ADS, and other features, though they differed significantly from ADS, were intermediate between those of IDS and ADS. In fact, IDS is dynamically affected by feedback from the infant: IDS is reduced when the contingency of the infant's responses is disturbed by decoupling TV sequences of mother-infant interaction (Braarud & Stormark, 2008). Inversely, IDS pitch is higher when, experimentally, IDS high pitch does produce an infant's engagement in response, compared to when low pitch strengthens an infant's engagement (Smith & Trainor, 2008). Mothers also match their pitch to infant vocalizations. In the first 3 months, IDS and infant vocalizations are correlated in pitch, and melody types are correlated in some (3 of 8) mother-infant pairs (Shimura & Yamanouchi, 1992), with tonal synchrony: harmonic or pentatonic series were found in 84% of vocal exchanges, and pitch and/or interval imitations in another 10% (Van Puyvelde et al., 2010). In a longitudinal case study, parents showed a consistent adjustment toward their 3- to 17-month-old infant, whereas the infant did not adjust toward the parents' vocal patterns (G. W. McRoberts & Best, 1997).

Besides vocalizations, mothers adapt their IDS to infants' reactivity. Though full-term infants more often followed their mothers' utterances with a vocalization than did preterm infants, mothers of premature babies more often followed their infants' vocalizations with an utterance directed at the child than did mothers of full-term babies (N. Reissland & Stephenson, 1999). A mother of two 3-month-old fraternal twins instinctively accommodated her IDS, as a strategy to elicit a response, by using a higher mean f_0 and rising intonation contour when she spoke to the infant whose vocal response was less frequent, compared with her IDS to the other infant (K. Niwano & K. Sugai, 2003). Likewise, playing with a Jack-in-the-box, mothers exclaimed in surprise with a higher pitch when the child did not show a surprise facial expression, and infant expression was a stronger predictor of maternal vocal pitch than was the age of the infant (Nadja Reissland et al., 2002). In the same way, mothers adapted their communication to the needs of an unfamiliar deaf (5-year-old) child, using more visual communicative devices, touches, and simpler speech than when communicating to an unfamiliar hearing (4 1/2-year-old) child. Initiations toward the deaf children being however less successful than those toward the hearing children, the women compensated by initiating interactions more often, so that the women and deaf children interacted as frequently as did the women and hearing children (Lederberg, 1984). Finally, parents of children with Down syndrome spoke in a higher register and with a significantly wider mean pitch variance than parents of other children with mental retardation (Fidler, 2003).

Mothers also tailor their communication to infants' levels of lexical-mapping development. Teaching their infants four target words by using distinct objects, mothers used target words more often than non-target words in synchrony with object motion and sometimes touch, and synchrony decreased in parallel with

infants' decreasing reliance on synchrony across age (Gogate et al., 2000). Likewise, IDS semantic content shows strong relationships with changes in the child's developing language from zero to one-word utterances (Kavanaugh & Jirkovsky, 1982), and a clear signal of non-comprehension from the child results in shorter utterances (Bohannon & Marquis, 1977). In IDS to their profoundly deaf infants with cochlear implants, mothers tailored pre-boundary vowel lengthening to infants' hearing experience rather than chronological age, whereas they exaggerated prosodic characteristics in IDS regardless of infants' hearing status (Bergeson, Miller, & McCune, 2006; Kondaurova & Bergeson, 2010).

Do parental peculiarities modify motherese production?

Whether a mother grew up with siblings or not could explain individual variability in IDS: when reading picture books aloud to a young child, young women who were only children were less likely to show prosodic modifications (higher mean pitch and pitch excursions) (Ikeda & Masataka, 1999). Regarding socio-economic status (SES), most studies have been conducted with children aged 18 to 24 months and older. Significant social class (working-class versus upper-middle-class) differences were found in the mothers' CDS (Hoff & Tian, 2005; Hoff-Ginsberg, 1991; Rowe, 2008). However, there are also main effects of communicative setting (mealtime, dressing, book reading, or toy play) on mothers' CDS, and the amount of time mothers spend interacting with their children may also have an important influence (Hoff-Ginsberg, 1991). Further, the link between CDS and SES (as measured by income and education) is mediated by parental knowledge of child development (Rowe, 2008).

Parental neurophysiological factors seem to mediate an influence of being a parent on IDS. Unlike mothers with older children, mothers with preverbal infants showed enhanced activation in the auditory dorsal pathway of language areas in functional MRI when they listened to IDS, and higher cortical activation was also found in speech-related motor areas among extroverted mothers (Matsuda et al., 2011). Additionally, in the first 6-months, maternal oxytocin level is related to the amount of affectionate parenting behavior, including "motherese" vocalizations, expression of positive affect, and affectionate touch (Gordon et al., 2010).

Finally, maternal pathology seems to impair IDS. Depressed mothers fail to modify their behavior according to that of their 3- to 4-month-old infants, are significantly slower to respond to infant vocalization, have more variable utterances and pauses, and are less likely to produce motherese (Bettes, 1988). Also, with their 6- and 10-month-old infants, depressed mothers speak less, with fewer affective and informative features in their IDS. Moreover, the affective components of their IDS don't vary with time, in contrast with non-depressed mothers, whose affective salience decreases between 6 and 10 months of infant age (Herrera et al., 2004). Especially noteworthy is that the IDS of depressed mothers to their infants shows smaller f0 variance, except, interestingly, when taking antidepressant medication and being diagnosed as in at least partial remission (Kaplan et al., 2001). IDS of

mothers with schizophrenia is also reduced, compared to mothers with other reasons for post-natal hospitalization (Wan, Penketh, Salmon, & Abel, 2008).

Motherese effects on the infant

As hypothesized early on, IDS may function developmentally to communicate affect, to regulate infant arousal and attention, and to facilitate speech perception and language comprehension (Fernald, Taeschner, Dunn, Papousek, de Boysson-Bardies, et al., 1989; McLeod, 1993).

Communication of affect

IDS conveys mothers' affect and influences infants' emotions. As reported above, prosodic patterns are more informative in IDS and the variation of prosodic contours according to the mother's intention provides the infant with reliable cues to his mother's affect and intention. Indeed, hearing IDS in an unfamiliar language, 5-month-olds smile more to approvals, and show negative affect more often in response to prohibitions, whereas they don't show differential affect in response to approvals and prohibitions in ADS (Fernald, 1993). Similarly, IDS approval contours elevate infant looking compared with disapproval and control contours, whereas disapproval contours inhibit infant looking (Papoušek et al., 1990). Concerning psycho-physiological effects, in 9-month-old infants, EEG power, specifically to the frontal region, was linearly related to the affective intensity of IDS: the response was greatest to fear, then surprise, then love/comfort. Moreover, heart rate decelerated to IDS, though independently of affective content (Santesso, Schmidt, & Trainor, 2007). Another reported psycho-physiological effect is that infants under 6 months of age grew more rapidly if their primary caregiver spoke high quality/quantity IDS (Marilee Monnot, 1999). Another study (Snowdon & Teie, 2010) reported that tamarins are calmed by music with "acoustical characteristics of tamarin affiliation vocalizations."

Facilitation of social interaction through infants' preference for IDS

Many studies have shown that infants prefer IDS over ADS. In an operant auditory preference procedure with natural IDS and ADS samples spoken by unfamiliar women, 4-month-old infants showed a listening preference for IDS (Anne Fernald & Patricia Kuhl, 1987). Five- and eight-month-old infants, as well as severely handicapped children (Santarcangelo & Dyer, 1988), watch longer and show greater affective responsiveness to IDS than ADS. Moreover, infants' behavior in response to IDS makes them more attractive to naive adult judges, and thus IDS may facilitate and maintain positive adult-infant interactions (Werker & McLeod, 1989). Furthermore, 5-month-old infants keep in memory and prefer to look at an individual who had previously appeared to use IDS (Schachner & Hannon, 2010). Even infant-directed signing raised greater attentional and affective responsiveness in both deaf and hearing infants compared with adult-directed signing (N. Masataka, 1998).

Infant preference follows a developmental course; it is present from birth and may not depend on any specific postnatal experience, but there is a possible role for prenatal auditory experience with speech. One-month-old and even newborn infants prefer IDS over ADS (Robin P. Cooper, 1993; R. P. Cooper & Aslin, 1990; Pegg, Werker, & McLeod, 1992). Moreover, frontal cerebral blood flow increases more with IDS in neonates during their sleep, compared with ADS, suggesting that IDS alerts the brains of neonates to attend to the utterances even while sleeping (Saito et al., 2007). Subsequently, IDS preference changes with development. During the first year, it appears to follow a U-shaped developmental shift: 4-month-old infants tend to prefer IDS over ADS, this preference decreases temporarily, and then older infants again show a consistent preference for IDS (Hayashi, Tamekawa, & Kiritani, 2001; Newman & Hussain, 2006). Moreover, 4-month-olds prefer slow IDS when affect is constant and IDS with high affect when rhythm is constant. In contrast, 7-month-olds prefer normal over slow IDS regardless of its affective level (Panneton, Kitamura, Mattock, & Burnham, 2006). However, as regards the speech of their own mothers, only 4-month-old infants (and not 1-month-olds) prefer IDS over ADS, whereas unfamiliar 1-month-olds hearing the same IDS and ADS tapes prefer IDS (Robin Panneton Cooper, Abraham, Berman, & Staska). And newborns prefer their mothers' normal speech to IDS (Hepper, Scott, & Shahidullah, 1993). The developmental course of infants' preference is also consistent with the type of affective intent used by mothers at each age point (Christine Kitamura & Burnham, 2003): infants' preference shifts between 3 and 6 months from comforting to approving, and between 6 and 9 months from approving to directive (Christine Kitamura & Lam, 2009). Rising, falling, or bell-shaped IDS contours arouse 4- to 8-month-olds' attention (Kaplan & Owren, 1994). The terminal falling contour of IDS (a comforting utterance) may especially serve to elicit infants' vocal response: the rate of 3-month-old infants' vocal responses is higher when IDS is terminated with a falling contour than with a rising or flat contour, whereas their response doesn't vary with the mean f₀ (K. Niwano & K. Sugai, 2002). However, infants' processing of IDS changes with age: unlike 6-month-olds, 4-month-olds fail to categorize (either low-pass filtered or unfiltered) IDS utterances into different classes (approving or comforting) (Spence & Moore, 2003). Finally, adults prefer ADS content as well as prosody over IDS (Johnson, Dixon, Coon, Hilker, & Gouvier, 2002).

What are the acoustic determinants of this infant preference for IDS? When lexical content is eliminated, young infants show an auditory preference for the f₀ (pitch) patterns of IDS, but not for the amplitude (correlated to loudness) or duration patterns (rhythm) of IDS (R. P. Cooper & Aslin, 1994; Anne Fernald & Patricia Kuhl, 1987; Leibold & Werner, 2007). This pattern is consistent with the finding that infants prefer higher-pitched singing (Laurel J. Trainor & Zacharias, 1998). However, deaf infants also show greater attentional and affective responsiveness to infant-directed signing than to adult-directed signing (N. Masataka, 1998). Although an auditory stimulus with the characteristics of IDS was more easily detected in noise than was one that resembled ADS (Colombo, Frick, Ryther, & Coldren, 1995), and mothers accentuated some IDS characteristics in a noisy context (Newman & Hussain, 2006),

infants' preference doesn't depend on background noise (Newman & Hussain, 2006). Actually, IDS preference relies on a more general preference for positive affect in speech. When affect is held constant, 6-month-olds do not prefer IDS. They even prefer ADS if it contains more positive affect than IDS. Higher and more variable pitch is neither necessary nor sufficient for determining infants' preferences, although pitch characteristics may modulate affect-based preferences (Leher Singh et al., 2002). This result should be linked with the finding that IDS prosody is driven by the widespread expression of emotion toward infants, in comparison with the more inhibited manner of adult interactions (L. J. Trainor et al., 2000). Finally, preference is also based on linguistic criteria: 6-month-olds prefer IDS directed toward older infants when the frequency of repeated utterances is greater, thus matching IDS to younger infants (Gerald W. McRoberts, McDonough, & Lakusta, 2009). This preference for repetitiveness may explain why 6-month-old infants prefer audiovisual episodes of their mother singing over (infant-directed) speaking (Nakata & Trehub, 2004; Trehub & Nakata, 2001).

Arousing infants' attention

IDS facilitates associative learning. In a conditioned-attention paradigm with IDS or ADS as the signal for a face, IDS only (not ADS) elicited a significant positive summation, but only when it preceded the presentation of the face (not in the backward pairing position), and only with a smiling or sad face, not with a fearful or angry face (Kaplan, Jung, Ryther, & Zarlengo-Strouse, 1996). Actually, IDS shows arousing properties: in contrast with ADS, infants' looking time in response to IDS increased between the first and second presentations. Similarly, when alternating ADS and IDS, response to ADS is greater if preceded by IDS, while response to IDS is lesser if preceded by ADS (Kaplan, Goldstein, Huckleby, & Cooper, 1995). IDS may in fact serve as an ostensive cue alerting the child of a referential communication directed to him: eye-tracking techniques revealed that 6-month-old infants followed the adult's gaze (a potential communicative-referential signal) toward an object (joint attention) only when it was preceded by ostensive cues such as IDS or direct gaze (Senju & Csibra, 2008). Likewise, the prosodic pattern of motherese (as with eye contact, saying the infant's name and contingent reactivity) triggers 14-month-olds to attend to others' emotion expressions that are directed toward objects (Gergely, Egyed, & Kiraly, 2007).

However, experience-dependent processes influence the effects of IDS. Kaplan conducted several studies using the same conditioned-attention paradigm with face reinforcers, to assess how parental depression affects infants' learning. IDS produced by depressed mothers didn't promote associative learning in their own infant or in unfamiliar infants. However, infants of depressed mothers showed strong learning in response to IDS produced by an unfamiliar, non-depressed mother (Kaplan et al., 2002; Kaplan et al., 1999), although this learning was poorer when maternal depression was longer (e.g., with 1-year-old children of mothers with

perinatal onset) (Kaplan, Danko, Diaz, & Kalinka, 2010). Nevertheless, infants of chronically depressed mothers still acquired associations with the IDS of a non-depressed father (Kaplan et al., 2004). In fact, father involvement may affect infant responsiveness to male IDS: in contrast with infants of unmarried mothers, infants of married mothers learned in response to male IDS, and this happened especially if the infant's mother was depressed (Peter S. Kaplan et al., 2010). However, infants of depressed fathers showed poorer learning with their fathers' IDS (Kaplan, Sliter, & Burgess, 2007). Finally, if the reduced perceptual salience of depressed mothers' IDS leads to deficient learning in otherwise competent learners, current mother-infant interactions also influence an infant's learning from his mother's IDS. In fact, f_0 modulation, although smaller in depressed mothers' IDS, doesn't predict infant learning, whereas maternal sensitivity (estimated through Emotional Availability Scale ratings) does, even after taking maternal depression into account (Kaplan et al., 2009).

Facilitation of language acquisition

Does IDS prosody help language acquisition, and how?

IDS prosody facilitates syllabic discrimination in the first 3 months: infants can discriminate the three-syllable sequences [marana] versus [malana] when supra-segmental characteristics of IDS (f_0 amplitude and duration) emphasize the middle syllable, but they can't do so with ADS prosody (Karzon, 1985). Moreover, in synthetic [ra] and [la] tokens modeled on IDS, infants can discriminate rising versus falling pitch patterns (Karzon & Nicholas, 1989). As regards vowel discrimination, IDS contains the distributional information needed to form native-language vowel categories: when exposed to vowel tokens drawn from either English or Japanese IDS, an algorithm successfully discovered the language-specific vowel categories, reinforcing the proposal that native-language speech categories are acquired through distributional learning (Vallabha, McClelland, Pons, Werker, & Amano, 2007). Of note is that though the exaggerated pitch contours of IDS aid infants' acquisition of vowel categories, the high pitch of IDS might actually impair infants' ability to discriminate vowels, and thus must serve another function, such as attracting infants' attention or aiding emotional communication (L. J. Trainor & Desjardins, 2002).

IDS prosody may also help the pre-linguistic infant to segment speech into clausal units within which grammatical rules apply: in a preference procedure using matched samples of IDS, constructed by inserting pauses either at clause boundaries or at within-clause locations, 7- to 10-month-old infants oriented longer to the samples segmented at the clause boundary (Kathy Hirsh-Pasek, Kemler Nelson, Jusczyk, Cassidy, et al., 1987); this preference held for IDS but not for ADS (Kemler Nelson et al., 1989). Moreover, pitch peaks of IDS, especially at the ends of utterances, can also help word segmentation and recognition and facilitate speech processing. Infants are able to distinguish words from syllable sequences spanning word boundaries after exposure to a set of nonsense sentences spoken with IDS

characteristics, but not after hearing the same sentences spoken with ADS intonation contours (Thiessen, Hill, & Saffran, 2005). The maternal input of 20-month-old late-talkers (LTs) differs from that of typical children in that mothers of LT produce fewer common nouns, mark fewer nouns with a pitch peak, and use more flat pitch contours than mothers of typical children (D'Odorico & Jacob, 2006). Thus, reviewing the research, Morgan suggested that prosody is an important contributor to early language understanding, and assists infants in developing root processes of parsing (Morgan, 1996). Stress information in the ambient language not only shapes how statistics are calculated over the speech input, but is also encoded in the representations of parsed speech sequences: to parse sequences from an artificial language, 9- and 7-month-old infants adopted a stress-initial syllable strategy and appeared to encode stress information as part of their proto-lexical representations (Curtin et al., 2005). Further, high affective variation in IDS helps preverbal infants to recognize repeated encounters with words, in turn creating both generalizable representations and phonologically precise memories for words, whereas conversely, low affective variability appears to degrade word recognition on both fronts, compromising infants' ability to generalize across different affective forms of a word and to detect similar-sounding items (L. Singh, 2008). Finally, IDS may be more easily detectable in a noisy environment than ADS (Colombo et al., 1995). Concerning neural correlates, event-related potentials (ERPs) of 6-month-old infants increase in IDS versus ADS only in response to familiar words, whereas for 13-month-olds, ERPs increase in response to both familiar and unfamiliar words in IDS versus ADS, suggesting that IDS serves as an attentional spotlight to increase brain activity to potentially meaningful words (Zangl & Mills, 2007).

However, some studies find moderators of these results; for example, slow speaking rate and vowel hyper-articulation improve 19-month-olds' ability to recognize words, whereas wide pitch range doesn't (Song, Demuth, & Morgan, 2010). Words artificially isolated from parents' speech to their 2- to 3-year-olds were found to be less intelligible to native English-speaking undergraduates than were words originally spoken to an adult (Bard & Anderson, 1983). Word learning with IDS prosody may impair word recognition in ADS: in fluent speech, 7.5-month-old infants prefer to listen to words produced with emphatic stress, but recognition is most strongly enhanced when the degree of emphatic stress is identical at familiarization and at recognition (Bortfeld & Morgan, 2010). Also, automatic isolated-word speech recognizers trained on IDS do not always exhibit better recognition performance; however, on mismatched data, their relative loss in performance is less severe than that of recognizers trained on ADS and then presented with IDS, due to larger class overlaps in IDS (Kirchhoff & Schimmel, 2005). But over the long term, word recognition by 7- to 8-month-old infants is successful for words introduced in IDS, but not for those introduced in ADS, regardless of the register in which recognition stimuli are produced (Leher Singh, Nestor, Parikh, & Yull, 2009).

Do IDS linguistic properties help language acquisition, and how?

In response to Chomsky's view that motherese is a form of degenerate speech, and the resulting theoretical impetus towards nativist explanations of language acquisition, several researchers sought evidence that language input to children is highly structured and possibly quite informative for the learner. There has been a lively debate between proponents of motherese as a useful tool for language acquisition and those who contend that it doesn't help language acquisition. First, Newport (Newport et al., 1977) claimed that motherese is not a syntax-teaching language, and that motherese may be an effect rather than a cause of learning language. Newport and colleagues found few correlations between syntax in caregivers' speech and language development. Responding to Furrow (D. Furrow & Nelson, 1986), a further study with two groups of children matched for age (18- to 21-month-olds and 24- to 27-month-olds) again found few effects of the syntax of mothers' IDS on the child's language growth, with most effects being restricted to a very young age group and suggesting that increased complexity of maternal speech is positively correlated with child language growth in this age range (Gleitman, Newport, & Gleitman, 1984). Scarborough (Scarborough & Wyckoff, 1986) also found that maternal speech type had no influence on language development.

However, other studies that took into account children's level of language competence at the time when maternal speech was assessed found a relationship between IDS semantic and syntactic categories and language development. Several characteristics of mothers' speech (e.g., utterance length and use of pronouns) to their 18-month-old infants predicted subsequent (27-month-old) child speech, in that mothers' choice of simple constructions facilitated language growth (David Furrow, Nelson, & Benedict, 1979). And Rowe, controlling for toddlers' previous vocabulary ability, found that CDS at 2;6 predicted child vocabulary ability one year later (Rowe, 2008). As early as 13 months of age, pre-existing differences were found between mothers of earlier and later talkers. Moreover, when individual differences in style of language acquisition (expressive versus non-expressive styles) were examined, for the "non-expressive" group several associations emerged between IDS type at 13 months and mean length of utterance at 20 months (Hampson & Nelson, 1993).

Which linguistic characteristics of motherese may help language acquisition? First, statistically prominent structural properties of CDS that may facilitate language acquisition are indeed present in realistic CDS corpora (Waterfall et al., 2010). In particular, the partial overlap of successive utterances, well-known in CDS, enhances adults' acquisition of syntax in an artificial language (Onnis et al., 2008). CDS contains both isolated words and short, frequently used sentence frames, and a familiar sentence context may help word acquisition, because 18-month-old infants are slower to interpret target words (familiar object names) in isolation than if they are preceded by a familiar carrier phrase (Fernald & Hurtado, 2006). Especially, the tendency in IDS to put target words in sentence-final position may help in segmenting the linguistic stream. Indeed, hearing IDS in an unfamiliar non-Western language (Chinese), adults demonstrated learning of the target words only when

these were placed in final position, rather than in a medial position (Golinkoff & Alioto, 1995). Finally, use of diminutives (a pervasive feature of the CDS registers in many languages) facilitates word segmentation in adults hearing an unfamiliar language (Kempe et al., 2005; Kempe et al., 2007) and enhances gender categorization (Kempe et al., 2003) and gender-agreement in Serbian children, even though CDS uses few diminutives in this language (Seva et al., 2007).

Discussion

Summary review: IDS is universal; it transcends specific languages. Not only mothers but also fathers, grandmothers and other caregivers modify their speech when addressing an infant, and infants demonstrate a preference for IDS. Yet various factors related either to the caregiver or to the infant influence IDS quantity and quality, and IDS, like the infant's preference for IDS, if present from birth, follows a developmental course that can be influenced by the infant's experience (see Kaplan's work). IDS consists of linguistic and supra-linguistic modifications. Linguistic modifications include shorter utterances, vocabulary and syntactic simplifications, use of diminutives and repetition, all of which are obviously designed to facilitate comprehension and aid language acquisition. Prosodic modifications seem to have more ubiquitous functions. High pitch matches infants' preference and, with increased f_0 modulation, may facilitate infants' arousal and learning. Prosodic contours convey caregivers' affect and intention and some of them stimulate infant responsiveness. Finally, exaggerated pitch contours and phonetic modifications facilitate vowel discrimination and phonetic categorization, and also assist in sentence or word segmentation, word recognition and syntax acquisition.

Placing IDS within a more global communication phenomenon: We saw above that mothers adjust their IDS to infants' abilities. From a larger communication perspective, IDS may be part of a more general phenomenon of adaptation to the partner in communication. First, there are other cases of speech adjustment to the listener. Adults simplify their vocabulary choices when speaking with children aged up to 12 years (Hayes & Ahrens, 1988). Likewise, in speech to elderly adults, CDS (which clarifies instructions, which are given in an attention-getting manner) is often used and may improve performance and arousal in difficult tasks (Bunce & Harrison, 1991). Even in normal ADS, new words are highlighted by prosodic cues: in both IDS and ADS, repeated words are shorter, quieter, lower-pitched, and less variable in pitch than words on first mention, and they are placed in less prominent positions relative to new words in the same utterance (Cynthia Fisher & Tokura, 1995). And even in master-dog dyads, the structural properties of "doggerel" (PDS) are strikingly similar to those of motherese, except in functional and social areas (K. Hirsh-Pasek & Treiman, 1982). Second, we know that other speakers adjust their speech to infants. It is not only human mothers and other caregivers who adapt their speech to infants. Girls can produce IDS with their 12-month-old brothers, with few differences in the functions of the utterances or topics introduced, although there are differences in

the amount of language and types of utterances, when compared with their mothers (Nwokah, 1987). Even 4-year-old children modify some of their prosodic characteristics when speaking to infants: they speak more slowly, tend to lower their f_0 , and change their amplitude variability (Weppelman, Bostow, Schiffer, Elbert-Perez, & Newman, 2003). The linguistic content of educational children's programs has also been shown to generally follow the linguistic constraints and adjustments evident in adults' CDS (Rice & Haight, 1986). The use of IDS by humans has also been compared to the "caregiver call" (almost exclusively infant-directed) in squirrel monkeys, the variability of which in several acoustic features, most notably pitch range and contour, is associated with particular contexts of infant care, such as nursing or retrieval (Biben, Symmes, & Bernhards, 1989). Likewise, tamarins are calmed by music with the "acoustical characteristics of tamarin affiliation vocalizations" (Snowdon & Teie, 2010). Furthermore, Falk (Falk, 2004) compared mother-infant gestural and vocal interactions in chimpanzees and humans and even suggested that pre-linguistic vocal substrates for motherese evolved as females gave birth to relatively undeveloped neonates and adopted new strategies that entailed maternal quieting, reassuring, and controlling of the behaviors of physically removed infants (unable to cling to their mothers' bodies).

Integrating IDS into the thick of mother-infant interaction: IDS implies emotion sharing, mother-infant adjustment, synchrony and multimodal communication. Indeed, IDS is part of a multimodal, synchronous communication style used with infants to sustain the interaction and highlight the message. Mothers support their vocal communication with other modalities (e.g., gestural, tactile, and visual). At a gestural level ("gesturese"), mothers with their 16- and 20-month-old infants employ mainly concrete deictic gestures (e.g., pointing) that are redundant with and reinforce the message conveyed in speech by disambiguating and emphasizing the verbal utterance; moreover, children's verbal and gestural production and vocabulary size may be correlated with maternal gesture production (Iverson et al., 1999; O'Neill, Bard, Linnell, & Fluck, 2005). Mothers' demonstrations of the properties of novel objects to infants are also higher in interactiveness, enthusiasm, proximity to partner, range of motion, repetitiveness and simplicity, indicating that they indeed modify their infant-directed actions in ways that likely maintain infants' attention and highlight the structure and meaning of action (Rebecca J. Brand et al., 2002). Likewise, mothers' singing and synchronous behaviors with the beat ("songese") provide a segmentation of the temporal structure of the interaction: 3- to 8-month-old infants are sensitive to their mothers' emphasis by producing more synchronous behaviors on some beats than on others. The multimodal sensory information provided by mothers shares the characteristics of "motherese" and may ensure effective learning in infants (Longhi, 2009). Mothers also use contingency and synchrony (intrapersonal and interpersonal) to reinforce the dialogue and exchange. By highlighting focal words using nonlinguistic contextual information available to the listener and using frequent repetition and formulaic utterances, IDS may be a form of "hyper-speech" which facilitates comprehension, not by modifying the phonetic properties of individual words but rather by providing contextual support on

perceptual levels accessible to infants even in the earliest stages of language learning (Fernald, 2000). Pragmatic dimensions of IDS may also provide contingent support that helps language comprehension and acquisition. In a case study, both parents used roughly equal amounts of language with their infant but the functions of the mother's speech differed importantly from those of the father's, providing more interactive negotiation, which could be a crucial factor in language development (Matychuk, 2005).

Also, IDS is regarded as an emotional form of speech. Several studies highlight the impact of emotion on both motherese production and effects, especially concerning prosodic characteristics, that are conditioned by vocal emotion (L. J. Trainor et al., 2000). In general, acoustic analyses of fundamental frequency (f_0) are positively associated with subjective judgments of emotion (M. Monnot et al., 2003). Thus, prosody (linked with f_0 value and contours) reveals actually quantity and quality of affect. A review of the literature on infants' perception of facial and vocal expressions shows that infants' recognition of affective expressions first relies on multimodally presented information, then on recognition of vocal expressions and finally on facial expressions alone (Walker-Andrews, 1997). Moreover, IDS affective value is responsible for infant preference (Leher Singh et al., 2002). Therefore mothers' affective pathology, such as maternal depression, alters motherese and impairs infants' conditioned learning with IDS. As one hypothesis, IDS, music and emotion may be linked before birth, through prenatal associations between the mother's changing physical and emotional state and concomitant changes in both hormone levels in the placental blood and prenatally audible sound/movement patterns. This may be responsible for infants' sensitivity to motherese and music (Parncutt, 2009).

Finally, IDS highlights mother-infant adjustment along interaction. Mothers adjust their IDS to infants' age, cognitive abilities and linguistic level, and thus IDS may arouse infants' attention by signaling speech that is especially addressed to the infant, the content and form of which is then adapted to the infant. Moreover, mothers adapt their IDS to infants' reactivity and preference. Indeed, mothers' continuous adjustment to infants results in facilitation of exchange and interaction, with positive consequences not only for sharing emotions but also for learning and language acquisition. Thus, maternal sensitivity predicts infant learning better than f_0 modulation (Kaplan et al., 2009). On the other hand, infant reactivity is also important to consider because we know that infant presence increases motherese (Fernald & Simon, 1984) and that infants' positive, contingent feedback makes them more attractive (Werker & McLeod, 1989) and increases motherese quality in turn (Braarud & Stormark, 2008; Smith & Trainor, 2008). Mother-infant contingency and synchrony are thus crucial in IDS production and prolongation.

Conclusion

We can concur with authors who hold the perspective that beyond language acquisition, IDS plays a large role in the cognitive and emotional development of

infants (H. Papousek & Papousek, 1983). Because IDS is a rich, dynamic and interactive process, further research is needed to investigate how this process is altered by infants' communicative troubles, such as early signs of autism spectrum disorder, and how these alterations can in turn affect infants' developmental course.

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4. Projet d'étude du motherese dans les interactions précoces des bébés à devenir autistique

4.1. Introduction

Nous avons décidé d'enrichir notre étude des interactions synchrones à l'aide de la prise en compte de la qualité affective des vocalisations parentales. Le mamanaïs stimule l'engagement social, l'attention conjointe et l'acquisition du langage. Or nous savons que ces domaines sont déficitaires dans le développement de l'autisme. Dans le cas de l'autisme, quelles sont nos attentes et nos hypothèses au sujet du mamanaïs vis-à-vis des 2 sens de l'interaction ?

4.1.1. Le bébé autiste répond-il au mamanaïs ?

L'équipe de Zilbovicius a montré que le sillon temporal supérieur du cerveau, zone ordinairement dévolue au traitement du langage, ne fonctionne pas correctement chez les sujets autistes et qu'ils traitent donc la parole humaine de la même façon qu'un autre bruit (Boddaert et al., 2004). De même, Patricia Kuhl a montré que les enfants autistes préfèrent écouter du non-langage plutôt que du mamanaïs (Kuhl et al., 2005). Cela signifie-t-il que dès la naissance les bébés autistes sont privés de la capacité de traiter spécialement et finement la voix humaine ? Nous faisons plutôt l'hypothèse que c'est la non-mise en place de cette fonction communicative verbale chez le bébé qui va déboucher secondairement sur une non-spécialisation (ou un non-fonctionnement) de la zone du sillon temporal supérieur chez l'enfant. En effet, notre expérience clinique avec des bébés autistes montre que ces bébés, bien que globalement fermés à la relation, sont capables de s'engager affectivement (regards, sourires, vocalisations) lorsqu'on s'adresse à eux en mamanaïs (Laznik, 2007). Nous faisons donc l'hypothèse d'une amélioration de l'engagement et de la réponse des bébés autistes, au moins au début, lorsqu'on s'adresse à eux avec la prosodie du mamanaïs.

4.1.2. Quelles sont les conséquences de l'autisme sur le mamanais ?

Nous avons vu que la qualité du mamanais dépend en partie du feed-back du bébé, de son engagement dans la relation, réalisant une boucle interactive qui décrit normalement un cercle vertueux. Ce cercle vertueux débouche probablement, avec d'autres cercles vertueux de même type, sur la consolidation de la capacité d'être dans une relation avec l'autre et la construction de la capacité de comprendre l'autre comme un sujet intentionnel et communicant (intersubjectivité), avec ces passages obligés que sont l'attention conjointe et la communication verbale.

Chez le bébé autiste, ce cercle vertueux ne fonctionne pas et nous pouvons même nous attendre à un cercle vicieux: nous avons vu que le bébé autiste est trop peu réactif et qu'il manque déjà spontanément d'intérêt pour l'autre. Nous savons que les parents, s'ils ont identifié leur bébé comme nécessitant d'être sollicité, peuvent user du mamanais dans ce but (comme ce qui se passe par exemple avec des prématurés (Reissland & Stephenson, 1999), ou d'autres causes de moindre réactivité du bébé (Niwano & Sugai, 2003)). Inversement, lorsque les difficultés du bébé débordent leurs capacités d'adaptation, nous pouvons craindre que le manque de réactivité de leur bébé ne tarisse leur propre production de mamanais, dans une sorte d'extinction de la richesse relationnelle: il s'agirait alors cette fois d'un cercle vicieux. Celui-ci aurait des conséquences négatives sur la relation, la construction de l'intersubjectivité et l'acquisition du langage. Ces non-constructions pourraient rendre compte de la 2e phase du développement autistique: le décrochage et la fermeture que nous avons observés dans notre analyse de la littérature des films familiaux et aussi dans notre étude expérimentale: il y a un moment, ou plusieurs moments successifs, dans la deuxième année ou plus précocément, où le bébé se referme et commence à nettement éviter l'autre. Dans cette perspective, l'extinction du mamanais (pris dans ce cercle interactif vicieux), se comporterait donc comme un cofacteur de la construction autistique (ou de la non-construction de la communication avec l'autre ou de l'intersubjectivité).

D'une façon plus générale, comme nous avons vu que le mamanais traduit l'émotion vécue dans la relation à l'autre et l'interaction, l'étude de sa dynamique devrait refléter finalement la qualité des interactions et de la relation.

Notons que dans ces hypothèses, nous nous attendons à observer une différence entre l'évolution du mamanais de la mère ("en première ligne"), celui du père (qu'on peut imaginer moins "vulnérable" au manque de réponse du bébé), et le mamanais d'un tiers (a priori sans inquiétude ni malaise dans sa relation à ce bébé, ne subissant donc que l'effet immédiat du manque de réaction, et non l'effet chronique lié à une longue expérience de cette relation). Nous prendrons soin de distinguer ces 3 types de locuteurs dans nos analyses.

Cette étude nécessite la réalisation d'un algorithme spécifique permettant la détection automatique du mamanais, à grande échelle, sur des bandes acoustiques de films sonores.

Le projet est de pouvoir utiliser cet algorithme sur notre banque de films, afin de compléter les analyses des interactions synchrones déjà effectuées, par la caractérisation des vocalisations parentales en "mamanais" ou non-mamanais". Nous pourrions ainsi étudier d'une part la réponse du bébé autiste au mamanais dans le sens Care-giver→bébé (faisant l'hypothèse qu'il y sera sensible au moins au début, avant la phase secondaire de fermeture); d'autre part la sensibilité immédiate du mamanais du care-giver aux réactions du bébé, dans le sens bébé→care-giver (nous faisons l'hypothèse que le mamanais des *parents* d'autistes, comme celui des parents de bébés normaux, est renforcé par les réactions du bébé); enfin la sensibilité à long terme du mamanais à l'épreuve de la relation avec un bébé autiste: évolution du taux de mamanais au fil du temps (nous faisons l'hypothèse qu'il y a, surtout chez la mère, une chute de ce médiateur de la relation).

4.2. Création d'un détecteur de motherese

4.2.1. Méthodologie

En collaboration avec des ingénieurs informaticiens spécialisés en traitement du signal, nous avons créé un algorithme de détection du mamanais. Parmi plusieurs films de bébés italiens dont nous disposons dans la banque de Pise, nous avons choisi les films d'un bébé autiste dont la qualité sonore était satisfaisante (et qui bien sûr n'appartenait pas à la base de données que nous voulions ultérieurement étudier). Nous disposons de 3 heures cumulées de film sur la première année de vie du bébé. Nous avons segmenté et étiqueté manuellement les vocalisations maternelles adressées au bébé en les classant soit « mamanais », soit « non-mamanais ». Cette classification a été réalisée séparément par 2 cotateurs indépendants avec une fidélité interjuge offrant un kappa de 0.82. Nous avons retenu 100 séquences (d'une durée de 0.5 à 4 secondes) de chaque catégorie pour lesquelles il n'existait pas de désaccord entre les 2 cotations. Les caractéristiques acoustiques de chaque segment vocal ont été extraites, en séparant les caractéristiques segmentales (Mel Frequency Cepstrum Coefficients) et supra-segmentales (tonalité, énergie et durée). Ces données ont été entrées dans un algorithme d'apprentissage automatique, alimentant 2 classifieurs distincts : l'un utilisant les caractéristiques segmentales, l'autre utilisant les caractéristiques supra-segmentales. De plus, 2 algorithmes d'apprentissage différents (GMM et k-nn) ont été testés. Finalement, différentes combinaisons (fusion) des 2 types de caractéristiques et/ou des 2 types d'algorithmes ont

été évaluées. L'efficacité et la précision de ces différentes méthodes de classification ont été analysées par des courbes ROC prenant en compte sensibilité et spécificité de la détection (comparées à l'annotation manuelle).

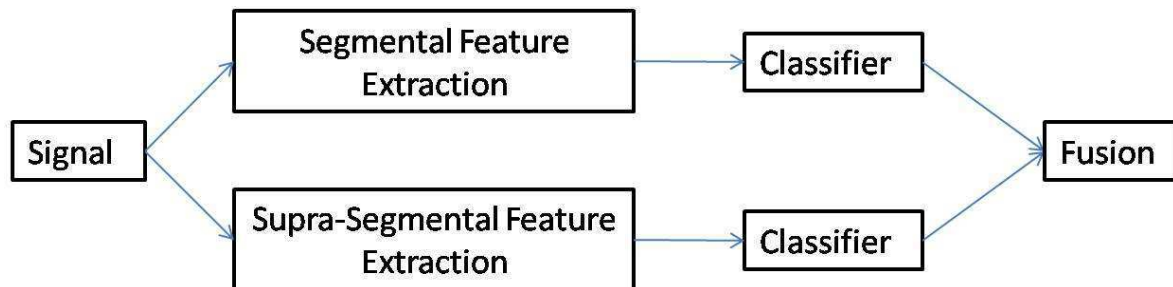


Figure 9 – Système de détection du mamanaï utilisé dans l'algorithme

4.2.2. Résultats et discussion

Le meilleur classifieur utilisait les caractéristiques supra-segmentales avec la méthode GMM. Pour effectuer la fusion, les performances de différents systèmes de classification ont été analysées (courbes ROC), séparément puis fusionnées, en optimisant à chaque fois les paramètres de classification et de pondération. La meilleure configuration utilisait une pondération presque égale entre les caractéristiques segmentales (0,6) et supra-segmentales (0,4), et atteignait une précision (taux de réponses justes) de 87%. Les performances du système ont ensuite été testées en condition indépendante du locuteur, soit avec 12 locutrices différentes sur 10 autres films, et gardaient une précision très satisfaisante, de 82%.

Toutefois, une limitation actuelle de cet algorithme est qu'il n'est pas tel quel généralisable car seules des locutrices italiennes ont été étudiées ici alors que nous savons que les spécificités culturelles et langagières pourraient modifier les caractéristiques du motherese et donc les performances du système. Une autre limite tient au fait que l'algorithme donne une réponse binaire : mamanaï/ non-mamanaï, alors que la distribution des différents types de vocalisations répond probablement plus à un continuum entre 2 polarités opposées plutôt qu'à 2 catégories discrètes. Il pourrait être intéressant de faire évoluer cet outil en y intégrant la prise en compte d'une sorte de « degré » de motherese comme un indice affecté à chaque vocalisation.

Cependant, ce travail fournit plusieurs avancées ; d'abord sur un plan théorique, en démontrant que les caractéristiques segmentales peuvent

largement contribuer à caractériser le mamanais. Ensuite sur un plan pratique, l'entraînement des soignants, voire des parents, au motherese par biofeed-back pourrait constituer une application possible dans le champ de l'autisme ou d'autres situations pathologiques ou non (l'efficacité du motherese dans l'engagement social et l'apprentissage étant démontré dans diverses situations (Santarcangelo & Dyer, 1988)... Enfin ce détecteur pourrait trouver d'autres applications dans le champ de la recherche sur les interactions ou le développement du langage. Mais le premier but de cet algorithme est l'application aux interactions naturelles avec des bébés autistes dans les films familiaux de la base de Pise. Toutefois, avant de nous lancer dans ce travail, nous avons décidé de d'abord mettre notre détecteur à l'épreuve dans une étude sur deux cas uniques.

4.2.3. Article publié (IJMPR)

Computerized home video detection for motherese may help to study impaired interaction between infants who become autistic and their parents

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motherese, autism,
computerized detector

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Received 1 August 2008;
revised 15 June 2009;
accepted 22 July 2009

Abstract

Autism is a well-defined clinical syndrome after the second year of life, but information on autism in the first two years of life is still lacking. The study of home videos has described children with autism during the first year of life as not displaying the rigid pattern typical of later symptoms. Therefore, developmental/environmental factors are claimed in addition to genetic/biological ones to explain the onset of autism during maturation. Here we describe (1) a developmental hypothesis focusing on the possible implication of motherese impoverishment during the course of parent–infant interactions as a possible co-factor; (2) the methodological approach we used to develop a computerized algorithm to detect motherese in home videos; (3) the best configuration performance of the detector in extracting motherese from home video sequences (accuracy = 82% on speaker-independent versus 87.5% on speaker-dependent) that we should use to test this hypothesis. *Copyright* © 2011 John Wiley & Sons, Ltd.

Introduction

Autism is a severe psychiatric syndrome characterized by the presence of abnormalities in reciprocal social interactions,

abnormal patterns of communication, and a restricted, stereotyped, repetitive repertoire of behaviours, interests, and activities. Although it is a well-defined clinical syndrome after the second, and especially after the third,

year of life, information on autism in the first two years of life is still lacking (Short and Schopler, 1988; Stone *et al.*, 1994; Sullivan *et al.*, 1990). Home movies (that is, films recorded by parents during the first years of life, before diagnosis) and direct observation of infants at high risk due to having an autistic sibling are the two most important sources of information for overcoming this problem. They have both described children with autism disorder (AD) during the first year of life (and also in the first part of the second year) as not displaying the rigid patterns described in older children. In particular, the children can gaze at people, turn toward voices and express interests in communication as typically developing infants do. It is of seminal importance to have more insight into these social competencies and in which situations they preferentially emerge in infants who are developing autism. In this paper, we focus on a verbal stimulus called motherese (a special kind of speech that is directed towards infants) that has been shown to be of crucial importance in language acquisition (Kuhl, 2004), and question whether its course during parent/child interaction might be affected by the autistic child.

First clinical manifestations of autism

Long before a diagnosis is established, parents are often aware of the differences exhibited by their autistic children (Werner *et al.*, 2000). Parents' descriptions include extremes of temperament and behaviour (ranging from marked irritability to alarming passivity), poor eye contact, and lack of responsiveness to parents' voices or attempts to play and interact (e.g., Dahlgren and Gillberg, 1989; De Giacomo and Fombonne, 1998; Ohta *et al.*, 1987).

Data from prospective and longitudinal studies focusing on high-risk infants (siblings of AD children) have also yielded important insights into what constitutes the initial behavioural signs of autism. Studies have reported various behavioural markers that, in part, predict a subsequent diagnosis of autism in a sibling sample. These markers include atypicalities in eye contact, visual tracking, social smiling, and reactivity (Zwaigenbaum *et al.*, 2005), lack of orienting to the child's own name (Nadig *et al.*, 2007; Zwaigenbaum *et al.*, 2005), prolonged latency to disengage visual attention (Swettenham *et al.*, 1998; Bryson *et al.*, 2007; Zwaigenbaum *et al.*, 2005), deficits in joint attention skills (Mundy *et al.*, 1990; Baron-Cohen *et al.*, 1996; Sullivan *et al.*, 2007), lack of pointing to objects (Baron-Cohen *et al.*, 1996), lack of imitation (Baron-Cohen *et al.*, 1996; Zwaigenbaum *et al.*, 2005), delayed expressive and receptive language (Sullivan *et al.*, 2007; Landa and Garrett-Mayer,

2006), and a lack of interest or pleasure in self-initiated contact with others (Bryson *et al.*, 2007; Baron-Cohen *et al.*, 1996; Zwaigenbaum *et al.*, 2005).

Several studies focusing on early home videos have also revealed atypical developmental tendencies in infants later diagnosed with autism spectrum disorders (ASDs). In the first year, autistic infants tend to lack social interest, to interact poorly (Maestro *et al.*, 2002; Zakian *et al.*, 2000; Adrien *et al.*, 1993), to look less at others (Clifford and Dissanayake, 2007; Osterling and Dawson, 1994; Osterling *et al.*, 2002; Maestro *et al.*, 2002, 2005b, 2006) and to show less communicative skills (e.g., vocalizations *to people*). Compared with delayed infants, the characteristics of a reduced response to the infant's own name, a reduced quality of affect and a tendency to look less at others appear more specific to autistic children (Clifford and Dissanayake, 2007; Baranek, 1999; Osterling *et al.*, 2002). In the second year, pre-autistic signs (lack of social behaviour and joint attention) become more obvious and signs particular to autism more numerous: lower eye contact quality, gaze aversion, lower social peer interest, less positive affect, less nestling, less protodeclarative showing, less anticipatory postures and less conventional games (Clifford and Dissanayake, 2007; Clifford *et al.*, 2007); eye-contact quality and affect quality have been found to be the best predictors of a later diagnosis of autism (Clifford *et al.*, 2007; Maestro *et al.*, 2001). Whether these early signs impact the interactive process between an infant and his/her parents and, as a consequence, whether they influence the development of the infant himself, remain two challenging issues.

Early language acquisition and social interactions

To explore these points, we will now briefly review what we know about language learning, social interactions, and ways to integrate the disadvantages of autistic children in both domains within the course of development. Studies of language acquisition are too numerous for an extensive review; however, we wish to highlight some specific points regarding the developmental course of language acquisition in children developed by Kuhl (2007, 2004, 2003, 2000) and Goldstein *et al.*, (2003). (1) From birth, infants possess the ability to discriminate all languages at the phonetic level and to recognize their prosodic features. (2) They develop a strategy of learning based on input language signs and characteristics and explore language statistical properties, leading to "so-called" probabilistic learning (Milgram and Atlan, 1983). (3) The language experience will commit the perceptual system at the neural level, increasing native-language speech perception

and decreasing foreign-language speech perception with a “magnet effect” (Kuhl, 2000). However, simple exposure does not explain language learning; in both speech production and speech perception, the presence of a human being interacting with a child has a strong influence on learning (Goldstein *et al.*, 2003).

Regardless of the influence of the neurobiological and genetic factors on autism (Cohen *et al.*, 2005), one should keep in mind that infants’ survival and development depend on social interaction with a caregiver who serves the infant’s needs for an emotional attachment. In cases of early severe deprivation, the consequences for infant development are sometimes impressive. Rutter’s studies of children adopted into the United Kingdom following early severe deprivation in Romania showed that dramatic damage stemmed from institutional deprivation, and its heterogeneity in outcome includes cognitive deficit and attachment problems, but also quasi-autistic patterns (e.g., Rutter *et al.*, 2007a, 2007b; Croft *et al.*, 2007).

The quality of social interaction depends on a reciprocal process, an active dialogue between parent and child based on the infant’s early competencies and the mother’s (or father’s) capacity for tuning. Micro-analysis of film records examining rhythms and patterns in mother–infant face-to-face interaction in the neonatal period (Brazelton *et al.*, 1975) and early communication (Condon and Sander, 1974; Stern *et al.*, 1975) have emphasized the importance of synchrony and co-modality of these early interactions for infants’ development.

Combining early language acquisition and social interaction

Interestingly, researchers in language acquisition and researchers in early social interactions have encountered an important peculiarity that affects both the language and social development of infants: the way adults speak to infants. A special kind of speech that is directed towards infants, often called “motherese” (“parentese”), characterized by higher pitch, slower tempo, and exaggerated intonation contours (Fernald, 1985; Grieser and Kuhl, 1988), seems to play an important role in both social interaction and language development. Studies have revealed that this particular prosody may be responsible for attracting infants’ attention, conveying emotional affect, and conveying language-specific phonological information (Karzon, 1985; Hirsh-Pasek *et al.*, 1987; Kemler Nelson *et al.*, 1989; Fernald, 1985; Fernald and Kuhl, 1987). (1) When given a choice, infants show a preference for mothers’ infant-directed speech (so-called motherese) as opposed to adult-directed speech (Pegg *et al.*, 1992; Cooper and

Aslin, 1990; Werker and McLeod, 1989; Fernald, 1985; Glenn and Cunningham, 1983). This particular prosody helps to engage and maintain the limited attention of the baby. (2) Motherese contains particularly good phonetic exemplars – sounds that are clearer, longer, and more distinct from one another (e.g., vowel hyperarticulation) – when compared to adult-directed speech (Kuhl *et al.*, 1997; Burnham *et al.*, 2002).

In addition, the baby’s reactions amplify the contours of prosody curves in the mother’s voice (Burnham *et al.*, 2002). Mothers’ infant-directed speech was found to depend on the quality of infants’ responsiveness, which suggests that infants are actively involved in early interactions (Braarud and Stormark, 2008).

Is it possible to implicate motherese impoverishment in the pathogenesis of autism?

In our view, the well-known autistic impairments in language, cognition and social development, as well as the tendencies toward self-absorption, perseveration and self stimulation (Volkmar and Pauls, 2003), may be downstream effects of primary difficulties in the ability to engage in interactions involving emotional signals, motor gestures and communicative acts directed to others. This view is also supported by testimony of adult individuals with autism who expressed themselves (Chamak *et al.*, 2008). If learning depends on a normal social interest in people and the signals they produce, children with autism, who lack a social interest, may be at a cumulative disadvantage in language learning. Their poor response to parental engagement may impoverish both parental engagement and motherese production over time. As a consequence, this impoverishment will reinforce social withdrawal and language acquisition delay.

In a previous exploratory study, we observed home movie sequences in which a withdrawn infant who will later develop autism may suddenly appear joyful when the parent implements a vocal expression using motherese. During such interactions, infants and toddlers with autism exhibit social focal attention: their faces light up, unexpected interactive skills appear, and real protodialogues expand (Laznik *et al.*, 2005). However, we were unable to find any study comparing interest in motherese speech versus other human speech in children with autism. Even if we know that autistic children can process some aspects of human voices (Groen *et al.*, 2008), however, studies have shown that autistic individuals display no specific cortical activation in response to human voices (e.g., Zilbovicius *et al.*, 2006). Further, five-year-old autistic children do not show the expected preference for their mother’s speech when given it

as a choice with the noise of superimposed voices (Klin, 1991). Similarly, 32- to 52-month-old children with an ASD have a significant listening preference for electronic non-speech motherese analogue signals in comparison to motherese signals (Kuhl *et al.*, 2005). Given that home movies offer a unique opportunity to follow infant development and parent–infant interactions, we planned to use a multi-disciplinary approach with a child psychiatrist, developmental psychologist, psycholinguist and engineer to test the following research questions: (1) Are infants who later develop autism initially equipped to respond to motherese specifically? In other words, is this competency stable and correlated with positive interactions? (2) As motherese amplification is bidirectional, does the parental quantity of motherese decrease overtime?

Aims of the present paper

In this paper, we describe (1) a computerized algorithm to detect motherese developed for this research; (2) its characteristics in extracting motherese from home video sequences. Given that micro-analysis of home video is highly time consuming, we consider the production of this algorithm as the first step of our multi-disciplinary research project. Indeed, even if motherese is clearly defined in terms of acoustic properties, the modelling and detection is expected to be difficult, as is the case with the majority of emotional speech, because the characterization of spontaneous and affective speech in terms of features is still an open question since several parameters have been proposed in the literature (Schuller *et al.*, 2007). As a starting-point following the acoustic properties of motherese, we characterized verbal interactions by the extraction of supra-segmental features (prosody). Given that home movies are not recorded by professionals and often contain adverse conditions (e.g., with regard to noise, the camera, or microphones), however, acoustic segmentation of home movies shows that segmental features play a major role in robustness (Schuller *et al.*, 2007). Consequently, the utterances are characterized by both segmental (Mel Frequency Cepstrum Coefficients, MFCCs) and supra-segmental (e.g., statistics with regard to fundamental frequency, energy, and duration) features. These features, along with the known emotional labels of a training set of emotional utterances, are provided as input to a machine learning algorithm. Here, we compared the performance of two learning algorithms, GMM (Gaussian Mixture Model) and k-nn (k-nearest neighbours), on segmental and non-segmental features alone using the ROC (receiver operating characteristic) analysis method. To improve detection,

we also investigated several combinations or fusion schemes (segmental/supra-segmental; GMM/k-nn) to select the one that is optimal in comparison to manual segmentation of motherese sequences from home videos.

Method

Database

The speech corpus used in this experiment is a collection of natural and spontaneous interactions. This corpus contains expressions of non-linguistic communication (affective intent) conveyed by a parent to a preverbal child. The corpus consists of recordings of Italian mothers and fathers addressing their infants. We decided to focus on the analysis of home movies, as it enables a longitudinal study (months or years) and gives information about early behaviours of autistic infants long before the diagnosis is made by clinicians. All sequences were extracted from the Pisa home video database, which includes home movies from the first 18 months of life for three groups of children aged four to seven years (Maestro *et al.*, 2005a, 2005b). Children are matched for gender and socio-economic status. The first group was composed of 15 children (Male/Female 10:5) with a diagnosis of autism based on the Autism Diagnostic Interview-Revised (ADI-R) (Rutter *et al.*, 2003). All cases with Childhood Autism Rating Scale (CARS) total-scores (Schopler *et al.*, 1988) below 30 were excluded. The second group was composed of 12 children (Male/Female 7:5) with a diagnosis of Mental Retardation (MR) who had a non-autistic CARS total score under 25. Children with MR or AD secondary to neuropsychiatric syndromes (e.g., Fragile-X, Rett, or Down Syndrome) or evident neurological deficits or physical anomalies were excluded. Participants in the AD or MR group were administered the Griffiths Mental Developmental Scale or Wechsler Intelligent Scale in order to determine intellectual functioning. For both AD [mean IQ = 59.26; standard deviation (SD) = 8.49] and MR (mean IQ = 56.82; SD = 8.16) groups, the composite IQ score was below 70. A third group was composed of 15 typical developing (TD) children (Male/Female 9:6) recruited from children attending a local kindergarten.

The large size of this corpus, however, makes it inconvenient for human review. For the development of the first algorithm, we focused on one home video of superior acoustic quality that totalled three hours of the first year of life of an infant who later developed autism (at six years: ADI-R communication score = 9; ADI-R social interest score = 12; ADI-R repeated interest score = 5; CARS total score = 36; IQ = 71). The verbal interactions of the infant's mother were carefully annotated by two

blind psycholinguists into two categories: infant-directed speech (motherese) and adult-directed speech (normal) [Cohen's kappa = 0.82; 95% confidence interval (CI) = 0.75–0.90]. From this manual annotation, we extracted 100 utterances for each category. The utterances are typically between 0.5 seconds and 4 seconds in length. To conduct a secondary performance characteristic study, we collected an independent set of utterances (50 motherese and 50 normal speech) extracted from 10 randomly selected home movies (five from the AD group and five from the TD group).

System description

Automatic speech sounds segmentation requires several steps: feature extraction, classification and decision fusion are conducted sequentially. These steps can be divided into two major processing phases, namely the training phase and the test or classification phase. Figure 1 shows a schematic overview, which is described in more detail in the following paragraphs. The first step, namely feature extraction, shown in Figure 1 is needed in both training and test. The second step, called classification, aims at classifying the whole utterances. The last step, which is called decision fusion, is necessary for classification and combines the different streams to form one common output.

Feature extraction

After the segmentation of the database into utterances, the next step is to extract features, resulting in a representation of the speech signal as input for the motherese classification system. In this paper we evaluate two approaches, respectively termed segmental and supra-segmental features. The first is characterized by the MFCCs, while the second is characterized by statistical measures of both the fundamental frequency (F0) and the short-time energy. A 20 ms window is used, and the overlapping between adjacent frames is halved. A parameterized vector of order 16 was computed. The supra-segmental features are characterized by three statistics (mean, variance and range) on both F0 and

short-time energy, resulting in a six-dimensional vector. One should note that the duration of the acoustic events is not directly characterized as a feature but is taken into account during the classification process by a weighting factor. The feature vectors are normalized (zero mean, unit standard deviation).

Classification

In this study, two different classifiers – the k-nn classifier and the GMM-based classifier – were investigated. The k-nn is a distanced based classifier often used in pattern recognition. GMM is a statistical signal model trained by sequences of feature vectors that are representative of the input signal (Reynolds, 1995).

A posteriori probabilities estimation. The GMM is adopted to represent the distribution of the features. Under the assumption that the feature vector sequence $x = \{x_1, x_2, \dots, x_n\}$ is an independent identical distribution sequence, the estimated distribution of the d -dimensional feature vector x is a weighted sum of M component Gaussian densities $g(\mu, \Sigma)$, each parameterized by a mean vector μ_i and covariance matrix Σ_i ; the mixture density for the model C_m is defined as:

$$P(x|C_m) = \sum_{i=1}^M w_i g(\mu_i, \Sigma_i)(x) \quad (1)$$

Each component density is a d -variate Gaussian function:

$$g_{(\mu, \Sigma)}(x) = \frac{1}{(2\pi)^{d/2} \sqrt{\det(\Sigma)}} e^{-1/2(x-\mu)^T \Sigma^{-1}(x-\mu)} \quad (2)$$

The mixture weights ω_i satisfy the following constraint:

$$\sum_{i=1}^M w_i = 1 \quad (3)$$

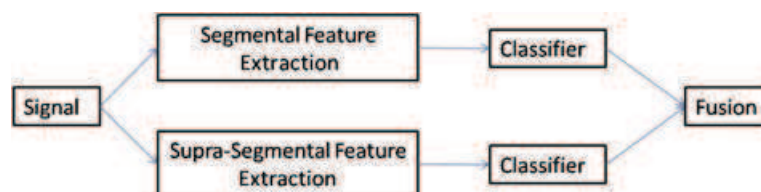


Figure 1 Motherese classification system used in the algorithm.

The feature vector x is then modelled by the following a posteriori probability:

$$P_{gmm}(C_m|x) = \frac{p(x|C_m)p(C_m)}{p(x)} \quad (4)$$

where $P(C_m)$ is the prior probability for class C_m , we assume equal prior probabilities. We use the expectation maximization (EM) algorithm for the mixtures to obtain maximum likelihood. The k-nn classifier is a non-parametric technique which classifies the input vector with the label of the majority k-nn (prototypes) (Duda *et al.*, 2000). In order to keep a common framework with the statistical classifier (GMM), we estimate the a posteriori probability that a given feature vector x belongs to class C_m using k-nn estimation (Duda *et al.*, 2000):

$$P_{knn}(x|C_m) = \frac{k_m}{k} \quad (5)$$

where k_m denotes the number of prototypes that belong to the class C_m among the k-nn.

Segmental and supra-segmental based characterization. Segmental features (i.e. MFCC) are extracted from all the frames of an utterance U_x independently to the voiced or unvoiced parts. One should note that the nature of the segments can also be exploited (vowels/consonants) (Ringeval and Chetouani, 2008). A posteriori probabilities are then estimated by both GMM and k-nn classifiers and are respectively termed $P_{gmm,seg}(C_m|U_x)$ and $P_{knn,seg}(C_m|U_x)$.

The classification of supra-segmental features follows the segment-based approach (SBA) (Shami and Verhelst, 2007). An utterance U_x is segmented into N voiced segments (F_{xi}) obtained by F0 extraction (see earlier). Local estimation of a posteriori probabilities is carried out for each segment. The utterance classification combines the N local estimations.

$$P(C_m|U_x) = \sum_{xi=1}^N P(C_m|F_{xi}) \times \text{length}(F_{xi}) \quad (6)$$

The duration of the segments is introduced as weights of the a posteriori probabilities: importance of the voiced segment ($\text{length}(F_{xi})$). The estimation is also carried out by the two classifiers, resulting in supra-segmental characterizations: $P_{gmm,supra}(C_m|U_x)$ and $P_{knn,supra}(C_m|U_x)$.

Fusion

The segmental and supra-segmental characterizations provide different temporal information, and combining them should improve the accuracy of the detector. Many decision techniques can be employed (Kuncheva, 2004), but we investigated a simple weighted sum of likelihoods from the different classifiers:

$$C_l = \lambda \cdot \log(P_{seg}(C_m|U_x)) + (1 - \lambda) \cdot \log(P_{supra}(C_m|U_x)) \quad (7)$$

with $l=1$ (motherese) or 2 (normal directed speech); λ denotes the weighting coefficient. For the GMM classifier, the likelihoods can be easily computed from the a posteriori probabilities [$P_{gmm,seg}(C_m|U_x)$, $P_{gmm,supra}(C_m|U_x)$] (Reynolds, 1995). However, the k-nn estimation can produce a null a posteriori probability incompatible with the computation of the likelihood. We used a solution recently tested by Kim *et al.* (2007), in which the a posteriori probability is used instead of the log probability of the k-nn:

$$C_l = \lambda \cdot \log\left(e^{P_{knn,seg}(C_m|U_x)}\right) + (1 - \lambda) \cdot \log(P_{gmm,supra}(C_m|U_x)) \quad (8)$$

Consequently, for the k-nn classifier we used Equation 7, while for the GMM the likelihood is conventionally computed. We investigated cross combinations (Table 1).

Results

Classifier configuration

First, to find the optimal structure of our classifier, we had to adjust the parameters: the number of Gaussians (M) for the GMM classifier and the number of neighbours (K) for the k-nn classifier. We searched for the optimal configuration in terms of accuracy. Table 2 shows the best

Table 1 Table of combinations of classifiers (GMM/k-nn) \times features (segmental/supra-segmental)

Combination 1	$P_{knn,seg}$	$P_{knn,supra}$
Combination 2	$P_{gmm,seg}$	$P_{gmm,supra}$
Combination 3	$P_{knn,seg}$	$P_{gmm,supra}$
Combination 4	$P_{gmm,seg}$	$P_{knn,supra}$
Combination 5	$P_{gmm,seg}$	$P_{knn,seg}$
Combination 6	$P_{gmm,supra}$	$P_{knn,supra}$

Note: GMM, Gaussian Mixture Model; k-nn, k-nearest neighbours; seg, segmental; supra, supra-segmental.

Table 2 Accuracy of optimal configurations for GMM and k-nn classifiers according to segmental and supra-segmental features

	Segmental	Supra-segmental
k-nn	72.5% ($K=11$)	61% ($K=7$)
GMM	78% ($M=15$)	82% ($M=16$)

Note: GMM, Gaussian Mixture Model; k-nn, k-nearest neighbours; M , number of Gaussians for the GMM classifier; K , number of neighbours for the k-nn classifier.

configuration of GMM and k-nn with segmental and supra-segmental features and further shows that the GMM classifier trained with prosody features outperformed the other classifiers in terms of accuracy.

Fusion of best system

In this study the performance of the classifier was quoted using class sensitivities, predictivities and overall accuracy, and the optimal classifiers were determined by employing ROC graphs to show the trade-off between the hit and false positive rates. A ROC curve represents the trade-off between the false acceptance rate (FAR) and the false rejection rate as the classifier output threshold value is varied. Two quantitative measures of verification performance, the equal error rate (EER) and the area under the ROC curve (AUC), were calculated. All calculations were conducted with Matlab (version 6). For best configuration data, results were given with the 95% CIs that were

estimated using Cornuéjols *et al.* (2002) method. It should be noted that while EER represents the performance of a classifier at only one operating threshold, the AUC represents the overall performance of the classifier over the entire range of thresholds. Hence, we employed AUC and not EER to compare the verification performance of two classifiers and their combination. However, the result shown in Table 2 motivated an investigation of the fusion of both features and classifiers following the statistical approach described in the previous section. Improvement by the combination of features and classifiers is known to be efficient (Kuncheva, 2004). However, caution should be used, because the fusion of best configurations does not always give better results; the efficiency will depend on the nature of the errors produced by the classifiers (independent versus dependent) (Kuncheva, 2004). Table 1 and the previous section show that six different fusion schemes could be investigated [Combination 1 (Comb₁) to Combination 6 (Comb₆)]. For each of them, we optimized parameter classifiers (K value for k-nn and M value for GMM, respectively) and weighting λ (Equation 6) parameters of the fusion. In Figure 2, we can see that for the k-nn classifier, the best scores (0.8113/0.812) were obtained with an important contribution of the segmental features ($\lambda=0.8$), which is in agreement with the results obtained without the fusion (Table 2). The best GMM results (0.932/0.932) are obtained with a weighting factor equal to 0.6, revealing a balance between the two features. Table 3 summarizes the best results in terms of accuracy as well as the positive predictive value (PPV) and negative predictive value (NPV) for each classifier fusion (top section) and cross-classifier fusion (bottom section).

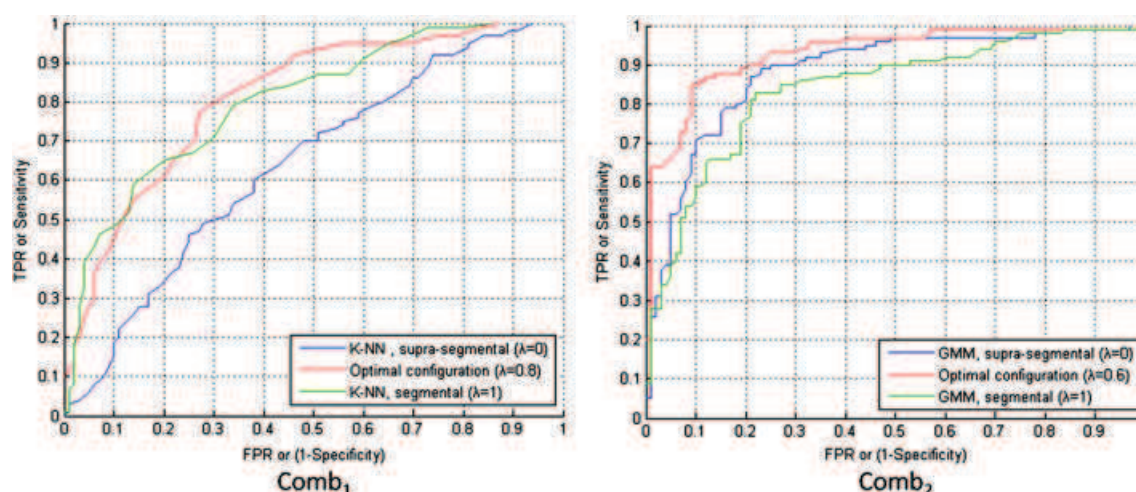


Figure 2 ROC curves for Combination 1 (Comb₁) and Combination 2 (Comb₂). Combination 1 = $P_{knn,seg} \times P_{knn,supra}$; Combination 2 = $P_{gmm,seg} \times P_{gmm,supra}$; λ = weighting coefficient used in the equation fusion for each combination.

Table 3 Accuracy, positive predictive value (PPV), and negative predictive value (NPV) of fusion configurations according to classifiers and segmental and supra-segmental feature parameters

		Accuracy	PPV	NPV	λ	
<i>Using only one classifier</i>						
Combination 1	k-nn, seg × k-nn, supra	k-nn, seg ($K=11$) k-nn, supra ($K=1$)	74%	77.91%	71.05%	0.9
		k-nn, seg ($K=7$) k-nn, supra ($K=11$)	72.5%	74.42%	71.84%	0.8
Combination 2	GMM, seg × GMM, supra	GMM, seg ($M=12$) GMM, supra ($M=15$)	87.5%	88.47%	86.41%	0.4
		GMM, seg ($M=16$) GMM, supra ($M=16$)	86.5%	84.85%	88.42%	0.5
<i>Combining k-nn and GMM classifiers</i>						
Combination 3	K-nn, seg × GMM, supra	k-nn, seg ($K=11$) GMM, supra ($M=12$)	85.5%	89.41%	83.81%	0.7
		K-nn, seg ($K=5$) GMM, supra ($M=12$)	85%	90.7%	82.69%	0.6
Combination 4	GMM, seg × k-nn, supra	GMM, seg ($M=15$) k-nn, supra ($K=11$)	80.5%	79.61%	81.44%	0.2
		GMM, seg ($M=16$) k-nn, supra ($K=1$)	79.5%	77.57%	81.72	0.3

Note: PPV (positive predictive value) = TruePositive/(TruePositive + FalsePositive). PPV evaluates the proportion of correctly detected motherese utterances out of all utterances labelled as motherese. PPV can be viewed as the reliability of positive predictions induced by the classifier. NPV (negative predictive value) gives similar information about the detection of normal speech.

Table 3 shows that different combinations of segmental and supra-segmental features can reach similar accuracies with different PPVs. With regard to the k-nn method, the best scores (accuracy = 74%; PPV = 77.91%) were obtained with an important contribution of the segmental features ($\lambda = 0.9$). The best GMM results (accuracy = 87.5%; PPV = 88.47%) were obtained with a weighting factor equal to 0.4 (i.e. a balance between the two features). We also investigated cross-classifier fusion (Table 3, bottom). The accuracy of this method can be lower than that for the single classifiers (Table 2). However, significant improvements (90.7%) in the PPV were reached for Combination 3: $P_{knn,seg} \times P_{gmm,supra}$ combination ($\lambda = 0.6$). This result reveals the importance of evaluation metrics for fusion, which is dependent on the task in this study (motherese detection).

In sum, the best fusion configuration used only the GMM classifier for both segmental and supra-segmental features ($M = 12$ and $M = 15$, respectively, and $\lambda = 0.4$). Performance of this fusion corresponds to Combination 2 from Table 3, and were as follow: accuracy = 87.5%

(95% CI = 82.91–92.08%); PPV = 88.47% (95% CI = 83.03–95.18%); NPV = 86.41% (95% CI = 79.4–92.88%). We also investigated the performance of the detector with these fusion parameters in detecting motherese versus normal speech within a second set of utterances extracted from 10 randomly-selected home videos with 12 independent speakers. Performances under speaker-independent conditions were as follows: accuracy = 82% (95% CI = 73.87–89.58%); PPV = 86.36% (95% CI = 66.52–89.48%); NPV = 77.55% (95% CI = 76.73–96.6%).

Discussion

Motherese detector validity

Our goal was to develop a motherese detector by investigating different features and classifiers. Using classification techniques that are often used in speech and speaker recognition (GMM and k-nn), we have developed a motherese detection system and tested it on mode dependent of speaker. The fusion of features and classifiers was also investigated. We obtained results from which we

can draw several interesting conclusions. First, our results show that segmental features alone contain much useful information for discrimination between motherese and adult direct speech, since they outperform supra-segmental features. Thus, we can conclude that segmental features can be used alone. However, according to our detection results, prosodic features are also very promising. Based on the previous two conclusions, we combined classifiers that use segmental features with classifiers that use supra-segmental features and found that this combination improves the performance of our motherese detector considerably.

Thus, we can conclude that a classifier based on segmental features alone can be used to discriminate between motherese and normal-directed-speech, but a significant improvement can be achieved in most cases when this classifier is fused with another that is based on prosodic features. Furthermore, fusing scores from k-nn and GMM is also very fruitful.

Limitations and strengths

For our motherese classification experiments, we used only speech excerpts that were already segmented (based on human transcription). In other words, detection of the onset and offset of motherese was not investigated in this study but can be addressed in a follow-up study. Detection of the onset and offset of motherese (motherese segmentation) can be seen as a separate problem that gives rise to other interesting questions, such as how to define the beginning and end of motherese and what kind of evaluation measures to use. These are problems that can typically be addressed within a Hidden Markov Model framework.

In its best configuration, the novel detector had positive and negative predictive values reaching 90%; this level of prediction is suitable for further studies of home videos. When we explored the motherese detector's performance on sequences blindly validated by two psycholinguists (speaker-independent), the performance of the detector remained very good (accuracy = 82%). As we hypothesize the detector to be language independent, however, we still need to explore the motherese detector's performance on sequences randomly extracted from different languages. As noted, although motherese is itself a highly variable and complex signal (Fernald and Kuhl, 1987), it would be interesting to investigate to what extent motherese is dependent on the speaker, culture, etc.

Finally, the aim of this study was to develop a motherese detector to enable emotion classification. Our plan for emotion recognition is based on the fact that emotion is expressed in speech by audible paralinguistic features or events, which can be seen as the “building

blocks” or “emotion features” of a particular emotion. Adding visual information could further help to improve emotion detection. Our plan is thus to perform emotion classification via the detection of audible paralinguistic events. In this study, we have developed a motherese detector to provide a first step in this plan towards a future emotion classifier.

Possible applications to the field of autism

Despite the limitations listed earlier, we are now systematically exploring in home videos from the Pisa database (Maestro *et al.*, 2005b) the natural courses of motherese and parent–infant interaction and their co-occurrence. The pattern of parent–infant interactions has been extensively explored in infants later diagnosed with autism (for reviews see Saint-Georges *et al.*, 2010; Palomo *et al.*, 2006). However, whether motherese and positive interactions co-occur has not been investigated. This will be tested on randomized sequences extracted from the database using group comparisons matched for age and sex: autism versus typically developing; autism versus children with intellectual disability; early onset autism versus late onset autism. These analyses are made possible by the availability of several cases matched for age and sex with normal and delayed developing controls (Maestro *et al.*, 2005b). We hypothesize that motherese should be correlated with positive interactions both in autism and non-autism, but to a lesser extent in autism.

The second analysis will focus on a longitudinal view of motherese using a subset of cases with several videos at different ages. We hypothesize that in early onset autism, motherese will decrease over time in terms of relative frequency due to lack of interactive feedback from the child (Muratori and Maestro, 2007). This deficit in stimulation would have developmental consequences, which would lead in particular to the specific social and language impairments found in older autistic children (Zilbovicius *et al.*, 2006). Indeed, motherese prosody is related to the mother's emotions and seems an authentic marker of the quality of parent–child interactions. In their infants' absence, mothers cannot produce “faked” motherese into a microphone (Fernald and Simon, 1984): the full range of prosodic modifications in mother's speech is evoked only in the presence of the infant. On the contrary, baby's reactions improve the amplitude of prosody contours in mother's speech (Burnham *et al.*, 2002). But when a baby seems indifferent, can his/her parents still continue to produce motherese? If motherese can no longer be produced by such parents, the deficit of motherese would appear to be one of the cofactors in the

development of an interactive vicious circle. Figure 3 shows how the detector may be useful in performing such a study. In a sequence of duration 12 seconds during which a positive interaction occurred (note the baby's smile), the detector can automatically analyse the sound signal, prosodic characteristics, and main speaker and determine whether motherese is being produced.

Possible applications outside the field of autism

If our previous hypotheses are confirmed (i.e. if a decrease of motherese appears as a cofactor in the pathogenic process), a possible application for infants at risk for autism could be to improve parental motherese by

training using a screen warning for motherese production (biofeedback). As motherese has been shown to improve responsiveness and learning in various developmentally disabled children (Santarcangelo and Dyer, 1988), such training could also be useful for nurses, teachers, or other professionals working in the field of infant mental health outside the field of autism (e.g., maternal depression).

As motherese is an important factor and a valuable tool to study both first interactions and language development, we can easily imagine possible applications of its automatic detection in various research projects performed with an experimental or naturalistic design (e.g., Braarud and Stormark, 2008). Similarly, motherese prosody reflects the

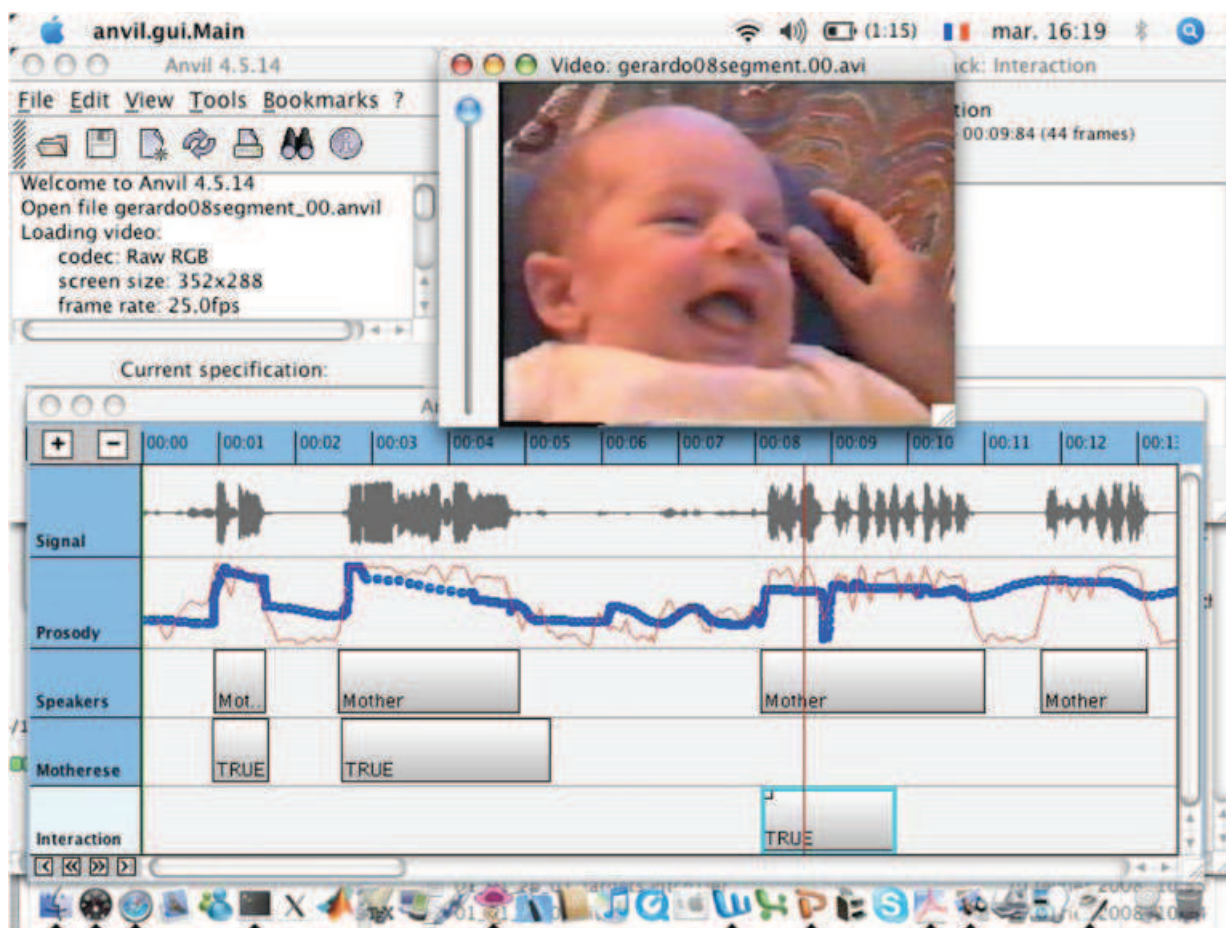


Figure 3 Use of the detector as a tool to study motherese in a home video. In a sequence of duration 12 seconds during which a positive interaction occurred (see baby's smile), the detector automatically analyses the acoustic signal, prosodic characteristics (frequency, in hertz, in blue; intensity, in dB, in red), main speaker, and whether motherese is produced. In parallel, existing positive interactions are computerized with the same temporal scale in the Pisa home video database. The red vertical line indicates the timing of the baby's picture shown (in this case, eight seconds after the sequence's starting point).

emotional affect conveyed in the voice (Trainor *et al.*, 2000). Because manual investigation are highly time consuming, automatic motherese detection could also be useful for various types of research on emotional speech (e.g., Beaucousin *et al.*, 2007).

Conclusion

By using different features, segmental and supra-segmental, we were able to automatically discriminate motherese segments from normal speech segments with low error rates. We conclude that the motherese detector is a powerful tool to study motherese in home videos, allowing in-depth

study of large samples of sequences and exhibiting good performance characteristics.

Acknowledgements

The Pisa “home video in autism” project was supported by grants PRIN 2003-2005 and PRIN 2005-2007 from the Italian Ministry of Instruction, University, and Research (MIUR). The current study was supported by a grant (n°2008005170) from the *Fondation de France* given to MC and DC.

Declaration of interest statement

The authors have no competing interests.

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4.3. Etude préliminaire sur 2 cas

4.3.1. Introduction et méthodologie

Cette étude pilote sur 2 cas uniques (1 enfant autiste/ 1 enfant contrôle typique) constitue une étape préliminaire sur la voie d'une étude de groupe ultérieure. Il s'agissait d'approfondir notre étude comparée des interactions synchrones des bébés autistes et des bébés normaux avec leurs care-givers, en complétant l'étude quantitative des vocalisations parentales par une étude qualitative (prosodique) pour enrichir l'étude comportementale de la dynamique interactive, en l'ancrant dans la subjectivité et l'émotion (Saint-Georges et al., submitted). De plus, il nous a paru pertinent, dans la mesure où l'on s'intéresse au comportement du care-giver, de différencier celui du père de celui de la mère, puisque la place et la dynamique en sont sans doute différentes (Field, 1978).

L'enjeu principal de l'étude préliminaire sur les 2 cas uniques est de tester la fonctionnalité de notre algorithme et de déterminer la faisabilité et les écueils éventuels d'une étude de groupe. De plus, la dynamique interactive varie potentiellement d'une dyade ou triade à l'autre (que ce soit d'ailleurs avec un bébé normal ou pathologique), et ces particularités dynamiques pourraient se trouver gommées ou obscurcies par le moyennage statistique dans une étude de groupe. L'étude individuelle, si elle ne permet pas la généralisation, présente l'avantage d'exposer clairement une dynamique interactive individuelle.

Nous avons choisi 2 sujets dans la banque de Pise (décrite plus haut dans le chapitre 2.2 (Muratori et al., 2011)), l'un issu du groupe autiste, l'autre issu du groupe typique. Les critères du choix étaient la qualité de la bande sonore et la quantité de séquences disponibles à chacun des 3 premiers semestres. Nous avons initialement prévu d'étudier aussi un cas de bébé avec retard mental mais la difficulté à trouver un film avec des vocalisations analysables nous a obligés à renoncer: globalement, il y avait trop de superpositions vocales dans les scènes dont nous disposions.

Dans les 2 films choisis, toutes les séquences de mauvaise qualité sonore ont également été exclues. Le bébé autiste a été diagnostiqué à 5 ans avec une CARS à 36,5 et un QI à 83. Le bébé normal s'est développé normalement selon la CBCL (Child Development Behavior Check List). La cotation des interactions avait déjà été réalisée en aveugle à l'aide du logiciel Observer (cf chapitre 2.2) sur quelques scènes dans chaque semestre. Nous avons repris ces cotations après avoir réduit la grille en éliminant les réponses du bébé en direction d'un objet, et certains items rares ou complexes, de façon à ne garder que les items impliquant vraiment une réponse adressée à la personne. Nous avons effectué avec un expert de l'équipe de Pise un entraînement à la cotation de la grille ICBS sur Observer, afin d'assurer une bonne fiabilité interjuge, et avons ainsi pu compléter la cotation des

interactions sur toutes les scènes disponibles, de façon à disposer d'une plus grande quantité de résultats et surtout d'une meilleure vision développementale. A cette cotation des interactions, nous avons alors adjoint la cotation en mamanais ou non-mamanais établie, pour chaque vocalisation de l'adulte adressée à l'enfant, par notre algorithme de détection automatisée (décrit dans le chapitre 4.2 (Mahdhaoui et al., 2011)). Pour ce faire, nous avons découpé et étiqueté chaque segment de parole comme venant de la mère, du père ou d'un autre locuteur. Le taux de mamanais et son évolution ont ainsi pu être déterminés pour chaque locuteur.

Ensuite, nous avons réutilisé notre filtrage des interactions synchrones (cf chapitre 2.2 (Saint-Georges et al., in press)) pour sélectionner seulement les vocalisations ayant été suivies dans les 3 secondes d'au moins une réponse du bébé. Cela nous a permis de calculer, pour chaque bébé et pour chaque locuteur, un index d'efficacité du mamanais, et de suivre son évolution au fil des semestres. De plus, nous avons pu établir la contribution respective du mamanais et du non-mamanais aux interactions réussies (pourcentage de chacun dans le pool des interactions synchrones, soit l'ensemble des comportements parent suivis d'au moins une réponse bébé dans les 3 secondes), de même que la contribution respective de chaque parent aux interactions réussies. En effet, Pedersen a montré que les mères vocalisent plus avec leur bébé que les pères (Pedersen & Robson, 1969).

4.3.2. Résultats et discussion

Les vocalisations parentales :

La fréquence d'occurrence des vocalisations brutes, approximativement 0,2 par seconde, s'avère relativement similaire entre les 2 cas et également stable d'un semestre à l'autre (quoique l'analyse des résultats, non plus en fréquence mais en durée, montre que durant la première année, la durée des vocalisations adressées au bébé autiste excède celle des vocalisations adressées au bébé normal). Ce résultat corrobore ceux de notre étude précédente (Saint-Georges et al., in press) qui montrait que les parents des bébés autistes stimulaient autant ou plus leur bébé que les parents des bébés normaux. D'autres travaux, avec des enfants plus grands, ont également montré que les parents d'autistes répondaient aussi bien que les parents de bébés normaux (Siller & Sigman, 2002; Watson, 1998).

La quantité absolue (et aussi relative) des **vocalisations paternelles** adressées au bébé, d'abord faible, augmente au 3^e semestre chez le bébé normal, mais pas chez le bébé autiste. Le père devient donc un partenaire important de la relation pour notre cas de bébé normal tandis que notre bébé autiste reste dans un duo assez fermé avec sa mère.

Le **taux de mamanais** :

Plus élevé chez les 2 mères (3/4 des vocalisations au 1^{er} semestre) que chez les 2 pères (entre le tiers et la moitié des vocalisations du 1^{er} semestre), il décroît chez chacun des parents au fil du temps pour nos 2 bébés, si bien qu'au 3^e semestre, il ne constitue plus qu'1/4 des vocalisations maternelles, et un 1/10^e des vocalisations paternelles (figure 10)! Notons que le taux de mamanais adressé au bébé autiste par son père est ici quelque peu supérieur à celui adressé au bébé typique, surtout au début.

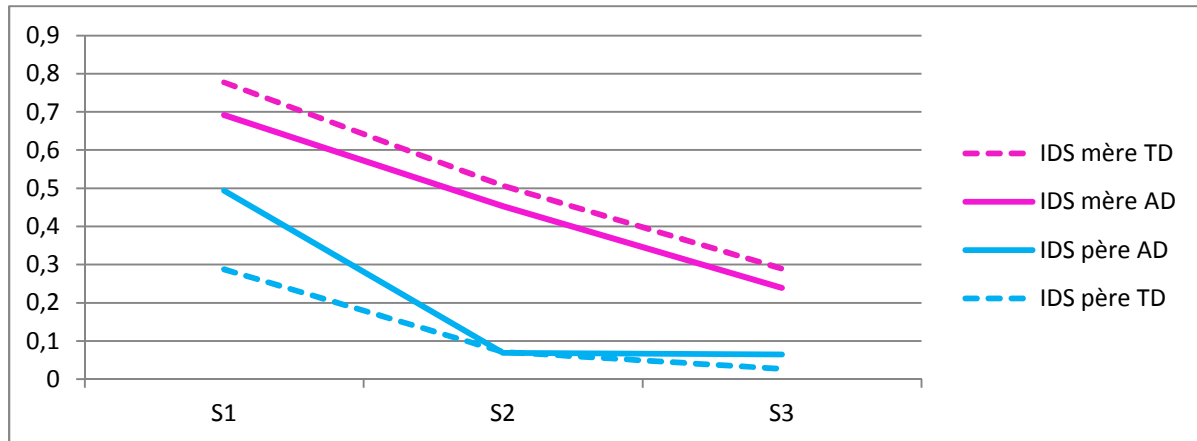


Figure 10. Evolution du taux de mamanais (IDS) dans les vocalisations maternelles et paternelles adressées aux bébés typique (TD) et autiste (AD)

L'effet du mamanais sur le bébé :

Au 1^{er} semestre, la **proportion de mamanais impliqué dans l'ensemble des réponses du bébé** est de 60 à 70 %, mais cette contribution décroît pour nos 2 triades au fil du temps. Cependant, alors qu'elle continue à décroître chez notre bébé normal, elle tend à se maintenir au 3^e semestre chez notre bébé autiste (où le mamanais est encore impliqué dans 1/3 des interactions). Peut-on y voir un effort fait par les parents de notre bébé autiste pour soutenir une interaction défaillante au 3^e semestre et/ou bien, l'effet chez le bébé autiste d'une facilitation persistante des interactions par le mamanais, malgré la baisse globale de réactivité du bébé autiste au 3^e semestre ? En d'autres termes, les interactions pourraient continuer à avoir lieu, mais au prix d'une stimulation par le mamanais. Ce résultat irait dans le sens de notre étude précédente des interactions synchrones : au 3^e semestre, chez les autistes, les interactions se faisaient au prix d'une prolongation d'un taux élevé de stimulation tactile (touching) et stimulation intensive (reg-up).

Pour préciser la part respective des parents et du bébé dans ce phénomène, nous avons calculé **l'indice d'efficacité du mamanais** : taux de mamanais suivi d'une réponse du bébé dans les 3 secondes, rapporté à l'ensemble des vocalisations en mamanais (voir figure 11).

Dans le cas de notre bébé typique, lorsqu'on prend en compte l'ensemble des vocalisations (père, mère, ou « autre »), on observe comme prévu un indice d'efficacité de l'IDS (Infant-Directed Speech ou mamanaï) supérieur à celui de l'ADS (Adult Directed Speech). Lorsqu'on distingue les locuteurs, on observe que l'IDS maternel est plus efficace que l'ADS et cette efficacité augmente linéairement, cependant l'indice d'efficacité de l'ADS maternel rattrape celui de l'IDS au 3^e semestre. On pourrait l'interpréter comme le fait que le bébé étant pleinement entré dans la relation avec sa mère, l'IDS n'a plus d'utilité pour susciter une réaction du bébé. Pour le père, l'efficacité de l'IDS ne dépasse pas celle de l'ADS lors de la première année, mais remonte spectaculairement au 3^e semestre (atteignant 100% d'efficacité).

Que se passe-t-il maintenant dans le cas de notre bébé autiste ? Au 1^{er} semestre, la réactivité au mamanaï est inférieure à celle du bébé normal (30% au lieu de 50%) et ne dépasse pas la réactivité à l'ADS (contrairement à notre bébé typique). Selon une dynamique déjà observée dans notre étude précédente sur l'ensemble des interactions, la réactivité aux vocalisations du bébé autiste s'améliore au 2^e semestre puis décroît au 3^e semestre (alors qu'elle continuait d'augmenter chez le typique). Cependant l'efficacité de l'IDS maternel chute moins que celle de l'ADS et lui reste supérieur (contrairement à ce qu'on avait observé chez le bébé typique). Chez le père, au 3^e semestre, on observe comme pour le bébé typique une grande supériorité de l'IDS sur l'ADS, ainsi qu'une efficacité supérieure de l'IDS paternel sur l'IDS maternel (cependant rappelons que les interactions vocales paternelles restent faibles chez notre bébé autiste au 3^e semestre). Nous pouvons donc conclure que malgré la baisse pathologique de la réactivité de ce bébé autiste aux vocalisations au 3^e semestre, l'utilisation du mamanaï permet de soutenir un certain nombre d'interactions tant avec le père qu'avec la mère (contrairement au bébé normal pour lequel l'IDS de la mère n'apportait aucun bénéfice en terme d'efficacité).

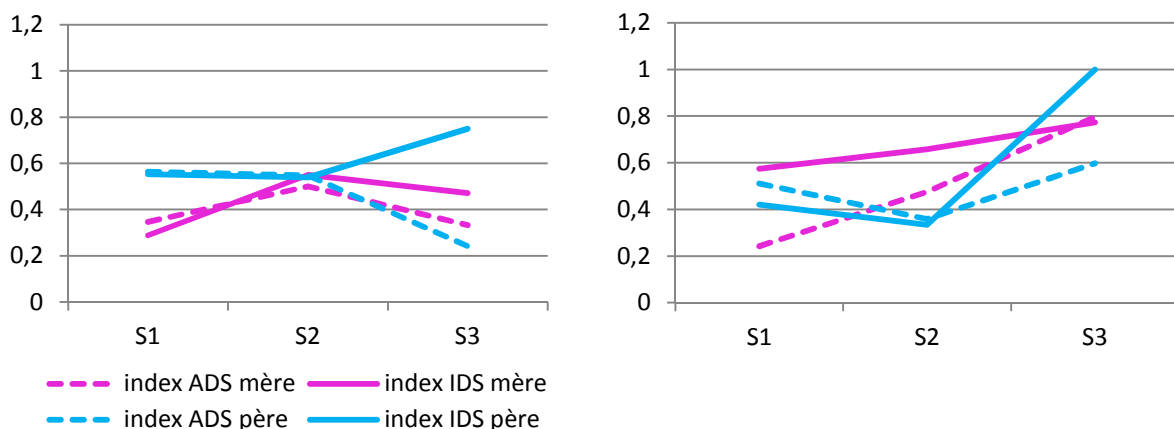


Figure 11: Index d'efficacité (taux de réponse du bébé) des vocalisations adressées au bébé autiste (à gauche) et typique (à droite) par chacun des parents en fonction du type de prosodie

Concernant nos hypothèses de départ :

Sur l'amélioration de la réactivité du bébé autiste lorsqu'on s'adresse à lui en mamanaï : cette hypothèse ne se vérifie pas, sur ce cas, durant la première année, où le bébé autiste est trop peu réactif, sans amélioration par le mamanaï. Mais il faut noter que notre hypothèse semble se vérifier au 3^e semestre, au moment où justement la réactivité du bébé aux vocalisations chute : le mamanaï suscite alors un gain de réponse du bébé.

Sur l'effet possible du manque de réactivité du bébé sur le mamanaï parental : le fait qu'au 3^e semestre notre bébé autiste se mette à moins bien répondre à l'IDS maternel mais qu'il améliore simultanément sa réactivité à l'IDS paternel amène à s'interroger. La qualité du mamanaï maternel est-elle moindre, et/ou bien sont-ce d'autres canaux communicatifs simultanés qui sont perturbés chez la mère (comme par exemple la mimique, ou la gestualité), ou bien est-ce la qualité globale de la communication et de la relation mère-enfant qui sont en souffrance ? En d'autres termes, faut-il voir ici l'indice d'une difficulté relationnelle qui au 3^e semestre, de l'enfant se répercuterait à la mère, dont les stimulations deviendraient alors moins efficaces alors même que l'enfant serait encore stimuable par le mamanaï d'autres intervenants ? Dans le cas de la dépression maternelle, Kaplan a montré que les bébés, insensibles au mamanaï de leur mère déprimée, étaient d'autant plus sensibles à celui de leur père (Kaplan et al., 2010). Notre bébé autiste serait-il, au 3^e semestre, sensible à une certaine altération du mamanaï de sa mère, témoignant d'une spirale interactive négative ? Le père serait épargné par sa naturellement moindre implication dans l'interaction avec le bébé. Dans ce cas de figure, nous n'observons pas une baisse particulière de *la quantité d'IDS maternel* (pas plus que dans la dyade normale) mais nous observons une baisse de *l'efficacité de l'IDS maternel* alors que celle de l'IDS paternel continue d'augmenter, donc il y pourrait y avoir une *baisse de la qualité* du mamanaï maternel.

Quoiqu'il en soit, cette étude pilote sur 2 cas uniques nous a permis 1) de vérifier l'efficacité de notre détecteur de mamanaï, puisque nous avons retrouvé les caractéristiques attendues du mamanaï, tant au niveau de son efficacité (supérieures à celle de l'ADS) (Fernald & Kuhl, 1987) que de sa décroissance au fil du temps (Stern et al., 1983), 2) de mesurer l'importance d'une étude séparée des différents care-givers et surtout de la mère et du père puisqu'il s'avère que la dynamique évolutive et l'efficacité en sont bien différents. Concernant, les autres résultats, ils demandent à être confirmés ou infirmés par une étude de groupe.

4.3.3. Article soumis (Interaction Studies)

Course of maternal prosodic incitation (motherese) during early development in autism: an exploratory home movie study

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Abstract

We examine the course of parents' motherese and the course of infant's response based on home movies from two single cases: a child with typical development (TD) and a child with autism development (AD). We used two separated and blind analyses. The first assessed infant caregiver (CG) interaction using a computer-based coding procedure with Observer, while the second analyzed speech and motherese CG production using a computerized algorithm for motherese speech detection. An interaction analysis was conducted based on time after fusing the two procedures and filtering for co-occurrence using a time window of 3 seconds. Frequencies of vocalization for the TD and AD cases were similar. Mothers spent more time interacting with infants during the first 12 months, and fathers appeared to interact with their child preferentially between 12 and 18 months in the TD case, but not in the AD case. Motherese speech represents an important proportion of interactions between infants and caregivers during the first 6 months; however, its predominance decreases over time, with the TD child responding equally well to motherese compared to other speech after 1 year of age. For the AD child, the responses to both types of speech were lower than in the child with TD and decreased from the second to the third semester. The fathers' motherese appears to be more effective than the mothers' motherese. In this exploratory study, we conclude that the course of parents' motherese differs based on gender (father vs. mother) and child status (TD vs. AD). The course of an infant's response to CG vocalization differs according to the type of speech (motherese vs. other speech) and child status (TD vs. AD).

Key-Words: Autism - motherese - early interaction - computational methods

Introduction

Autism is a developmental disorder characterized by the presence of abnormalities in reciprocal social interactions, in patterns of communications, and by a restricted, stereotyped, repetitive repertoire of behavior, interest, and activities (ICD 10; DSM IV). Although autism manifestations are extremely variable, children's inability to develop any sociability or to communicate are at the core of this pathologic developmental process.

Symptoms, such as speech delay and stereotyped behavior, are often evident in the second and third year, but these clearly are not the initial manifestations of autism (Short & Schopler, 1988; Stone, Hoffman, Lewis, & Ousley, 1994; A. Sullivan, Kelso, & Stewart, 1990). Retrospective studies on early home videos (for a review, see (C. Saint-Georges et al., 2010) and data from parental interviews (e.g., Adrien et al., 1993; (Werner et al., 2000) have revealed atypical developmental tendencies in infants who were later diagnosed with autism spectrum disorders (ASD). In addition, prospective studies based on siblings of ASD children have reported various behavioral markers that, in part, predict a subsequent diagnosis of autism (Zwaigenbaum, 2005). The first signs are abnormalities in eye contact, social behavior, joint attention, orienting to name, and body language. These behaviors constitute important prerequisites for communication and social competencies; however, whether these first signs impact the interactive process between an infant and their parents and whether they influence the development of the infant himself remain two complex issues.

The major contributions of these studies on screening for the first signs of autism notwithstanding, none or very few studies have addressed the importance of infant caregiver synchrony and reciprocity in early interactions. Data on the interactions of typically developing children and their parents are numerous; however, similar studies on pathologic groups are still lacking. Social interaction is a reciprocal process, and its quality depends on an active dialogue between the parent and the child based on the infant's early competencies and the parent's capacity to be attuned (Stormark & Braarud, 2004); Trevarthen, 1983; (Crown et al., 2002). Micro-analysis of film records examining rhythms and patterns in mother-infant face-to-face interactions in the neonatal period (Brazelton et al., 1975) and early communication (Condon & Sander, 1974); (D. N. Stern et al., 1975) have emphasized the importance of synchrony and the co-modality of these early interactions for infants' development. The maturation of the infant's relational skills and the development of self-regulation and social fitness are accelerated by a high level of arousal that infants co-construct with their parents during short daily episodes of face to face play (Feldman, 2003). In addition, parent-infant synchrony provides the foundation for the child's later capacity for intimacy, symbol use, empathy, and the ability to read the intentions of others (Feldman, 2007). In preterm infants, the quality of the early mother-infant relationship has been noted as one of the factors that may exacerbate or soften the potentially adverse impact of preterm birth (Forcada-Guex, Pierrehumbert, Borghini, Moessinger, & Muller-Nix, 2006).

Social interactions also have an important impact on language learning (Bloom, 1975; Bloom & Esposito, 1975; Goldstein, King & West, 2003). Simple exposure to language does not explain phonetic learning. Features inherent in the social setting, such as interactivity and contingency, are critical for language learning (Kuhl, 2007). Since Itard, we have known that a complete lack of social interaction has devastating impacts on human language learning (Carrey, 1995). Rutter's adoption studies (Croft et al., 2007; Rutter et al., 2007) show the dramatic damage following severe early deprivation and its heterogeneity in outcomes, including cognitive deficits, attachment problems and quasi-autistic patterns.

Researchers in language acquisition and in early social interactions have demonstrated that adult vocal behavior is a fundamental factor that affects the language and social development of infants. A special type of speech that is directed towards infants, called 'motherese' (or infant-directed speech), which is characterized by higher pitch, slower tempo, and exaggerated intonation contours (Fernald, 1985; Greiser & Kuhl, 1988), seems to play an important role in both social interaction and in language development. Studies have revealed that this particular prosody may be responsible for attracting infants' attention, conveying emotional affect and providing language-specific phonological information (Karson, 1985; Fernald, 1985; A. Fernald & P. Kuhl, 1987; Kathy Hirsh-Pasek, Kemler Nelson, Jusczyk, & Cassidy, 1987; Kemler Nelson et al., 1989). In addition, the infant's reactions amplify the contours of the prosody curves in the mother's voice (Burnham et al., 2002). Mothers' infant-directed speech was found to depend on the quality of the infants' responsiveness, suggesting that infants are actively involved in the course of motherese (Braarud & Stormark, 2008); Saint-Georges, C., Cassel, R. S., Mahdhaoui, A., Chetouani, M., Muratori, F., Laznik, M.C., Cohen, D., submitted).

The link between social interaction and language learning theories of autism and the study of motherese in early interactions of infants who become autistic may provide cues for understanding the development of communication skills in children with autism. In a previous work, we extensively described our hypotheses (Mahdhaoui et al., 2011) concerning this relationship between early interaction, language learning and autism. Summarizing them, we postulated that if learning depends on normal social interest in people and the signals they produce, children with autism, who lack social interest, may be at a cumulative disadvantage in language learning. Their poor response to parental incitation may impair both parental incitation and motherese production over time. As a consequence, this impairment will reinforce social withdrawal and language acquisition delay.

Aims of the study

In this paper, we test the use of a computerized algorithm created for the detection of motherese speech (Mahdhaoui et al., 2011) and focus on parent's vocalizations and infants' responses simultaneously. We proposed the following hypotheses. 1) As motherese amplification is bidirectional and AD children lack social interest, caregiver's motherese towards AD children should decrease over time; this decrease will likely be greater than that seen in caregiver's motherese towards the TD child. 2) The AD child should be capable of interacting and responding to

motherese specifically at the start of life. The study presented here is exploratory. It examines the course of parents' motherese and the course of an infant's response using home movies from two single cases: a child with typical development (TD) and a child with autism development (AD). This manuscript will provide the methodological process that will be used to assess a large data base of home movies.

Methods

Participants

We studied the home movies of two children from the Pisa Home Movie (HM) data base during the first 18 months of life using the following criteria: the first was diagnosed with an autism disorder (AD) and the second was a typical developing control (TD). The two cases were selected according to the audio band quality of the videos and the fact that they had the largest number of video sequences. An editor, who was blind to the children's diagnoses, selected among the HM of each child all segments running for at least 40 seconds where the infant was visible and could be involved in human interaction (standard situations). For each infant, the sequences were organized into three 6 month periods (≤ 6 month; $6 < \text{age} \leq 12$ months; > 12 months). All scenes showing a situation in which social interaction could occur (i.e., all scenes with an infant and an adult) were extracted and, if necessary, segmented into short sequences for scoring (for a complete description of the Pisa Home Movie database see (F. Muratori et al., 2011); Maestro et al., 2005). We excluded all video sequences with poor audio quality (background noise such as loud music, outdoor sequences, birthday parties or baptism celebrations).

Case 1 is a case of early onset autism (AD) that involved diagnosis at age 5 by a psychiatrist based on DSM-IV criteria. Parents received the Autism Diagnostic Interview-Revised (ADI scores=23, 20, 6 for social, communication, limited interest domains respectively) (Rutter, Le Couteur, & Lord, 2003) to confirm the diagnosis. The Childhood Autism Rating Scale was used to assess the severity of autistic symptoms (CARS score=36.5) (Schopler, Reichler, & Renner, 1988). The child also received an Autism Diagnostic Observation Schedule (ADOS; [Lord et al., 2000](#)) (ADOS module 1 scores=5, 9, 14, 3, 4 for communication, social interaction, total, play and limited interests, respectively). IQ score was 83, based on the Leiter scale. Case 2 involves a child with a history of typical development (TD) and no psychiatric and/or developmental symptoms, as confirmed with the Child Behavior Check List (i.e., all scores were below the clinical threshold) (Achenbach & Rescoria, 2000).

Procedures

We used two separated, blind analyses to assess first infant caregiver (CG) interaction using computer-based coding procedure; speech and motherese CG production were then analyzed using a computerized algorithm for motherese detection. Then an interaction analysis was conducted based on time after fusing the two procedures and filtering for co-occurrence using a time window of 3 seconds (see below).

The Observer 4.0® was configured for the application of the Infant Caregiver Behavior Scale (ICBS) to the video media file-material. The ICBS is composed of 29 items that reference the ability of the BB to engage in interactions and 8 items describing CG solicitation or stimulation toward the infant to obtain his attention (details of the grid can be found in Muratori et al., 2011; Saint-Georges et al., submitted). All target behaviors were described as Events, which occurred at a specific instant. Four coders were trained to use the computer-based coding system until they achieved satisfactory agreement (Cohen's Kappa ≥ 0.7). The standard situations derived from the HM were mixed, and each HM case was rated by one trained coder who was blind to the groups. For continuous verification of inter-rater agreement, 25% of standard situations were randomized and rated by two coders independently. The final inter-rater reliability, calculated directly by the Observer, showed a satisfactory Cohen-k mean value ranging from 0.75 to 0.77.

To extract the caregiver's vocalizations from the video segments, we performed a manual segmentation of CG vocalizations with The Observer 4.0®. We used Sound Forge 9.0 to extract the vocal segments from each video sequence. Vocal segments that presented with poor audio quality or were imperceptible to the ear were excluded. Manual segmentation provided us with a database of speech segments, separated by case (AD, TD) and by semester (S1, S2 and S3). In addition, manual segmentation allowed us to identify the following: the number/frequency of vocal segments, the duration of segments in each sequence of movie, and the identity of who was speaking to the child (i.e., mother, father, other CG).

The segments of speech were analyzed using a computerized classifier for motherese speech (infant-directed speech) or normal speech (adult-directed speech) categorization. Because the "manual" study of acoustic components (Laznik, Maestro, Muratori, Parlato, 2005) of the voice is very costly in terms of human time and only allows for the study of very short voice segments, the realization of such an algorithm made it possible to conduct an extensive study of home movies based on their acoustic characteristics.

The whole system concept was described by Mahdhaoui et al. (2011). Here, we briefly describe the key components of this automatic system. Using classification techniques that are often used in speech and speaker recognition (GMM and K-nn), we developed a motherese detection system and first tested it on the mode dependence of the speaker. The fusion of features and classifiers was also investigated. Given that home movies are not recorded by professionals and often contain adverse conditions (e.g., with regard to noise, the camera, or microphones), acoustic segmentation of home movies shows that segmental features play a major role in robustness (Schuller et al., 2007). Consequently, the utterances were characterized by both segmental (Mel Frequency Cepstrum Coefficients) and supra-segmental (e.g., statistics with regard to fundamental frequency, energy, and duration) features. We showed that segmental features alone contained much useful information for discrimination between motherese and adult-directed speech, as they outperformed the supra-segmental features. However, according to our detection results, prosodic features were also very promising. Based on the previous two conclusions, we combined classifiers that used segmental features with classifiers

that used supra-segmental features and found that this combination improved the performance of our motherese detector considerably. In its most effective configuration, the novel detector had positive and negative predictive values of 90%. When we explored the motherese detector's performance on 200 sequences from 10 different speakers who were blindly validated by two psycholinguists, the performance of the detector (speaker-independent) remained very good (accuracy=82%) (Mahdhaoui et al., 2011). This level of prediction made it suitable for further studies of home videos.

For the interaction analysis, we first fused video coding and acoustic analysis. The computer-based coding system (The Observer) provided ".txt" files with the description of ICBS behaviors based on time. Vocalizations analyzed by the computerized system provided two new tags: motherese vocalization or other speech. These tags were reintegrated to the .txt file as CG "state events". Second, we extracted all infants' responses to caregiver vocalizations co-occurring within a time window of 3 seconds using a Linux-based script. Any child behavior occurring within the 3 seconds following the caregiver vocalization was retained. The 3-second window was based on the available literature on synchrony (Feldman, 2003) and on previous work on infant-caregiver interaction (Saint-Georges et al., submitted). Interactive behaviors were calculated by type (motherese or other speech), by semester (S1, S2 or S3) and by speaker (all CG, father or mother), in terms of frequency (number of events) and duration of CG vocalizations (in seconds).

Results

Table 1 summarizes the characteristics of the segments extracted for each case: number of sequences, duration of sequences, frequency and duration of CG vocalizations, frequency and duration of mothers' and fathers' vocalizations, and the frequency and duration of the mothers' and fathers' motherese speech. Six sequences from the TD case and 9 from the AD case were excluded due to poor audio quality. In total, we analyzed 87 sequences for a total duration of 10,330 seconds (\approx 172 minutes). The frequency of vocalization towards the TD or AD case was similar when examined in terms of number of CG vocalizations per HM duration (seconds) and stable by semester around 0.2 (see Table 1, bottom). When examined in terms of CG vocalization duration per HM duration, some differences emerged. CG vocalization rate towards the AD case was higher than towards the TD case during S1 and S2 (0.33 and 0.36 vs. 0.19 and 0.13, respectively), but not in S3 (0.23 vs. 0.2). Taking these two results together, during S1 and S2, the duration of vocalizations towards the AD case was longer.

Table 1 : Characteristics of the movies for the typically developing (TD) and the autistic (AD) children

	TD				AD			
	S1	S2	S3	total	S1	S2	S3	total
N sequences	12	8	6	26	22	21	18	61
D sequences	1272	844	785	2901	2387	3031	2011	7429
N voc	214	124	150	488	472	670	350	1492
D voc	240	109	158	507	790	1101	471	2362
N MM	134	44	24	202	309	216	83	608
MM total D	155	43	25	223	516	359	125	1000
N voc mother	148	81	76	305	392	417	213	1022
D voc mother	166	75	78	319	689	744	313	1746
N MM mother	115	41	22	178	271	189	51	511
D MM mother	132	41	23	196	479	324	81	884
N voc father	66	42	74	182	77	77	62	216
D voc father	74	32	80	186	97	75	58	230
N MM father	19	3	2	24	38	13	4	55
D MM father	23	2	2	27	37	12	4	53
N voc / D sequences	0.17	0.15	0.19		0.20	0.22	0.17	
D voc / D sequences	0.19	0.13	0.20		0.33	0.36	0.23	

D = duration (seconds); N = number of events; S = semester; MM = motherese vocalization; voc = all vocalizations

Consistent with previous findings on parent-infant interactions, the mothers' vocalizations during S1 represented 81% of all vocalizations addressed to the AD case and 69% to the TD case. In the TD case, the mother's vocalizations remained constant during S2 (65%) and decreased during S3 (48%). For the AD case, the mother's vocalizations decreased earlier, i.e., between S1 and S2 (62% and 61% during S3). In contrast to the mothers, the father's vocalizations towards the TD case increased from S1 to S3 (30%, 34%, and 47%, respectively). This trend was not found for the father's vocalizations towards the AD case for which it remained considerably low (16%, 11%, and 18% of all vocalizations addressed to the infant in S1, S2 and S3, respectively). Taken together, the mother of the TD case spoke to the infant more than the father of the TD case during S1 and S2, but not during S3, at which time both were similar. This balance did not appear for the AD case. In the TD case, the father was absent in only 4 of the 26 sequences retained and spoke to the child in all other sequences, with the exception of 1 where he was just videotaping. In the AD case, the father appears in 48 sequences; in 8 of these, he is absent, and in 18 sequences he does not speak. In these two specific cases, the AD father speaks less than the TD father.

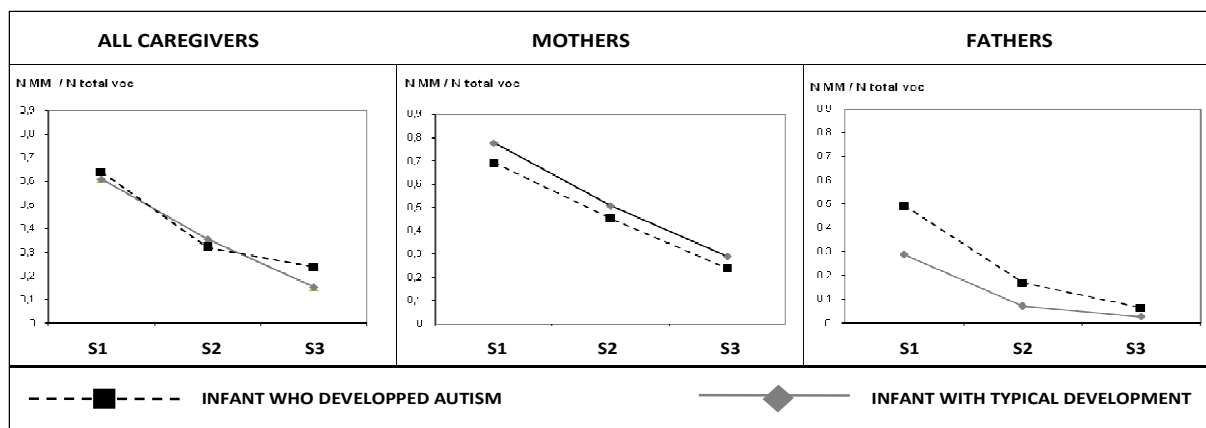


Figure 1. Course of motherese rates according to semester for all caregivers', mother's and father's vocalizations

TD=Typical development; AD=Autism disorder; MM=Motherese; Voc=vocalization; N=Number of sequences

Figure 1 shows the motherese rate per vocalizations addressed to the infant and that of mother and father alone. The TD and AD cases show a comparable profile. There was a decreasing course for both the mothers' and fathers' motherese over time, and the mothers' motherese rates were always higher than the fathers' motherese rates during all semesters. To understand how motherese is correlated with positive interactions, we examined motherese speech and other CG speech in relation to infants' behaviors after extracting CG vocalizations occurring within a 3-second window including an infants' response. Any child behavior occurring within the 3 seconds following the caregiver vocalization was retained. As the results obtained by number of events (number of vocalizations) or duration did not differ, we decided to report only the number of events in this manuscript.

Figure 2 shows the role of CG motherese speech when addressing infants. Motherese speech was involved in 70% of the interactions in the TD case versus 61% in the AD case at S1. Even if the frequency of motherese was proportionally higher in the TD case compared to the AD case, this result highlights the fact that motherese is more effective for eliciting and maintaining infant attention and emotional responses than other speech (M. Papousek, Papousek, & Symmes, 1991). In the TD case, the proportion of motherese speech followed by an infant response decreased linearly by 30% at each subsequent semester. Other speech addressed to the TD infant was involved in 30% of the interactions and increased to 82% at S3. In the AD case, the use of motherese speech in interactions reduced by 24% from S1 to S2 and remained almost constant from S2 to S3 (35% to 30%). It is possible that AD caregivers, sensing the infant's social difficulty, adapt their language to continue arousing the infant's attention. To answer this question, we decided to examine the contribution of motherese speech on interactions by defining an index of efficacy for each type of speech (motherese vs. other speech): Number of sequences with Motherese (or other speech) followed by an interaction / Total Number of sequences with Motherese (or other speech).

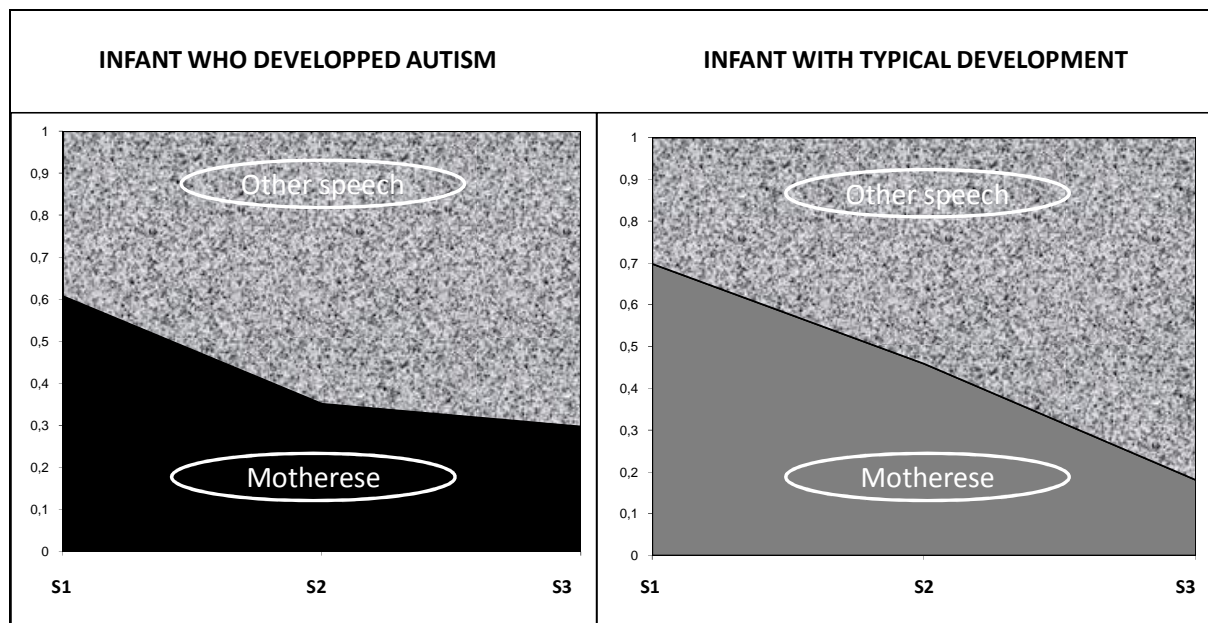


Figure 2. Contribution of motherese versus other speech to interaction according to child status: autism (left), typical development (right)

Figure 3 shows the index of efficacy for infants' responses to vocalization from any CG, from mother and from father. There was a growing tendency for the effectiveness of CG vocalizations overtime for the TD case. The infant responded more to motherese at S2 than at S1, and the responses to motherese increased even more, reaching 0.79 of effectiveness at S3. Interestingly, the curve of effectiveness for all other speech addressed to the TD infant changed from 0.40 at S1 to 0.41 at S2, and reached 0.68 at S3. Therefore, the TD child was capable of responding to all types of vocalizations, and this tendency increases over time. During S3, the TD child responded equally well to motherese as to other speech. However, the AD case showed a different profile. Comparatively, the AD child responded less well than the TD child to all types of speech at S1, S2 and S3. Motherese remained more effective at inducing an infant response, but rates were quite low, as maximum efficacy was only 0.52 at S2. The role and effectiveness of motherese or other speech addressed to the AD and TD infants by mothers or fathers separately followed the same pattern. Considering the effectiveness of fathers' vocalizations, the efficacy of motherese was particularly striking during S3. The TD infant responded to 100% of the father's motherese and 60% of the father's other speech. The AD infant respond to 75% of the father's motherese versus 24% of his other speech.

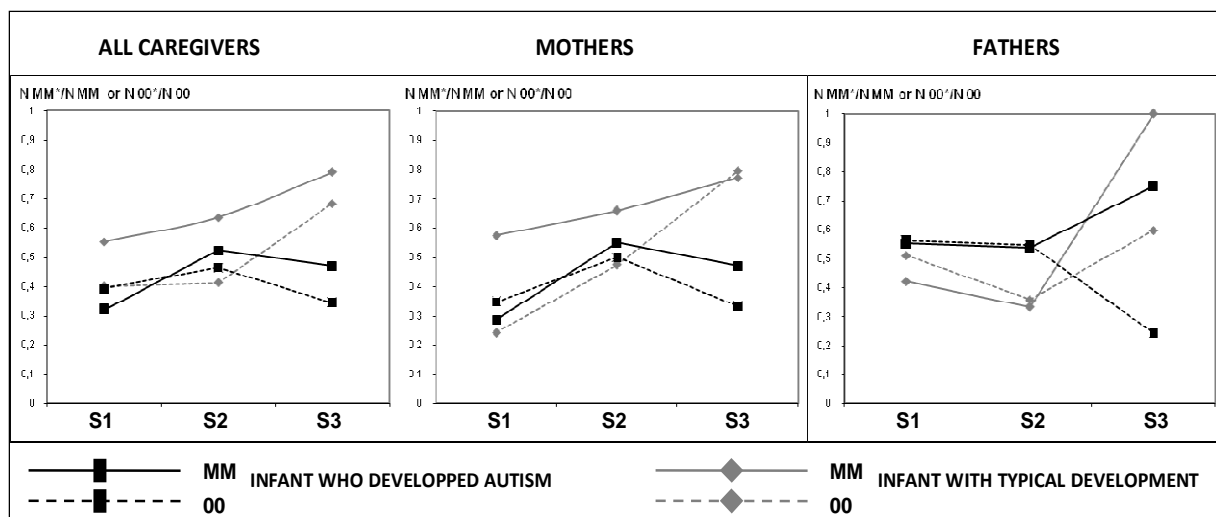


Figure 3: Efficacy of care-givers' motherese or other speech: all caregivers, mother and father.** MM=Motherese; 00= Other speech; *Number of sequences of MM or 00 followed by an infants' response; **Efficacy means the relative frequency of motherese (or other speech) sequences that were followed by a response from the child among the total sequences of motherese (or other speech)

Discussion

Summary of the results

First, parents more frequently addressed the AD child than the TD child during the first year. The TD mother spoke to the infant more than the TD father did during the first 12 months, but not after this point, when there was a balance between both. This balance did not occur for the AD child. Second, the course of both mother and father motherese decreased over time, and the mothers' motherese rates remained consistently higher than the fathers' motherese rates during the first 18 months. Figure 4 summarizes the most significant results of the present case study. The course of mother and father vocalization rates followed by a child response (or an interaction) (Figure 4, left) shows that the role of the TD infant's father appears to be more critical during the third semester. In contrast, the AD infant's father remained discrete. In addition, the efficacy of mother and father motherese (Figure 4, right) is increasingly important from S1 to S3 for the TD child, reaching 100% efficacy for the father's motherese during S3. This is not the case for the AD child, despite some efficacy of the father's motherese after the first year.

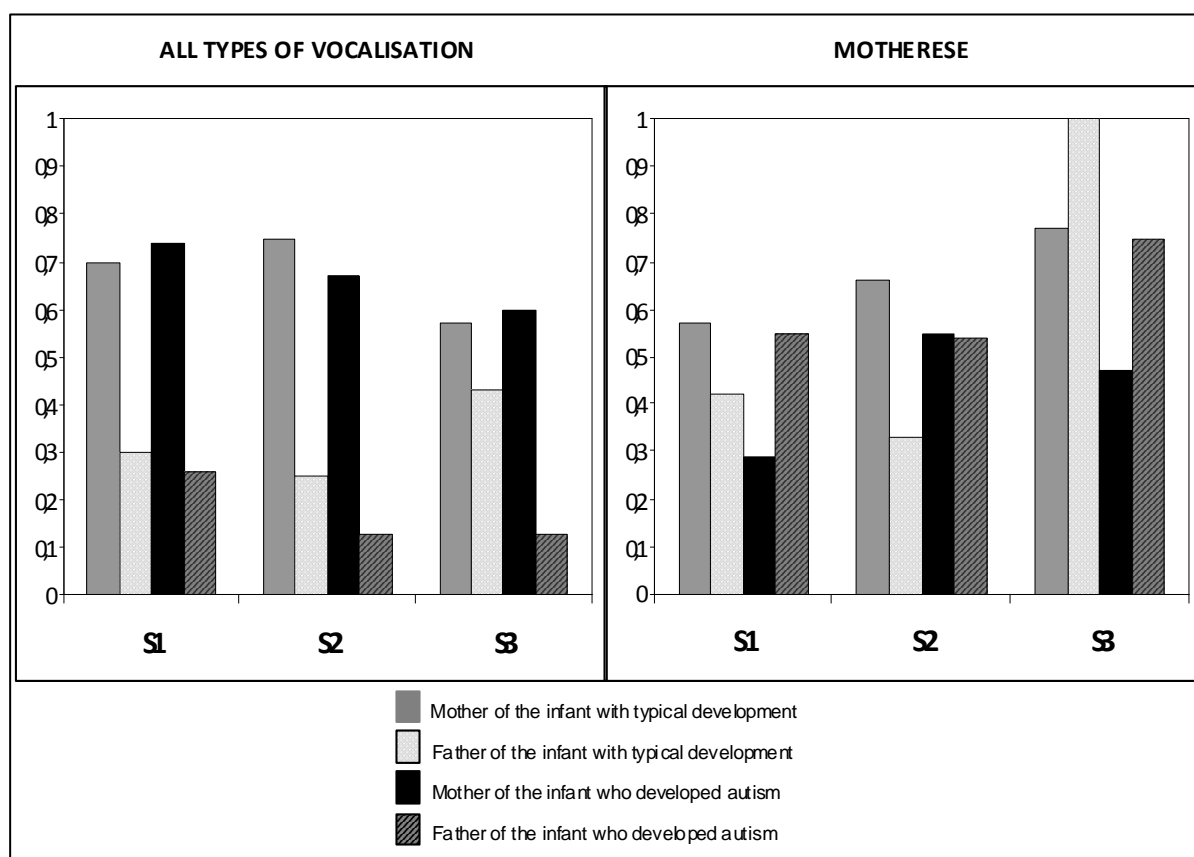


Figure 4. Summary: Mothers' and fathers' role when interacting with their child by semester (Left); Efficacy* of mother and father motherese by semester (Right)

*Efficacy means the relative frequency of motherese sequences that were followed by a response from the child among the total sequences of motherese

Comments

As expected, the analysis of caregivers' vocalizations towards infants confirms that vocalizations are the primary means by which caregivers interact with infants, and it is stable over all three semesters. Differences between the AD and TD cases are not obvious, suggesting that caregivers solicit AD infants as well as TD ones. Saint-Georges et al. (submitted) studied caregivers' responses to infants' behaviors in three different groups (TD, AD and ID [intellectual disability]) and showed that their responses to the child differed little, and consequently, their ability to be adequate parents was preserved.

Our most novel finding was revealed by the study of mothers' and fathers' vocalizations separately. In general, the focus within the literature tends to be solely on mothers in relation to their children, with little attention paid to the fathers. To our knowledge, no longitudinal study on a pathologic group has considered the dynamic between mother and father when interacting with the infant. Our analysis of mothers' and fathers' vocalizations during the first 18 months of life showed some differences that are worthy of consideration. Consistent with previous studies (Pedersen & Robson, 1969; Rebelsky & Hanks, 1971), mothers (as the primary

caregiver) spend more time interacting with infants during the first year than fathers did. The TD case showed a balance between mother and father motherese after the first year, consistent with normal child development. During the first year of life, the infant is very dependent on the adult, physically and emotionally, and needs specific care. Mothers spend more time than fathers feeding, cleaning, and playing with infants and engage in more affectionate displays and verbal interactions than fathers do during this time period (e.g., Clarke-Stewart, 1978; Field, 1978; Kotelchuck, 1976; Lamb, 1980; Parke & Sawin, 1980, Yogman, 1982). Fathers tend to engage in more active and stimulating interactions than mothers (e.g., Clarke-Stewart, 1978, 1980; Lamb, 1977a, 1977b; Power & Parke, 1981), which corresponds to the acquisition of autonomy (motor and language abilities) characteristics beyond the first year of life. This background information may explain the increase in father's interactions after the first year for the TD case, but it does not explain its absence in the AD case. The fact that the AD father spoke less than the TD one raises the question of whether this was a case specific difference or an important finding. We acknowledge that the present finding is only based on two single cases. Thus, it is unclear whether the father and mother would present a quantitative and qualitative difference when interacting with infants. Further analyses in a larger sample are needed to delineate these differences and to better understand the father's and mother's role in parent-infant interactions.

In terms of the course of motherese during the first three semesters of life, studies on parent-infant interactions highlight the universality of the intonation modification in adult speech to infants. Studies also emphasize the powerfulness and effectiveness of this special speech register for communicating with preverbal infants across different cultures (Fernald et al, 1989). Indeed, our study shows that motherese represents an important proportion of interactions between infants and caregivers during the first 6 months and its predominance decreases over time. Together, the decrease in motherese and the effectiveness of motherese over time in the TD case are likely the most important finding of this study. While the use of motherese by caregivers decreased over time, TD infant responses to motherese increased along with responses to other speech. After the first year, the TD child responded equally well to motherese speech as to other speech, which is not surprising. According to child development theories, in the earliest period, the attentional/affective functions are primary and orient the infant to the human voice to maintain social interaction (Fernald, Taeschner, Dunn, Papousek, Deboyssonbardies, et al., 1989). At the end of the first year, children start to deliberately create messages that have recognizable functions of language in communication with other people. Between 12 and 18 months, and with his/her new capacity to move, the child achieves a relative autonomy that allows him/her to come and go and easily seek contact or initiate interactions with others. Caregivers do not need to speak in motherese anymore to elicit the child's attention or to have a successful interaction with him/her.

Paradoxically, in the AD case, analyses of both the rates of interactions initiated by motherese and the efficacy of motherese based on semesters provides a different framework. The infant's response to both types of speech is not only lower than that of the TD child but decreases from S2 to S3. The quality of vocal emission

(CG) is preserved, but not the quality of reception (BB). This result is consistent with findings from home movie studies, which show that the decrease in responses corresponds to the moment that the first signs of autism become more evident. Surprisingly, our study shows, that during the same period the rate of motherese used in an interaction remains the same. Could we consider that the child with AD prefers motherese speech as compared to other speech and that he requires it to keep interacting with CGs? It could also be that there are unconscious concerns on the caregivers' part when interacting with the infant that motivate them to maintain the infant's arousal by using motherese speech. Does this mean that the AD parent should be able to increase their motherese production to ameliorate interactions with their baby?

The analysis of the efficacy of father and mother motherese separately allow us to support this hypothesis. Excluding the differences in the frequency of motherese production, we can conclude that the father's motherese was more effective and stable than the mother's in all three semesters. For the mother, it may be the consequence of a downward spiral, wherein the mother, not being gratified and encouraged by the infant's response reduces her motherese production, and the infant, not being aroused and stimulated by motherese speech, responds less. An alternative hypothesis is that the infant feels the mother's weariness and shows better responses to the father who is less affected by the non-interaction and can maintain and increase his motherese over time. There is an important difference between the infant's responses to the father's motherese and normal speech. It may also be that the father feels the difficulties of his baby and tries to assist the mother, even if his role in the interactions is much lower than that of the mother. The only study conducted on infants' responses to father's motherese suggests that a lower quality of maternal stimulation induces a type of neophilia in infants, such that they preferentially seek out interactions with male social partners (Kaplan et al., 2004).

Implication for further research

Infant-caregiver interaction is not a one-way process where the mother's behavior determines the infant's (Murray & Trevarthen, 1985). In a previous study (Saint-Georges et al, submitted), we examined interactions in home movies and found that the CG of different groups (AD, TD and DD – delayed development) responded almost identically to infants. The capacity of mothers to continue soliciting their babies with vocalizations is conserved, but whether the infants' behavior instigates or modifies the type of caregivers' response remains a subject for further research. Considering our hypothesis, it may be that motherese represents a way to respond to an infant. Because motherese conveys emotional information, the study of this type of speech related to infants' behaviors might be relevant in the qualitative aspects of social interactions in pathologic groups. Based on the methodology of the current case reports and the use of the automatic motherese detector (Mahdahoui et al., 2011), we will possibly obtained some answers to these questions. If early signs of abnormality on the quality of interactions can be detected, we can propose that a special intervention toward both the infant and the caregivers would be beneficial. The current exploratory case study showed the

importance of considering mothers from fathers separately, as they do not play the same roles in the early life of infants. Consequently, based on our hypothesis, fathers may not be as sensitive to motherese impoverishment. Although the generalization of this finding might be reconsidered because of the exploratory nature of this work, further research should distinguish mothers from fathers, as the role and timing of interactions appeared to differ dramatically.

In conclusion, the course of parents' motherese differs according to gender (father vs. mother) and child status (TD vs. AD). The course of infant's responsiveness to CG vocalization differs according to the type of speech (motherese vs. other speech) and child status (TD vs. AD). Whether these results based on case studies can be generalized needs further research and will be investigated using the Pisa Home Movie database.

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4.4. Perspective : l'étude de groupe (en cours)

4.4.1. Projet méthodologique

Il s'agit de l'étude de la banque complète en utilisant les mêmes analyses computationnelles que l'étude des interactions synchrones (Saint-Georges et al., in press), mais augmentées de la dimension émotionnelle spécifique du mamanais, dans le prolongement de l'étude pilote sur les cas uniques (Cassel et al., submitted). La figure 12 montre l'ensemble des étapes de cette étude.

Nous sommes donc repartis, dans la banque de films familiaux de Pise, des films de nos 15 bébés (de 0 à 18 mois) devenus autistes et des 15 bébés dont le développement sera normal (Muratori et al., 2011). La mauvaise qualité des enregistrements rendant la segmentation de la parole impossible, nous avons dû renoncer à utiliser les films des bébés qui auront un retard mental.

Toutes les vocalisations adressées au bébé, préalablement cotées, ont été manuellement découpées, étiquetées comme provenant du père, de la mère ou d'un tiers puis étiquetées par notre algorithme de classification automatisée (comme dans notre étude sur les 2 cas uniques) (Mahdhaoui et al., 2011). Nous avons ainsi obtenu les données concernant les vocalisations de chacun des parents: taux de mamanais et évolution. Nous avons ensuite repris notre filtre interactif de manière à ne retenir que les vocalisations efficaces c'est-à-dire suivies dans une les 3 secondes d'un comportement du bébé. Ceci nous a permis de calculer la part du mamanais dans les interactions réussies et son indice d'efficacité pour chaque locuteur et à chaque semestre. Comme dans l'étude pilote, nous avons éliminé de notre base d'interaction la méta-catégorie des comportements avec objets (décrite dans l'article sur les interactions synchrones: cf chapitre 2), afin de ne conserver que les réponses du bébé dirigées vers les personnes.

Poussant plus loin la précision dans les réponses attendues de la part du bébé vis-à-vis du mamanais, nous avons également recherché l'indice d'efficacité du mamanais à produire une réponse appartenant au méta-comportement "réceptif" (comprenant les items: regard, sourire, syntonie et "prenant du plaisir"- enjoying - avec autrui), cette catégorie correspondant plus précisément au type de réponse attendue d'après notre connaissance de la littérature (Saint-Georges et al., submitted).

Ayant, lors de notre travail précédent sur les interactions synchrones, observé une sur-représentation significative du comportement de "regulation-up" (reg-up) parmi les stimulations qui obtiennent une réponse du bébé autiste, nous avons fait l'hypothèse que ce comportement, défini comme une stimulation intensive, éventuellement multimodale, contenait une proportion élevée de mamanais. Nous avons donc recherché le taux de mamanais dans les vocalisations appartenant aux segments de "reg-up" pour le comparer au taux de mamanais calculé sur l'ensemble des vocalisations.

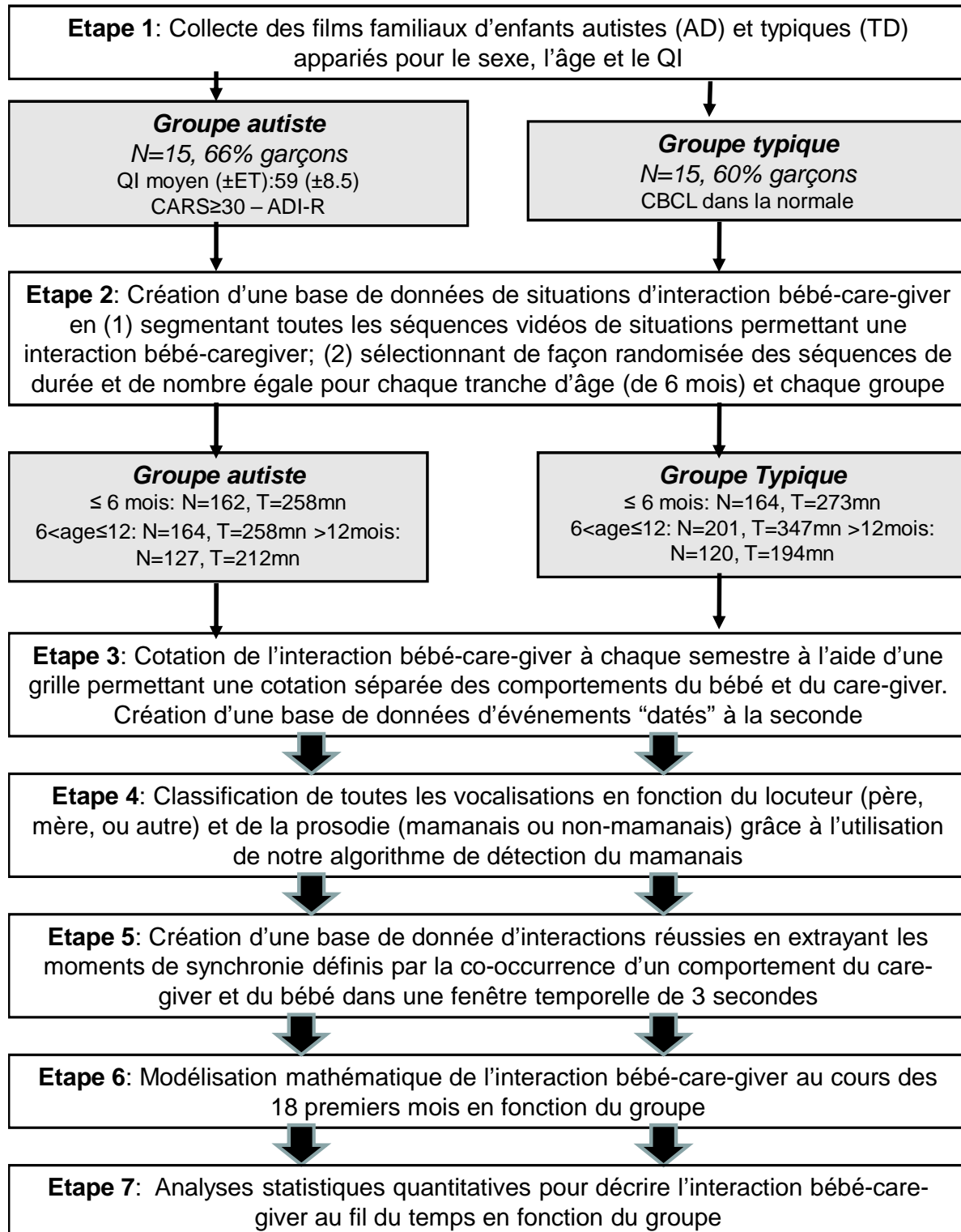


Figure 12: Diagram-flow de l'étude de groupe en cours prenant en compte le mamanais dans l'interaction

Nous avons également prévu d'étudier les interactions dans le sens bébé → parents de façon à préciser si le mamanais est ou non stimulé par les comportements interactifs actuels du bébé et, le cas échéant, par lesquels. La significativité des résultats sera analysée à l'aide des mêmes méthodes statistiques (modèle linéaire généralisé mixte) que lors de l'étude précédente sur les interactions synchrones, mais ne peut être présentée dans ce document.

4.4.2. Premiers résultats sur les vocalisations parentales

Evolution du taux de mamanais (figure 13):

Chez nos bébés typiques, au 1^{er} semestre le taux des vocalisations maternelles adressées au bébé en mamanais est de 50%, et diminue progressivement, tandis que le taux de mamanais paternel reste assez stable aux alentours de 10%. Chez nos bébés autistes, on observe le même type de courbe. Donc, avant même toute analyse statistique, nous constatons que, contrairement à notre hypothèse, et conformément aux résultats de l'étude pilote, il ne semble pas y avoir dans la triade du bébé autiste, de baisse particulière du mamanais au fil du temps, comparé aux triades typiques, et même, au 3^e semestre, les taux de mamanais maternel (30%) et paternel (10%) sont très comparables dans nos 2 groupes.

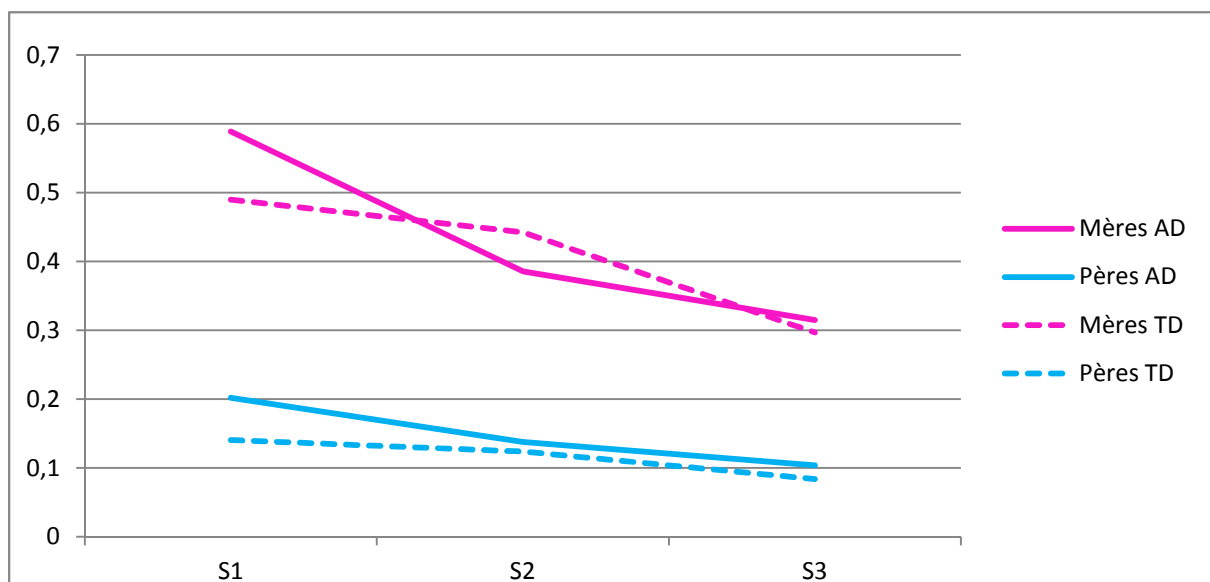


Figure 13: taux d'IDS dans les vocalisations adressées aux bébés typiques ou autistes

Taux de mamanais dans les vocalisations des comportements parentaux de « regulation up » comparé au taux de mamanais global (figure 14) :

On observe comme prévu que les séquences de reg-up contiennent un fort taux de mamanais, nettement plus élevé que le taux moyen de mamanais dans l'ensemble des vocalisations, et ceci pour les 2 types de bébé (normal ou autiste). Or l'augmentation du comportement reg-up était significative chez les parents d'autistes comparés à ceux des typiques aux 1^{er} et 3^e semestres. En résumé, le mamanais est augmenté dans nos échantillons de reg-up, qui est lui-même significativement augmenté dans les interactions réussies, ce qui pourrait indiquer que le mamanais soutient l'interaction sur les 2 semestres où le bébé autiste est justement moins réactif (le 1^{er} et le 3^e) : soit que les parents l'utilisent plus, soit que le bébé y réponde plus, soit probablement les 2. Mais on ne peut exclure que ce soit d'autres composantes du comportement de regulation-up qui soient à l'œuvre dans la réussite de ces interactions care-giver → bébé autiste.

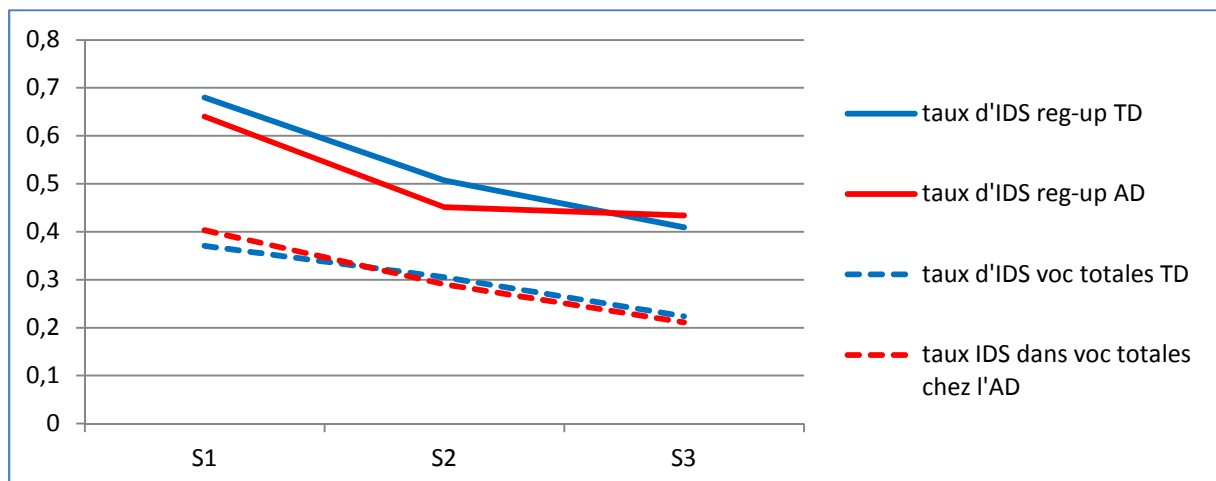


Figure 14: taux d'IDS dans le reg-up comparé au taux calculé sur l'ensemble des vocalisations

5. Discussion générale

Jusqu'ici les études des interactions précoces des bébés autistes s'étaient essentiellement centrées sur le bébé. Les études qui font exception en s'intéressant aussi au partenaire du bébé autiste, comme celle de Watson (Watson, 1998), Siller (Siller & Sigman, 2002), et l'étude de Muratori (Muratori et al., 2011) apportent des éléments de compréhension au fonctionnement et aux dysfonctionnements des interactions autistiques. Dans cette perspective, la prise en compte de la dimension développementale, de la dimension synchrone, et de la dimension émotionnelle des interactions nous a permis de nous avancer un peu plus dans l'analyse des interactions précoces et réciproques des bébés à devenir autistique.

5.1. Synthèse des avancées, et hypothèses psychopathologiques

Le fonctionnement interactif du bébé à risque autistique : un trou noir ?

Ces travaux s'inscrivent dans un contexte scientifique caractérisé par le manque d'information sur la psychopathologie de l'autisme. L'importance de ce trouble est pourtant en augmentation tant sur le plan de sa fréquence de survenue (Fombonne, 2005), que sur celui de l'attention qui lui est portée en tant que modèle conceptuel. En effet, l'évolution actuelle de la nosographie lui donne une place prépondérante dans les troubles du développement de l'enfant avec le développement de la notion de troubles du spectre autistique (révision proposée en 2011 pour le DSM 5). L'autisme apparaît ainsi comme un modèle organisateur de notre représentation de la psychopathologie précoce de l'enfant. Si le poids des facteurs génétiques est maintenant bien établi (Cohen et al., 2005), l'existence de facteurs environnementaux semble également validée (Guinchat et al., en révision). Mais le manque de données sur les processus probablement complexes en jeu dans la constitution du trouble autistique est problématique. Pourtant, de ces connaissances pourraient dépendre une meilleure prise en charge thérapeutique et un dépistage plus efficace, donc plus précoce.

L'étude développementale des films familiaux : une piste à creuser ?

L'autisme étant habituellement diagnostiqué après 2-3 ans, les premiers symptômes et dysfonctionnements dans les premiers mois restent trop mal connus. 3 méthodes existent actuellement pour cerner ces 2 premières années : les questionnaires remplis par les parents eux-mêmes pourraient être

sujets à divers biais, et les études prospectives restent rares du fait de leur lourdeur ; citons cependant, en France, l'étude Pré-Aut en cours (Delorenzi, 2008). En revanche, les études rétrospectives de films familiaux sont nombreuses, et les données se sont accumulées depuis plus de 30 ans. Il nous a donc paru utile, pour notre premier article (Saint-Georges et al., 2010) de rassembler et confronter toutes ces données pour essayer de dégager des tendances reproductibles de particularités du fonctionnement de ces bébés. De plus, nous avons essayé de préciser ces résultats en fonction de l'âge du bébé, d'une part pour apporter une contribution à des projets de dépistage, d'autre part, en vue d'essayer de « comprendre » la dynamique développementale du processus autistique. En effet, même si d'autres hypothèses ne sont pas exclues, les signes précurseurs peuvent être imaginés comme primaires et les signes ultérieurs comme secondaires, ainsi que l'ont proposé divers auteurs, notamment Trevarthen (Trevarthen & Daniel, 2005).

Or les films familiaux nous enseignent que les bébés autistes ne présentent généralement un évitement actif et des stéréotypies qu'à partir de la deuxième année. En revanche, les difficultés dans les compétences intersubjectives semblent débiter plus précocément dès le 2^e semestre, voire le premier. Le manque d'intérêt pour l'autre semble se manifester dès le premier semestre de vie : ils sourient moins, regardent moins, vocalisent moins et se tournent moins vers l'autre. Simultanément, on observe qu'ils possèdent quand même ces pré-compétences relationnelles à la naissance, puisque ces comportements ne sont pas absents : ils sont juste diminués en fréquence ! On apprend donc que la capacité d'entrer en contact avec l'autre par la voix, le regard, le sourire, qui semble perdue par la suite (au moment où le diagnostic est porté à partir de 2 ou 3 ans), existait cependant au départ (Maestro et al., 1999). Quel processus peut bien être impliqué dans cette disparition ? Il nous paraît fondamental d'essayer de répondre à cette question. L'hypothèse de Trevarthen, qui postule l'existence d'emblée chez le bébé d'une intersubjectivité primaire, qui pousse le bébé à entrer en contact avec l'autre, et qui est nécessaire au développement, à la construction progressive, de l'intersubjectivité secondaire, nous paraît pouvoir bien rendre compte des faits (Trevarthen & Aitken, 2001). En effet, si le bébé à devenir autistique manque d'une certaine intersubjectivité primaire (appétence pour autrui), s'il ne regarde pas souvent les visages et ne se tourne pas volontiers vers autrui, comment pourrait-il devenir compétent et expert pour comprendre l'autre (intersubjectivité secondaire) comme le deviennent les bébés ordinaires ? Il devient difficile de partager son attention avec quelqu'un sur un objet référent (attention conjointe) si on ne suit pas l'intérêt de l'autre, marqué par son expression et la direction de son regard. Cette lecture sur le visage de l'autre est vraisemblablement diminuée chez les bébés à devenir autistique. Sans attention conjointe, l'entrée dans la communication gestuelle et surtout verbale paraît compromise : pour savoir qu'un mot prononcé par l'autre se rapporte à une chose, il faut savoir où se porte l'intérêt de celui qui prononce ce mot. Carpenter a montré chez le bébé normal que l'attention conjointe influence le développement du

langage (Carpenter et al., 1998). Si l'enfant n'entre pas dans l'attention conjointe et le langage verbal, on peut imaginer que c'est toute une cascade de dysfonctionnements qui pourrait en découler. Ou réciproquement, on peut penser que l'entrée dans la communication et le langage (au moins réceptif) chez le bébé normal va complètement transformer la relation à l'autre, et que c'est cela qui n'a pas lieu, justement, chez le bébé en train de devenir autiste : il se structurerait sans être formaté par toute la complexité et la subtilité de l'échange avec l'autre, d'abord préverbal puis verbal, impliquant la réciprocité des interactions et transactions (Hobson, 1993). Il pourrait s'ensuivre des malentendus divers et répétés, des échecs de part et d'autre des tentatives de communication, des difficultés à gérer les frustrations, qui favoriseraient le repli et l'isolement qu'on observe à partir de la seconde année seulement.

La synchronie, une clé de l'étude de l'interaction dans les films familiaux ?

L'étude des films familiaux sous l'angle développemental nous a donc permis de poser des questions et soutenir des hypothèses psychopathologiques concernant les processus de constitution de l'autisme. Pour approfondir nos connaissances du fonctionnement pré-autistique précoce, il nous a paru intéressant de réinscrire ce fonctionnement dans une dynamique interactive, en prenant en compte les comportements de l'autre (adulte) et leur articulation avec ceux du bébé. En effet, les compétences relationnelles du bébé se manifestent évidemment préférentiellement dans le cadre de l'interaction avec un adulte (care-giver) et celui-ci adapte son comportement à celui de l'enfant, et dans une moindre mesure, réciproquement (Siller & Sigman, 2002). Les études sur les films familiaux n'ont qu'exceptionnellement pris en compte le comportement du parent. Une récente étude de Pise (Muratori et al., 2011) nous semble pionnière dans ce domaine. Cependant au-delà de l'addition des comportements de l'adulte d'un côté et de ceux du bébé de l'autre, la synchronie des comportements est un élément essentiel de l'interaction, de la relation, de la communication et de l'attention conjointe (Feldman, 2007). C'est pourquoi dans notre 2^e article (Saint-Georges et al., in press), nous avons tenté de modéliser l'interaction en prenant en compte cette dimension temporelle, dans le but 1) de décrire les composantes des interactions réussies : quels comportements des parents favorisent cette réussite ? 2) de distinguer les comportements d'un partenaire en réponse de ceux de ce même partenaire en initiation (même si cette coupure est quelque peu artificielle et que dans le cadre d'une boucle interactive un comportement réponse peut bien sûr être en même temps un comportement initiant une nouvelle interaction), 3) de rendre compte de l'évolution développementale de cette interaction. Une telle étude a été rendue possible par l'utilisation de méthodes computationnelles, qui nous ont permis de traiter les données en termes de synchronie, en prenant en compte la dimension temporelle dans des modélisations probabilistes d'interaction.

Au cours de ce travail nous avons retrouvé un manque d'intérêt pour autrui (manque d'orientation vers autrui, en réponse au care-giver) dès le 1^{er} semestre. Les bébés autistes tendent à rattraper leur retard dans les comportements interactifs réceptifs (regard, sourire, syntonie...) et d'intérêt pour autrui (orientation vers l'autre) au cours du 2^e semestre, mais creusent simultanément leur retard en comportement actif envers l'autre, qui augmente insuffisamment comparé à l'explosion de ce type de comportement chez le bébé normal. Puis, on assiste au 3^e semestre à une chute significative des comportements interactifs réceptifs, qui coïncide avec l'apparition des comportements actifs d'évitement repérée dans notre synthèse de la revue de littérature (avec particulièrement une diminution très nette des regards à autrui). De plus nous avons confirmé le manque de réponse du bébé par des comportements intersubjectifs, sur la globalité des 3 semestres, et plus spécifiquement sur le dernier : on voit que probablement depuis le 1^{er} semestre et de plus en plus nettement au fil du temps, l'intersubjectivité peine à se mettre en place. Nous retrouvons donc, dans cette étude développementale prenant en compte la synchronie de l'interaction, le profil particulier déjà aperçu dans notre travail précédent et nous pouvons noter que le déficit porte surtout les comportements pris en tant que réponse aux stimulations de l'adulte, alors que les comportements pris en tant qu'initiateurs d'interaction ne sont pas diminués, ce qui montre que les parents répondent, eux, normalement, à leur bébé, comme l'ont déjà montré d'autres travaux sur des enfants plus grands (Siller & Sigman, 2002; Watson, 1998).

De fait, ils semblent même, dès le 1^{er} semestre, réussir à les solliciter par plus de stimulations intensives (reg-up), puis par une prolongation des stimulations tactiles au 2^e semestre, et enfin au 3^e semestre, toucher et reg-up jouent un plus grand rôle dans les interactions réussies que chez le typique. Les interactions se font donc au prix d'un plus grand effort de la part de l'adulte. Ceci a son importance pour le dépistage de l'autisme : les parents augmentent spontanément leurs sollicitations, comme sentant que leur bébé a besoin d'être plus stimulé et les inquiétudes parentales même très précoces sont à entendre, alors qu'elles reçoivent trop souvent de simples réassurances de la part des pédiatres.

Le mamanais : données expérimentales, et hypothèses concernant le bébé autiste :

Pour expliquer le profil développemental particulier des bébés à devenir autistique (manque très précoce d'intérêt pour l'autre, décrochage secondaire des bébés autistes dans la relation après une phase d'amélioration de leurs performances), nous avons, à la suite d'auteurs comme Trevarthen et Hobson, proposé l'hypothèse qu'un trouble initial de l'intérêt pour autrui (ou intersubjectivité primaire) se répercuterait ensuite sur la possibilité de construire l'intersubjectivité secondaire, et consécutivement

le langage. La recrudescence du manque d'intérêt social et même sa mue en évitement actif découlerait alors peut-être en partie du dysfonctionnement de la communication, l'enfant étant sourd à l'autre (tant au niveau intersubjectif que verbal), ce qui limiterait les possibilités de négociation et serait inévitablement source de conflit. Ce type de dysfonctionnement interactif pourrait ainsi rendre compte aussi de l'augmentation de la prévalence de l'autisme chez les enfants avec surdité (Rosenhall, Nordin, Sandström, Ahlsén, & Gillberg, 1999).

Or si un dysfonctionnement interactif est secondairement impliqué (intriqué probablement à d'autres facteurs) dans le processus autistisant, on devrait pouvoir en saisir un reflet dans la qualité affective et émotionnelle des interactions. Pour rendre compte de la coloration affective des interactions, nous avons envisagé d'utiliser le mamanaïs. En effet, la prosodie du mamanaïs reflète probablement l'émotion des parents qui s'adressent à l'enfant. Afin de mieux connaître les caractéristiques de ce phénomène spontané situé au carrefour du langage et de la relation mère-enfant, nous avons recensé, dans notre 3^e article (Saint-Georges et al., submitted) tous les résultats des études expérimentales concernant 1) les caractéristiques de ce type de discours adressé au bébé, 2) les conditions et variations de celui-ci, 3) les effets observés sur le bébé. La compilation de tous ces travaux nous a permis de mettre en lumière que non seulement le mamanaïs est un phénomène universel qui traduit bien l'émotion du locuteur, mais aussi que c'est justement cette qualité qui suscite la préférence et les réactions affectives du bébé, qui de plus stimulent en retour le mamanaïs du caregiver, réalisant une boucle interactive positive. De plus, à un niveau cognitif, le mamanaïs s'ajuste en permanence au bébé et stimule l'acquisition du langage, l'apprentissage, et simplement l'attention du bébé. Il pourrait même jouer un rôle tout particulier dans l'attention conjointe puisque, de même qu'un regard direct adressé à l'enfant, le mamanaïs incite le bébé (de 6 mois) à suivre le regard de l'adulte vers un objet (Senju & Csibra, 2008). Le mamanaïs nous est donc apparu comme un produit de l'interaction (qui pourrait donc à ce titre témoigner d'un dysfonctionnement) et même un vecteur de l'interaction, impliqué dans les boucles interactives parents-bébé. Il pourrait donc jouer un rôle dans le développement (l'évolution) des interactions. Mais de plus il pourrait contribuer à développer l'intersubjectivité du bébé, puisqu'il joue vraisemblablement un rôle fondamental dans l'engagement relationnel, l'acquisition du langage, et aussi l'attention conjointe.

Sur la base d'observations cliniques (Laznik, 2007) et des résultats de nos travaux précédents qui montrent que 1) les bébés à devenir autistique ont les pré-compétences relationnelles même s'ils les exploitent insuffisamment, et que 2) ils peuvent être soutenus dans l'interaction par une stimulation plus intense, nous avons fait l'hypothèse que le bébé autiste, comme le bébé normal, est réceptif et réactif au mamanaïs. Cependant si le mamanaïs

témoigne de la qualité de l'interaction, il pourrait être amoindri par l'effet du manque de réactivité primaire du bébé autiste, par la difficulté à entrer en contact et communiquer avec lui, et par là-même venir aggraver les troubles relationnels du bébé autiste, réalisant une boucle interactive négative. Le mamanais maternel irait en s'amenuisant, renforçant secondairement le manque primaire de réactivité du bébé, le défaut d'attention conjointe, la difficulté du bébé à entrer dans la communication et le langage, ce qui constituerait alors un facteur précipitant de l'évolution autistique (cf figure 15).

Processus dynamiques dans l'autisme ?

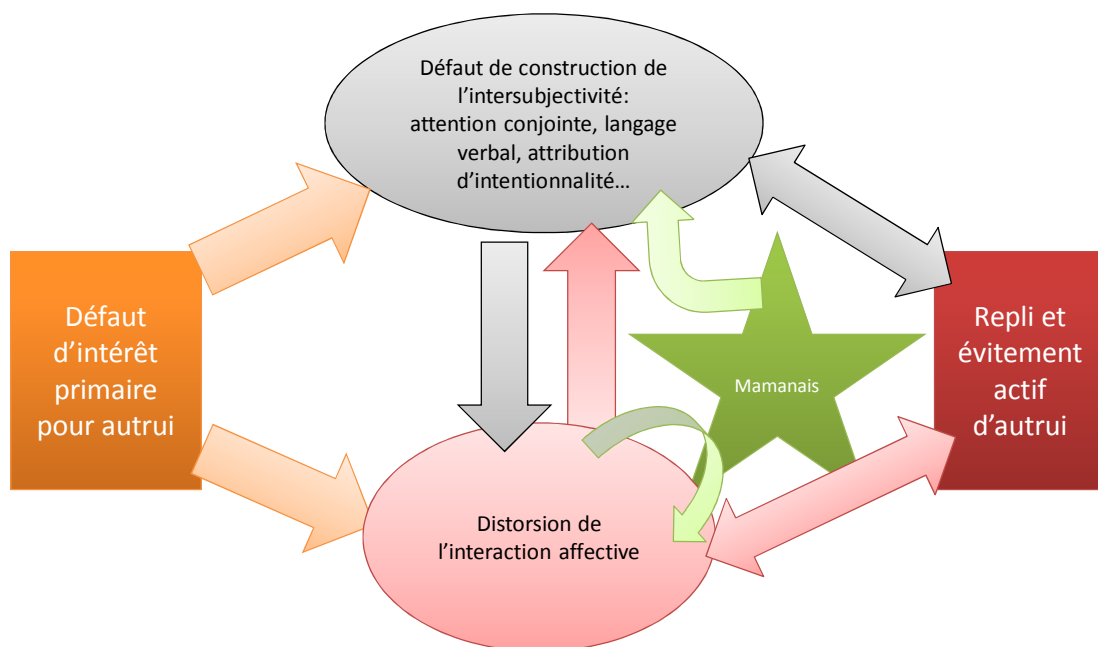


Figure 15. Tentative de modélisation des processus psychopathologiques en boucle possiblement en jeu dans l'installation du tableau autistique

Pour tester ces 2 hypothèses (réactivité du bébé autiste au mamanais et amoindrissement du mamanais au fil du temps chez les parents du bébé autiste), nous avons construit un outil décrit dans notre 4^e article (Mahdhaoui et al., 2011). Il s'agit d'un algorithme de détection automatisée du mamanais applicable à l'étude en condition naturelle des films familiaux. Les performances de ce détecteur ont été testées sur des films familiaux italiens et se sont révélées satisfaisantes, avec une précision de 82%.

L'étude du mamanais dans les films familiaux peut-elle mettre en lumière des dysfonctionnements de la triade père-mère-bébé consécutifs au manque de réactivité du bébé autiste ?

Le projet final est d'ajouter la dimension prosodique du mamanais à l'étude développementale des interactions synchrones réalisée précédemment. Mais nous avons préalablement testé notre protocole expérimental dans une étude pilote sur 2 cas uniques (un bébé au développement typique et un bébé au développement autistique) décrite dans notre 5^e article (Cassel, submitted). Celle-ci nous a permis de constater la différence des taux de mamanais et du profil évolutif entre les 2 parents et l'importance donc de distinguer les différents locuteurs, ce qui était d'ailleurs cohérent avec l'idée d'affiner la dynamique relationnelle subjective.

Nous avons tenté d'estimer l'effet du mamanais sur chacun de nos 2 bébés en établissant un indice d'efficacité du mamanais (taux de mamanais obtenant une réponse quelconque du bébé) et en le comparant à celui du non-mamanais (ou adult-directed speech: ADS). Chez le bébé autiste, l'effet du mamanais ne semble supérieur à celui de l'ADS qu'au 3^e semestre et surtout pour le père, alors qu'on observe simultanément une cassure anormale de l'efficacité des vocalisations de la mère, que ce soit en infant-directed speech (IDS) ou en ADS, avec toutefois une légère supériorité de l'IDS. Dans notre étude de groupe en cours, si l'absence de statistiques à l'heure actuelle ne nous permet pas d'interpréter les indices d'efficacité (qui semblent se dessiner en faveur d'une supériorité de l'IDS sur l'ADS, du moins pour le père), nous pouvons d'ores et déjà observer une élévation importante du mamanais dans les comportements de « stimulation intensive » (regulation-up) que nous avons trouvés significativement augmentés chez les parents des bébés autistes au 1^{er} comme au 3^e semestres. En attendant de pouvoir conclure à l'issue de notre étude de groupe, les premiers indices vont donc dans le sens d'une certaine efficacité du mamanais sur la réactivité du bébé autiste, ce qui constituait l'une de notre première hypothèse, conforme à des éléments de l'expérience clinique (Laznik, 2007).

En ce qui concerne le profil développemental de production du mamanais par les parents, il semble suivre une courbe descendante dans les 2 triades père-mère-bébé observées et la quantité de mamanais adressé par la mère à son bébé autiste semble finalement préservée, ce qui semble contraire à notre deuxième hypothèse. Les premiers résultats de l'étude de groupe en cours vont également dans ce sens, puisqu'au 3^e semestre, le taux de mamanais des pères, d'une part, et des mères, d'autre part, ne semble pas différer d'un groupe à l'autre, avant même d'effectuer des statistiques.

Cependant, si la quantité de mamanais maternel est bien épargnée, peut-être faut-il regarder du côté de la qualité de ce mamanais maternel. En effet, nous avons observé qu'au moment de sa « fermeture » au 3^e semestre, le bébé autiste de notre étude cas unique restait réactif au mamanais de son père mais qu'il répondait de moins en moins à celui de sa mère (et l'étude de

groupe en cours montre les mêmes tendances). Si les résultats finaux de l'étude de groupe confirmaient cette donnée observée dans l'étude préliminaire cas unique, cela pourrait avoir des implications théoriques sur une modélisation des processus interactifs dans la triade, au cours du développement autistique.

En effet, Kaplan a montré que le mamanaïs maternel peut perdre de son pouvoir sur le bébé dans certaines circonstances affectives concernant la mère, comme la dépression non traitée (Kaplan et al., 1999), alors que le bébé reste sensible à l'IDS d'une autre mère (Kaplan et al., 2002), ou du père (Kaplan et al., 2004).

Kaplan (Kaplan et al., 2009) a aussi montré qu'au-delà de la dépression et plus que la dépression, c'est la sensibilité maternelle (promptitude à détecter et répondre à des signaux et changements légers, établie au cours d'une brève interaction par le jeu à partir de l'emotional availability scale) qui joue le rôle le plus important pour prédire l'apprentissage avec une séquence d'IDS maternel. Donc des aspects de l'interaction mère-enfant actuelle prédisent la réponse du bébé à l'IDS maternel. Cette réponse du bébé est donc expérience-dépendante, et plus précisément dépend de la contingence des réponses de la mère. Il est peut-être intéressant de rapprocher ces résultats de ceux de Goldstein, qui montrait la nécessité de réponses *contingentes* de la part de la mère pour influencer les caractéristiques phonétiques du babillage (dans le sens d'une plus grande maturité et complexité), montrant que le lien social, et particulièrement sa contingence, sous-tendent l'acquisition du langage (Goldstein et al., 2003). Dans ces 2 expériences différentes, l'attention et l'apprentissage de ces bébés normaux semblent guidés par la disponibilité psychique et la réactivité de la mère, ou troublés par son indisponibilité, alors que leurs capacités sont intactes.

Dans le cas du bébé autiste, y aurait-il au 3^e semestre un phénomène de cet ordre, issu de boucles interactives négatives incluant plus particulièrement la mère et résultant en un manque d'effet du mamanaïs spécifiquement maternel sur le bébé, déjà peu réactif à la base ? Cela irait dans le sens de notre hypothèse d'un dysfonctionnement qualitatif de la relation secondaire aux troubles du bébé. Il s'agirait alors d'un cercle vicieux interactif impliquant la mère et le bébé dans une spirale négative. Le père, plus à distance dans la relation, serait épargné par les répercussions négatives du comportement du bébé.

Quoiqu'il en soit, Siller a montré que même si les compétences parentales ne sont pas en cause dans le fait d'avoir ou pas un enfant autiste, les enfants autistes progressent mieux en attention conjointe et en acquisition du langage quand leurs parents sont mieux synchronisés avec leurs activités et centres d'attention (Siller & Sigman, 2002).

Par ailleurs, si les statistiques sur l'étude de groupe venaient confirmer l'efficacité du mamanais du père observée dans l'étude cas unique (même si le père intervient peu, et rarement en mamanais), cela serait important pour des considérations théoriques et surtout thérapeutiques. En effet, si au 3^e semestre, un tiers moins impliqué dans la relation (comme le père et a fortiori un tiers étranger), réussit mieux à susciter une réponse du bébé, à condition de s'adresser à lui en mamanais, cela pourrait avoir des répercussions thérapeutiques intéressantes.

5.2. Applications

D'abord la meilleure connaissance des signes précoces, de la dynamique développementale et de la dynamique interactive doit favoriser la mise en place de stratégies de dépistage.

Ensuite l'identification précoce des bébés à risque doit déboucher sur une prise en charge préventive ou thérapeutique. La distinction des différentes étapes de l'installation de l'autisme au cours de la vie précoce devrait aider à adapter l'intervention thérapeutique à la dynamique actuelle des troubles.

De plus, l'attention portée particulièrement à la dynamique du développement autistique et sa compréhension pourraient indiquer de nouvelles voies de traitement pour faire le chemin en sens inverse ou retravailler les étapes manquées, ou simplement offrir des bases scientifiques à des approches thérapeutiques déjà existantes. Par exemple, nous avons proposé l'hypothèse selon laquelle le manque primaire d'intérêt pour l'autre aboutit secondairement à la non-mise en place de la compréhension de l'autre et de ses signaux de communication puis à l'installation d'un dialogue de sourd avec incompréhension réciproque. La difficulté de l'adulte à interagir avec l'enfant, dont pourrait témoigner la perte d'efficacité du mamanais au 3^e semestre s'inscrirait dans cette dynamique pathologique et viendrait la renforcer. Le tout déboucherait, dans un 3^e temps, sur l'évitement actif d'une relation douloureuse ou compliquée. De cette hypothèse, il découle par exemple la nécessité de proposer en priorité des outils visant à mettre en place la possibilité d'une communication (utilisation d'images, support visuel, travail sur l'attention conjointe, sur l'imitation...) afin de diminuer la réticence défensive à entrer en communication, sinon d'avance vouée à l'échec, avec l'autre. Citons des méthodes connues comme le PECS (Howlin, Gordon, Pasco, Wade, & Charman, 2007) ou des tentatives originales d'approche thérapeutique centrée sur l'imitation (Nadel, 2011), ou ciblant (notamment) l'attention conjointe, la synchronie et la sensibilité maternelle comme le PACT (Green et al., 2010).

Parmi les approches qui pourraient permettre de retravailler les étapes manquées de la co-construction de l'interaction et de l'intersubjectivité, citons également le modèle de Denver, élaboré en 1981 par Sally Rogers. Ce programme, d'orientation développementale, met l'accent sur le jeu, les relations interpersonnelles, les procédures de développement du langage pragmatique. Cette approche développementale postule que les anomalies autistiques sont plastiques, et souvent secondaires, en cascade, à un problème initial (socio-communicatif) moins « envahissant ». L'idée est de s'attaquer très précocément aux processus socio-communicatifs pour enrayer les effets autistiques en cascade, en favorisant l'établissement de relations affectives avec l'enfant et l'échange émotionnel à travers le jeu. La méthode Early Start Denver Model qui en est dérivée et y associe des techniques comportementales, est une méthode intensive, en « un pour un », impliquant les parents, et ciblant tous les aspects du développement de l'enfant. Une étude portant sur 48 enfants autistes âgés de 18 à 30 mois, pendant 5 ans, a produit des résultats encourageants : les enfants ayant été suivis selon la nouvelle méthode de traitement ont progressé de façon bien plus nette que ceux ayant suivi un programme d'accompagnement « classique », tant au niveau du quotient intellectuel, que dans leurs capacités d'écoute et de compréhension (Dawson et al., 2010).

La meilleure connaissance des processus dynamiques et réciproques, notamment des ajustements ou dysfonctionnements dans l'interaction mère-enfant avec un bébé autiste devrait aussi aider à proposer des stratégies préventives permettant à la mère elle-même d'être encouragée et soutenue pour faire un travail thérapeutique avec son enfant, par exemple en l'incitant à augmenter ses stimulations intensives multimodales et sa communication prosodique, particulièrement en réponse aux intérêts et bribes de communication du bébé, ou encore à trouver des relais qui limitent l'usure. Par exemple la « méthode des 3 i », dérivée en France de la méthode Son-Rise (Williams & Wishart, 2003) propose l'intervention de multiples personnes chacune en interaction individuelle sur un temps limité, ce qui pourrait limiter le phénomène d'usure face aux échecs répétés des tentatives de communication avec un enfant qui manque de réactivité, voire qui évite l'interaction. D'autre part, le repérage de l'efficacité du mamanaï, chez un tiers comme le père, pour maintenir la communication dans une période de fermeture, pourrait ouvrir des perspectives thérapeutiques pour la prise en charge, (par exemple une stimulation du mamanaï des soignants, éventuellement par des méthodes de biofeedback utilisant l'algorithme que nous avons construit). De plus, la démonstration de l'efficacité persistante du mamanaï pour engager le bébé dans la relation même lorsqu'il est en train de se refermer sur un mode autistique (au 3^e semestre) pourrait offrir des arguments en faveur de la musicothérapie dans la prise en charge des enfants autistes (Trevorthen, 2000), dont quelques études ont déjà montré la pertinence (Finnigan & Starr, 2010; Kim, Wigram, & Gold, 2009).

5.3. Limites et perspectives

En premier lieu, nous devons poursuivre l'étude des interactions réciproques et émotionnelles et étudier statistiquement l'ensemble des résultats concernant le mamanaï. D'autres limites de ce travail ouvrent autant de perspectives d'approfondissement.

Etude des interactions care-giver – bébé.

Des précisions seraient sans doute utiles, tels que le calcul d'indices d'efficacité sur les comportements parentaux autres que le mamanaï: par exemple touching, reg-up (puisque nous avons observé des modifications significatives de ces comportements chez les parents d'autiste). En particulier, il serait utile de prendre en compte la possible co-occurrence de ces comportements avec le mamanaï: en d'autres termes, l'efficacité du mamanaï peut-elle être isolée au sein de la communication multimodale de la mère, ou bien le mamanaï s'intègre-t-il dans un ensemble de comportements simultanés rassemblés dans des moments de communication affective plus intenses? Dans ce cas, le calcul de l'efficacité du mamanaï devrait prendre en compte les autres comportements parentaux pour être exact.

Notre étude de cas nous a amené à poser la question d'une baisse de l'efficacité apparente du mamanaï maternel au 3^e semestre chez le bébé autiste. Dans cette hypothèse, soit il y aurait une effective baisse de l'efficacité de la qualité acoustique (affective) du mamanaï, soit c'est la perturbation de la qualité relationnelle mère-enfant qui émuuserait l'efficacité du mamanaï maternel. Dans le premier cas, comme dans les travaux de Kaplan avec des mères déprimées (Kaplan et al., 1999), on devrait observer expérimentalement une baisse de l'efficacité de ces segments d'IDS pour susciter des réactions chez d'autres bébés. Une autre option intéressante serait de prendre l'ensemble des vocalisations ayant déclenché une réponse du bébé et de les comparer à l'ensemble des vocalisations n'ayant pas suscité de réponse du bébé: y aurait-il des caractéristiques acoustiques qui les distingueraient?

Etude des interactions bébé-care-giver :

Inversement, le calcul de l'indice d'efficacité du bébé pour déclencher des comportements de ses parents serait intéressant. Même si nous avons vu que les parents des autistes ne semblaient pas se distinguer des parents de bébé normaux en termes de réponse au bébé, le calcul de l'indice d'efficacité pourrait préciser ce point. En effet, nous avons par exemple constaté une diminution significative des réponses parentales aux comportements d'intersubjectivité du bébé et l'avons mise sur le compte de la baisse des

comportements d'intersubjectivité du bébé (postulant que les parents ne peuvent pas répondre à un comportement qui ne se présente pas) toutefois seul l'indice d'efficacité devrait nous permettre de l'affirmer.

L'importance des comportements du bébé pour susciter en particulier des réponses prosodiques (mamanais) du care-giver est une question que nous avons posée d'emblée dans notre recherche. Cette question a été abordée sur le long terme dans le cadre de l'étude longitudinale du taux de mamanais comparant parents de bébés normaux et parents de bébés autistes. Mais cette question doit aussi être abordée dans le cadre de l'interaction immédiate : les comportements du bébé normal influencent-ils comme prévu la survenue du mamanais chez les parents ? Et qu'en est-il chez les parents d'un bébé autiste ? Pour cela, l'indice d'efficacité de divers comportements du bébé pour obtenir du mamanais de ses parents doit être calculé.

Du fait du questionnement auquel nous sommes arrivés concernant l'importance de la contingence dans l'efficacité de l'interaction et plus spécialement du mamanais, l'étude des réponses interactives sur des fenêtres temporelles plus courtes serait aussi à envisager. En effet, les réponses parentales au bébé surviennent généralement dans un délai inférieur à une seconde, qui est le timing adéquat pour que le bébé établisse une relation de contingence entre son comportement et la réponse parentale (Warlaumont, 2009). De cette relation de contingence doit naître la conception de son agentivité dans la relation à autrui. En effet, c'est probablement à partir de la réponse parentale affective (telle que le mamanais) à ses comportements, que le bébé se sent exister comme sujet agissant émotionnellement sur l'autre et rentre dans les prémisses de l'intersubjectivité. De plus, la contingence des réponses maternelles permet aussi d'exercer la fonction de « mirroring », de résonance des affects du bébé dans la subjectivité maternelle : accordage (Stern, 1985)). Les travaux sur l'imitation montrent bien l'importance de la reconnaissance d'être imité par l'autre (Nadel, 2011) dans la possibilité de se reconnaître un sujet comme l'autre permettant d'entrer en relation avec celui-ci. Trevarthen (Trevarthen et al., 2003/2004) a insisté sur la musicalité du dialogue de la mère et de son bébé, comprenant une rythmicité temporelle des échanges. Des travaux récents ont montré, avec des bébés un peu plus grands, des troubles du dialogue temporel en termes de manque d'initiative des bébés et de délai de la réponse des mères (Warlaumont, 2009). Par rapport à cette question de la contingence et de la synchronie dans le dialogue, il serait intéressant de rechercher aussi les réponses du bébé aux réponses contingentes du care-giver (en filtrant les « boucles » : bébé→care-giver→bébé). Par exemple selon la modalité notamment vocale de l'interaction, ce filtre nous permettrait d'avoir un aperçu du « dialogue » bébé-care-giver, probablement crucial dans la construction de l'intersubjectivité.

Enfin notre étude du mamanaï fait entrevoir qu'il pourrait y avoir des différences importantes entre les interactions des 2 parents, ce qui suggère que notre étude précédente sur les interactions synchrones, dans laquelle nous n'avons pas différencié les care-givers, pourrait s'enrichir de cette distinction. Par ailleurs, nous avons souligné plus haut que l'étude des interactions dynamiques sur des cas uniques pourrait s'avérer fructueuse, même si évidemment pas généralisable, pour identifier des dynamiques qui sont peut-être différentes d'une triade à l'autre et dont le moyennage statistique pourrait gommer les points saillants.

Conclusion

Ce que nous avons entrepris :

Au cours de ce travail de thèse, nous avons tenté de décrire ou du moins d'ouvrir une fenêtre sur le fonctionnement interactif du bébé qui deviendra autiste ultérieurement. Nous sommes partis de l'étude des films familiaux, dont nous avons montré que les résultats tendent à être validés par les études prospectives, plus fiables apparemment mais plus lourdes à mettre en place. Dans la perspective de décrire non plus des symptômes isolés mais une dynamique du fonctionnement interactif, nous avons d'abord pris en compte la dimension évolutive développementale, pour mettre en évidence le parcours atypique et pathologique de ces bébés, qu'il nous a paru nécessaire de considérer avant toute théorisation psychopathologique. De plus, l'interaction ne saurait se passer d'un autre, qu'il s'agit de prendre en compte dans ses comportements d'ajustement. Au sein d'une dyade, l'interaction est plus que la somme des comportements des 2 membres de la dyade puisque chacun influe sur le comportement de l'autre dans une construction commune et perpétuellement évolutive : les comportements du bébé autiste influent sur ceux de ses parents qui vont à leur tour agir sur ceux du bébé (spirale interactive). Dans ces interactions et rétroactions dynamiques, la prise en compte de l'évolution au fil du temps est importante (dimension développementale déjà évoquée), mais aussi la prise en compte de la dimension temporelle immédiate entre les 2 partenaires : la synchronie. En effet, comme l'attestent de nombreux travaux, celle-ci est une composante indispensable d'une interaction vraie, en particulier dans une interaction préverbale, telle qu'elle existe entre une mère et son bébé. Dans le cas du bébé autiste, il n'y a pas forcément coïncidence entre un comportement potentiellement interactif et une vraie interaction réussie, dans un « dialogue » (qui suppose adaptation et synchronie) avec l'autre. Nous avons utilisé des méthodes computationnelles pour tenter de prendre en compte et étudier cette synchronie. Enfin l'interaction véritable suppose l'engagement affectif et émotionnel, que nous avons tenté d'approcher par l'étude du *mamanais* dans les vocalisations adressées au bébé. En effet nous avons montré que le *mamanais* stimule l'interaction, dans une boucle interactive qui repose finalement sur l'émotion transmise et partagée, et qui débouche de plus sur la possibilité d'une communication ajustée aux besoins cognitifs du bébé, dont le soutien de l'attention conjointe et de l'acquisition du langage. Nous avons construit un outil de détection automatisée du *mamanais* dans les films familiaux et l'avons appliqué à une étude pilote sur 2 cas uniques, en préalable à une étude statistique sur des groupes.

Ce que nous avons observé :

Lorsqu'on étudie la littérature des films familiaux sous l'angle développemental, on observe une réduction de l'intérêt pour l'autre dès le premier semestre, suivie d'une amélioration au 2^e semestre, avant un décrochage au 3^e semestre, où le bébé semble se «fermer», avec un évitement actif, une diminution importante des regards à autrui, une chute de la réponse au prénom et l'apparition de stéréotypies. En plus du manque d'intérêt pour autrui, l'intersubjectivité semble très tôt défaillante, au moins dès le 2^e semestre.

Lorsqu'on prend en compte la synchronie, on constate que les interactions des bébés autistes se font au prix d'un plus grand effort de la part des parents, qui s'adaptent, dès le premier semestre, avec plus de stimulations intensives (reg-up). Au 2^e semestre, alors que le bébé autiste se montre plus réceptif, l'élévation du comportement de reg-up cesse d'être significative pour le redevenir au 3^e semestre, au moment où le bébé autiste se referme. Du côté du bébé, on retrouve que l'orientation vers l'autre est défaillante dès les 6 premiers mois, et l'intersubjectivité l'est sur l'ensemble des 18 premiers mois.

Ces résultats montrent d'une part qu'il y a probablement des processus dynamiques dans l'attitude interactive du bébé, aboutissant au tableau final de repli, et d'autre part qu'il y a des processus dynamiques impliquant les parents au sein de la triade avec un bébé autiste. L'enjeu est alors de mieux identifier ces processus dynamiques à l'œuvre chez le bébé, en prenant en compte la dynamique des comportements du partenaire interactif, également dans ses aspects qualitatifs et émotionnels.

Nous avons identifié le mamanaïs comme un témoin de l'affect des parents, aussi comme un témoin de la qualité de l'interaction dans sa globalité, également comme un stimulateur de l'engagement relationnel du bébé, et enfin comme un facteur de développement cognitif du bébé incluant : soutien du partage d'émotion, de l'attention conjointe, de l'acquisition du langage, et finalement facilitateur de l'accès à l'intersubjectivité.

Nous avons donc conçu le projet d'étudier l'effet du mamanaïs sur le bébé autiste et l'effet de l'autisme du bébé sur le mamanaïs des parents. Dans cette intention, nous avons développé un algorithme détectant automatiquement le mamanaïs dans les films familiaux.

L'étude des vocalisations parentales à l'intérieur des séquences de reg-up (dont nous avons montré qu'elles soutiennent l'interaction des bébés autistes) révèle une élévation du taux de mamanaïs, ce qui est en faveur du rôle positif du mamanaïs pour soutenir les interactions du bébé autiste. Concernant les effets sur les parents des difficultés d'interaction avec leur

enfant, les résultats de l'étude exploratoire et des premiers éléments de l'étude de groupe montrent que, contrairement à notre hypothèse, la quantité de mamanaïs maternel ne faiblit pas chez la mère du bébé autiste. Cependant ces mêmes résultats pourraient suggérer que l'efficacité du mamanaïs maternel (donc potentiellement sa qualité) chuterait, alors même que le mamanaïs paternel resterait efficace... En d'autres termes, malgré le manque croissant d'engagement et de réponse du bébé en train de devenir autiste, la mère continue à solliciter normalement son bébé avec du mamanaïs, mais de la difficulté interactive émergerait quelque chose qui viendrait empêcher l'efficacité du mamanaïs maternel (et spécifiquement maternel, puisque celui du père resterait efficace). La possibilité de généraliser ces résultats devrait être tranchée à l'issue du traitement statistique de l'ensemble des données issues de l'étude de groupe en cours.

Ce que nous en concluons :

D'abord, l'application de méthodes automatisées à l'étude développementale et réciproque des réponses des bébés autistes nous a permis de préciser les ajustements qui ont lieu, ou pas, dans les interactions de ces bébés avec leurs parents et d'en suivre l'évolution. Les méthodes computationnelles, en permettant l'automatisation du recueil ou du traitement de données, donnent l'espoir de pouvoir considérer toute la complexité de ce qui se joue dans la relation, sans passer par des synthèses et appréciations subjectives (qui constituaient jusqu'ici le seul moyen d'appréhender la complexité du fonctionnement psychique humain). Ainsi, les méthodes computationnelles semblent ouvrir la voie à des recherches scientifiques qui permettraient de modéliser l'interaction normale ou pathologique sans réductionnisme excessif.

Ce travail nous a permis d'approcher une représentation du fonctionnement interactif du bébé autiste dans sa dimension développementale et d'en souligner les aspects dynamiques : dans le temps et à l'intérieur de la triade. Ceci nous a permis d'élaborer ou soutenir des hypothèses psychopathologiques, notamment celle de processus découlant en cascade d'un défaut primaire d'intérêt pour l'autre. Il en découlerait un défaut de construction de l'intersubjectivité et un dysfonctionnement interactif, avec une défaillance de la spirale interactive positive normale. L'ensemble concourrait finalement à un évitement actif défensif de la relation

Du côté du dépistage précoce, nous avons tenté de pointer les signes les plus pertinents du côté du bébé (en lien avec un manque d'intérêt du bébé pour autrui, et un manque d'intersubjectivité) et nous avons souligné l'importance de prêter attention aux inquiétudes et au style d'adaptation des parents vis-à-vis de leur bébé. Du point de vue de la prise en charge très précoce, il semblerait utile de pouvoir renforcer les sollicitations de l'engagement

relationnel et de l'attention conjointe du bébé. Le mamananais pourrait être un outil dans ce sens.

La poursuite de notre étude devrait nous permettre de confirmer (ou pas) que le mamananais renforce l'engagement même chez le bébé autiste, et de préciser si l'efficacité du mamananais diffère selon qu'il est produit par la mère ou le père, chez le bébé de plus d'un an. Plus généralement l'utilisation de la qualité prosodique des vocalisations dans les films familiaux ou d'autres protocoles expérimentaux, soutenue par l'automatisation du traitement des données, devrait permettre d'apporter une dimension émotionnelle intéressante à ce type de travaux.

En conclusion, nous avons apporté des bases à l'étude dynamique des interactions des bébés autistes avec leurs parents, en vue d'approcher les processus menant au tableau final, et de contribuer au dépistage et à l'amélioration de la prise en charge de ces bébés.

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