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DISSOCIATION ENTRE TRAITEMENT SPATIAL ET VISUO-PERCEPTIF DANS L'AUTISME DE HAUT NIVEAU

THÈSE PRÉSENTÉE
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«Faire une thèse» est une échappée solitaire
au milieu de compagnons de fortune (ou d'infortune).
On ne se rend pas toujours compte à quel point ils
peuvent être importants dans le travail et dans la vie,
jusqu'au jour où nos chemins se séparent.

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RÉSUMÉ

L'autisme est une variation développementale d'origine neurobiologique qu'on dit envahissante parce qu'il se manifeste dans plusieurs aires du développement. Ces atypies se manifestent dans le domaine de la communication, de la socialisation et de la vie imaginative. S'y ajoutent des comportements répétitifs et des intérêts restreints. (American Psychiatric Association, 1994)

Le tableau clinique de l'autisme varie considérablement selon l'âge, le quotient intellectuel et, s'il y a lieu, les conditions médicales associées. Faute d'un modèle neurologique validé des signes présents dans l'autisme, de nombreux travaux de recherche se sont orientés vers l'identification des particularités cognitives associés aux symptômes cliniques de l'autisme (Frith & Happé, 1994; Rumsey & Hamburger, 1988; Baron-Cohen, 1985). Plusieurs travaux ont révélé, chez des personnes autistes, un profil cognitif caractérisé par des dissociations significatives (atteintes vs fonctionnement normal ou supérieur), largement répliquées, que ce soit à l'intérieur d'un même « domaine » cognitif (Shah & Frith, 1993) ou entre des traitements de matériels distincts (Sous- tests du Wechsler: Rumsey & Hamburger (1988) ; Objets entre eux : Cipolotti, Robinson, Blair & Frith (1999); Visage vs. objets: Behrman et al. (2006)). Le but de ce travail de recherche était de caractériser les surfonctionnements spatiaux et perceptuels chez les personnes autistes et, le cas échéant, de déterminer les fonctions dont la supériorité entraîne un accroissement de la performance dans un nombre étendu de domaines (Morton & Frith, 1995). Cette thèse représente la première investigation systématique de la relation entre le traitement perceptif général et les pics d'habiletés visuo-spatiales chez les personnes autistes.

Après avoir succinctement présenté les caractères généraux de l'autisme, les principaux résultats concernant les caractéristiques cognitives de ce trouble et les modèles qui en rendent compte seront présentés. Parmi les modèles de surfonctionnement cognitif, les habiletés spatiales et perceptuelles rapportées chez les personnes autistes seront exposées. Enfin, à l'aide des cadres théoriques de la neuropsychologie cognitive, le présent travail présentera deux études de groupe avec des participants autistes de haut niveau dans lesquelles les principales dimensions cognitives évaluées seront abordées. Le premier volet sera consacré à l'étude des habiletés d'orientation spatiale des personnes autistes. Le deuxième volet se penchera sur l'évaluation des habiletés perceptuelles chez cette population. Enfin, les implications des résultats obtenus seront discutées en relation avec les modèles actuels de surfonctionnements cognitifs en autisme.

Mots-clés : autisme, surfonctionnement, perception visuelle, cognition spatiale, neuropsychologie

CHAPITRE I

CONTEXTE THÉORIQUE

1.1 L'autisme : notions de base

L'autisme, tel qu'il est décrit et caractérisé dans le DSM-IV (1994), appartient à la catégorie des troubles envahissants du développement (TED) et est caractérisé par une altération du fonctionnement dans plusieurs sphères du développement dont les capacités d'interactions sociales réciproques, les capacités de communication et la présence de comportements, d'intérêts et d'activités stéréotypés (DSM-IV, American Psychiatric Association, 2000; Volkmar et Pauls, 2003). L'autisme atteint la cognition de manière envahissante, i.e. il entraîne le déficit précoce d'un certain nombre d'opérations cognitives qui se traduit cliniquement par l'atteinte de fonctions apparemment non reliées entre elles dans les domaines sociaux, communicatifs, du jeu et de la diversité des intérêts. Ce trouble doit aussi être considéré selon une perspective développementale. En effet sa symptomatologie change avec l'âge quel que soit le niveau intellectuel. Certains symptômes disparaissent, d'autres persistent et se modifient. Ainsi, chaque porteur d'un TED peut être situé sur un continuum de sévérité/typicité où viennent se greffer des facteurs liés à l'âge chronologique, le niveau intellectuel et la présence de conditions médicales associées.

L'autisme ne peut plus être considéré comme un trouble neurodéveloppemental rare puisque sa prévalence est maintenant établie à 3.8 cas d'autisme et 11,6 cas de TED pour 1000 naissances (Baird et al. 2006). Il y aurait trois fois plus de garçons autistes que de filles (Fombonne, 2003), et le ratio garçon/fille augmente lorsque l'on considère l'ensemble des TED (jusqu'à dix garçons pour une fille; Miles & Hillman, 2000). Le niveau d'intelligence générale varie dans l'autisme; il s'étend de la déficience sévère à l'intelligence vive (Minshew, Goldstein, Muenz, & Payton, 1992; Ozonoff, Pennington, & Rogers, 1991; Rumsey, 1985; 1992; Rumsey et Hamburger, 1988; 1992). Contrairement à ce qu'on croyait auparavant, l'évaluation des capacités intellectuelles des personnes autistes a permis d'estimer à seulement

26% les cas d'autisme associés à une déficience intellectuelle (autisme de bas niveau) (Chakrabarti & Fombonne, 2001). Par opposition, les personnes autistes de quotient global supérieur à 70 sont désignées par l'appellation de l'autisme de haut niveau (AHN).

On distingue deux sortes d'autisme, l'un dit primaire ou idiopathique, dans lequel le tableau clinique n'est pas associé à une affection médicale associée. Il est attribué à une cause génétique dont le mode de transmission est inconnu. L'autre, dite fraction étiologique de l'autisme ou autisme secondaire, ne représente que 10 à 15% des cas et désigne les cas d'autisme dont le tableau clinique est associé à des maladies identifiées. De tels désordres incluent les anomalies génétiques (principalement le syndrome de l'X fragile) ou la sclérose tubéreuse, aussi bien que les autres formes d'anomalies telles que les maladies infectieuses (rubéole congénitale, encéphalopathie aiguë...) ou l'apparition de symptômes autistiques, coïncidant avec une vaccination ou une infection, suggérant le rôle possible d'une réponse inflammatoire ou immunologique dans l'autisme. Nous ne nous attarderons pas ici sur le rôle causal unique de ces incidents anatomiques ou environnementaux, étant donné que les personnes avec autisme secondaire sont écartées de la présente étude, et du fait que l'identité entre autisme primaire et secondaire est discutable.

Les arguments principaux en faveur d'une origine nature génétique de l'autisme primaire sont avant tout épidémiologiques (Rutter et al, 1999). D'abord, il existe un sexe ratio en faveur des garçons d'au moins 3 pour 1 (Fombonne, 2003), mais qui augmente considérablement lorsqu'on se limite au cas d'autisme primaire, et sans déficience intellectuelle. Ensuite, le risque d'autisme dans la fratrie d'un enfant autiste est d'environ 3 %, soit à peu près 50 fois plus que dans la population générale (Smilley, 1989). Ce risque augmente significativement lorsque l'on considère la concordance pour les jumeaux monozygotes (de 60 à 100 %) et dizygotes (près de 10%). Une proportion significative de parents d'autistes montrerait aussi une certaine atteinte des fonctions exécutives. La prévalence de plusieurs caractéristiques de la personnalité, d'anomalies langagière et de désordres psychiatriques au sein des familles d'autistes ont aussi été rapportées. Nous savons aussi que l'autisme est polygénique et qu'une dizaine de gènes pourraient être impliqués, mais l'identification des gènes responsables n'en est qu'à ses débuts (pour une revue, voir

Muhle, Trentacoste & Rapin, 2004 ou Nicolson & Szatmari, 2003). Il s'agit d'un travail considérable à cause de la multiplicité des gènes constituant le génome humain mais aussi à cause de l'hétérogénéité évidente de l'autisme. La diversité de l'autisme se reflète logiquement dans le nombre de gènes en cause et dans leur éventuelle combinaison pour créer une prédisposition. Ainsi, l'ensemble des études conduites auprès des familles et des jumeaux converge vers une origine génétique à la base d'un vaste "spectre autistique".

1.2 Caractéristiques cognitives dans l'autisme

L'étude des troubles envahissants du développement par la neuropsychologie cognitive consiste à dégager un profil des fonctions intactes et des fonctions préservées, tout en essayant de ramener l'inventaire des déficits et des surfonctionnements observés à des anomalies les plus élémentaires et les plus caractéristiques de ce groupe. Les travaux de recherche, effectués en majeure partie auprès des personnes AHN, ont permis de dégager un certain nombre de caractéristiques cognitives chez cette population, du traitement des informations les plus élémentaires aux opérations les plus complexes selon la neuropsychologie cognitive : perception, attention, mémoire, fonctions exécutives (pour une revue : Minshew, Webb & Williams, 2006). Le regroupement par niveau de traitement opposerait donc les processus perceptifs d'un côté, de l'extraction de traits jusqu'à l'identification et la nomination de configurations, aux processus non perceptifs de l'autre, regroupant les processus de manipulation consciente de plusieurs informations simultanées ou les fonctions exécutives. À l'heure actuelle, le domaine perceptif paraît regrouper les tâches pour lesquelles les autistes sont supérieurs aux non-autistes.

Au niveau empirique, plusieurs études ont révélé l'existence de capacités cognitives supérieures à celles de participants appariés en âge développemental ou en niveau d'intelligence générale chez des autistes. Ces capacités supérieures ont été démontrées notamment dans le domaine auditif et visuo-perceptif. C'est le cas, dans la modalité auditive, de la détection de modifications mélodiques (Mottron et al., 2000), de la discrimination de sons purs (Bonnel et al., 2003), mais aussi de l'indiçage phonologique. Dans la modalité visuelle, on retrouve des surfonctionnements dans la tâche de dessins avec blocs (Shah &

Frith, 1983 ; Shah & Frith, 1993 ; Jolliffe & Baron-Cohen, 1997), la détection de cibles visuelles simples (Plaisted, O'Riordan, & Baron-Cohen, 1998; 1998b; O'Riordan, 1998, Jarrold, Gilchrist, & Bender, 2005) et de figures géométriques cachées par leur inclusion dans un contexte visuel plus complexe (Joliffe & Baron-Cohen, 1997), ainsi que la reproduction de figures impossibles (Mottron, Belleville, & Ménard, 1999) (pour une revue, voir Mottron et al., 2006). On observe ces surfonctionnements comme « effet de groupe » chez une population de personnes avec autisme.

1.3 Modèles de surfonctionnements cognitifs dans l'autisme

Les travaux visant à caractériser le fonctionnement cognitif des personnes avec autisme cherchent à expliquer la présence de symptômes en apparence très différents entre eux à travers divers domaines de la cognition et du comportement (Baron-Cohen, 1985, Mottron & Burack, 2001). Il existe actuellement trois modèles cognitifs principaux qui expliquent les surfonctionnements en autisme : la faiblesse de la cohérence centrale, le modèle de généralisation réduite et le modèle de surfonctionnement perceptif.

Théorie de la faiblesse de la cohérence centrale (FCC)

Les premières études sur la perception dans l'autisme ont concerné la hiérarchisation perceptive ou construction d'une représentation perceptive. Ces recherches étudient les rapports de priorité qu'entretiennent entre eux les aspects globaux, configurationnels et locaux lors du traitement perceptif des stimuli visuels ou auditifs. Lorsqu'une forme est constituée de parties, on distingue ses aspects locaux, comme ses détails ou sa texture, ses aspects globaux, comme le contour de cette forme, et ses aspects configurationnels, que sont les propriétés qui émergent des relations entre ses parties. Pour les personnes non autistes, il existe un 'biais' pour les aspects globaux et configurationnels par rapport aux aspects locaux, c'est-à-dire une orientation spontanée ou une performance supérieure pour le traitement de ces aspects. Toutefois, les personnes autistes auraient tendance à traiter les informations et stimuli localement et auraient de la difficulté à les traiter dans leur aspect global. Une telle anomalie expliquerait par exemple les forces des personnes autistes dans des tâches où la détection d'une cible est facilitée par sa segmentation vis-à-vis du fond sur laquelle elle est posée. Ainsi, U. Frith (1989) a proposé un modèle de « Faiblesse de Cohérence Centrale» (FCC, Weak Central Coherence) pour tenter d'expliquer les surfonctionnements visuo-spatiaux dans l'autisme (Frith, 1989, Happé, 1999). Les tâches requérant d'intégrer plusieurs informations en un tout cohérent seraient, selon ce modèle, particulièrement exigeantes pour les individus autistes. Shah et Frith (1983) ont ainsi démontré la capacité supérieure des autistes (par rapport à des participants de même âge développemental), à détecter des « figures cachées ». Ils ont également démontré la supériorité de ce groupe au sous-test de dessins avec blocs de l'échelle de Weschler (Shah et Frith, 1993), une tâche dans laquelle la détection de l'identité entre des parties de la cible et des faces des blocs constitue un avantage. Dans chacun de ces paradigmes, le modèle de la FCC explique une supériorité dans une tâche « locale » par l'avantage paradoxal apporté à la réalisation de cette tâche par un déficit du traitement des aspects globaux de l'information présentée. Le même modèle, appliqué au traitement sémantique, expliquerait les difficultés documentées des autistes à extraire la signification à partir du contexte d'un texte lu ou l'incapacité à désambiguïser des mots homographes en fonction de leur contexte verbal (Happé, 1997).

Ce modèle a eu le mérite de rassembler l'ensemble des connaissances au moment où il a été proposé et de générer beaucoup d'avenues de recherches. Néanmoins, la théorie de la faiblesse de la cohérence centrale a récemment été remise en question par plusieurs résultats. Par exemple, plusieurs groupes indépendants ont montré à l'aide de stimuli hiérarchiques (e.g. grandes lettres formées de petites lettres) que les aspects globaux de l'information étaient normalement perçus, même en présence d'une supériorité du traitement local dans l'autisme (Ozonoff et al., 1994 ; Mottron, Burack, Stauder & Robaey, 1999 ; Plaisted et al, 1999 ; Rinehart et al., 2000; Wang, Mottron, Peng, Berthiaume, Dawson (2007).

1.3 Modèle de généralisation réduite et d'hyperdiscrimination

Un modèle plus récent, celui de la généralisation réduite et de l'hyperdiscrimination proposé par Plaisted et son équipe (2001), propose des mécanismes pouvant expliquer, en partie du moins, l'origine des particularités cognitives des personnes autistes. En effet, la supériorité du traitement local des personnes autistes peut provenir d'une meilleure perception de bas niveau comme tel, indépendamment de l'inclusion ou non d'un pattern élémentaire dans une configuration complexe. Plaisted (1998) a ainsi montré dans une tâche d'apprentissage perceptif que la discrimination perceptive visuelle chez des adultes autistes de haut niveau était supérieure à celle des individus typiques. Ce modèle a proposé une perception réduite des similarités chez les individus autistes, ces derniers étant portés à traiter davantage les traits uniques à chaque stimulus que les traits partagés avec les autres stimuli. Ceci aurait pour conséquence une meilleure discrimination, mais une difficulté à traiter les similitudes et donc à catégoriser l'information. Les personnes autistes auraient donc une supériorité dans le traitement des aspects différentiels des éléments composant un ensemble. Ceux-ci pourraient avoir davantage tendance à traiter les caractéristiques uniques d'un stimulus que les caractéristiques qu'il partage avec d'autres stimuli. Ces auteurs ainsi ont mis en évidence la supériorité des personnes autistes dans la tâche de recherche visuelle (Plaisted et al., 1998 ; O'Riordan & Plaisted, 2001). La tâche consiste à détecter la présence ou l'absence d'une cible définie par la co-présence de 2 caractères (e.g. X + rouge) dans un champ de distracteurs partageant avec la cible une dimension (e.g. T + rouge). La manipulation du niveau de similitude entre cibles et distracteurs n'a affecté que le groupe de comparaison. Ceci suggère que la performance supérieure du groupe clinique dans cette tâche est expliquée par une meilleure discrimination. Par ailleurs, cette même équipe a montré que les personnes avec autisme sont supérieures à un groupe de comparaison pour discriminer des figures qui diffèrent par la position de points, et ceci aux diverses étapes de l'apprentissage (Plaisted et al, 1998b). Un des mécanismes avancés par Plaisted pour expliquer la perception réduite des similarités concerne une inhibition latérale excessive dans les réseaux d'activation neuronaux chez les personnes autistes (d'abord suggérée par Gustafsson, 1997). Plus grande est la région où les collatérales sont excitatrices, plus le réseau sera enclin à la généralisation. Au contraire, plus cette région est petite, plus le réseau sera en mesure de discriminer. On peut donc penser qu'une hausse de l'inhibition latérale (i.e. des régions d'excitation latérale restreintes) aura pour conséquence une hausse des capacités de discrimination.

Le modèle de surfonctionnement perceptif

On peut par ailleurs faire l'hypothèse d'un surfonctionnement, non seulement de la discrimination, mais de l'ensemble des processus perceptifs de bas niveau dans l'autisme. En effet, le caractère très élémentaire des tâches perceptives visuelles dans lesquelles des performances des personnes autistes sont supérieures et l'absence de déficit dans la perception des aspects globaux de stimuli visuels hiérarchiques ont conduit Mottron & Burack (2001, 2006) au modèle de surfonctionnement perceptif (Enhanced Perceptual Functioning; EPF). Ce modèle propose que le traitement perceptif de bas niveau, depuis le traitement des dimensions psychophysiques (ex : hauteur tonale) jusqu'à la discrimination (e.g. : la capacité de détecter des différences entre deux dimensions presque identiques), la vitesse d'encodage, la trace mnésique et l'appariement perceptif entre des éléments simples (lettres, sons isolés, figures géométriques simples) sont intrinsèquement meilleurs dans l'autisme (Mottron & Burack, 2001, 2006). Selon ce modèle, il existerait dans l'autisme un biais en faveur du traitement de bas niveau (i.e. traitement perceptif). Les premiers résultats d'imagerie fonctionnelle obtenus lors de tâches perceptives de stimuli non sociaux dans l'autisme montrent d'ailleurs que certaines de ces tâches sont associées à une surface d'activation cérébrale plus importante chez les personnes autistes que dans le groupe de comparaison. Cette activation supérieure concerne les aires visuelles primaires occipitales et déborde sur les aires occipito-temporales durant une tâche de recherche de figure cachée (Ring et al 1999).

1.4 Objectifs généraux des deux études

Les personnes autistes sont considérées porteuses d'habiletés visuo-spatiales, allant de leurs très bonnes performances dans la réalisation de dessins avec blocs, aux casse-tête ou des dessins en trois dimensions jusqu'à leurs bonnes capacités en orientation spatiale. Le terme visuo-spatial rassemble donc des tâches cognitivement hétérogènes, mais que les personnes autistes paraissent réussir de manière supérieure à la moyenne. L'objectif des études réalisées dans cette présente thèse est de décomposer les deux fonctions majeures sous jacentes à ces performances pour déterminer si c'est dans le composant perceptif et ou dans le composant spatial que les personnes autistes sont effectivement supérieures. Au niveau fondamental, il importe de déterminer le rôle respectif de ces deux composants (lorsqu'ils sont présents dans une même tâche) dans le succès à cette tâche. Ainsi, dans la tâche d'orientation spatiale mesurée à l'aide de la performance aux labyrinthes, la perception visuelle entre en ligne de compte dans la capacité de détecter au niveau perceptif l'homologie entre une configuration représentée sur une carte et cette même configuration sur le terrain. Une supériorité dans cet aspect seulement de la performance aux labyrinthes nous indiquerait donc que seul le composant perceptif est supérieur dans l'autisme et non l'orientation spatiale à proprement parler.

La deuxième étude a eu pour objectif d'expliquer de façon plus fine les mécanismes sous-jacents responsables de l'hyperfonctionnement à la tâche de dessins avec blocs. Cette étude doit être considérée comme mesurant à la fois les capacités perceptives visuelles de bas niveau de façon globale et, à un niveau d'investigation supérieur, le rôle de plusieurs sous-composants perceptifs visuels dans la réussite à cette tâche (discrimination visuelle, durée de la trace visuelle, recherche visuelle). Toutefois, comme l'étude sur les processus visuo-perceptifs nécessite de sélectionner des sujets autistes ayant des performances exceptionnelles à la tâche de dessins avec blocs, il n'a pas été possible d'utiliser la même population dans les deux études. La synthèse entre les deux études se fera donc entre deux groupes comparables en âge, QI et sexe mais ne peut se faire, comme il aurait été idéal, en utilisant la performance à une tâche comme co-variable de l'analyse des résultats de l'autre tâche.

La présente thèse a donc pour objectif d'explorer les possibles dissociations entre le traitement spatial et visuo-perceptif dans l'autisme. Les expérimentations présentées se divisent donc en deux volets.

Étude 1 : Les habiletés spatiales en autisme

La présente étude représente la première évaluation systématique des habiletés spatiales propres à l'autisme. Plus précisément, elle consiste à déterminer si les individus atteints d'autisme ont une habileté supérieure dans l'apprentissage spatial d'un environnement exploré ou d'une carte. Il est en effet bien connu des cliniciens que les personnes autistes, quel que soit leur niveau d'intelligence, présentent des aptitudes remarquables dans certaines tâches de nature spatiale. Plus particulièrement, elles ont des habiletés particulières à s'orienter facilement dans un nouvel environnement, à détecter des modifications de trajectoires et à mémoriser des plans. Malgré les nombreux cas documentés du syndrome savant avec capacité spéciale de mémoire de trajet et les observations cliniques qui montrent un intérêt particulier pour les cartes géographiques, la cognition spatiale a très peu été étudiée dans l'autisme. En effet, il est fréquemment observé que les autistes mémorisent des adresses postales, des numéros de routes, des itinéraires de trains ou d'autobus. Les informations de nature spatiale semblent représenter un type d'informations privilégiées par les autistes. Néanmoins, aucune investigation empirique n'est venue étayer cette impression clinique.

Une habileté spatiale supérieure chez les individus autistes peut également être prévue à partir d'une mémoire de reconnaissance supérieure pour les points de repères topographiques tels que les édifices, les paysages ou les décors extérieurs (Blair et al., 2002, Cipolotti et al.1999). De plus, des rapports anecdotiques d'intérêt restreint pour les cartes géographiques et les trajets d'autobus, ainsi que l'habileté à détecter des changements de position dans l'environnement (Wing, 1976) suggèrent que les habiletés spatiales sont accrues chez les personnes autistes. Or les études empiriques ont surtout montré jusqu'ici des capacités perceptives visuelles (discrimination, détection) mais, en dehors de la notion clinique que l'orientation spatiale est supérieure, il n'y a aucun argument empirique dans le sens d'une supériorité spécifique au niveau des processus purement cognitivo-spatiaux.

Étude 2 : La supériorité visuo-spatiale dans l'autisme : tâche de dessins avec blocs

La deuxième étude a pour but d'étudier les mécanismes responsables de la supériorité des personnes autistes au sous-test visuo-spatial « dessins avec blocs » du test d'intelligence de Weschler (WAIS, WISC : Wechsler, 1981, 1994). La performance des personnes autistes au test de dessins avec blocs est, nous le savons, souvent supérieure à celle des individus typiques (Shah & Frith, 1983 ; Shah & Frith, 1993 ; Happé, 1994, Jolliffe & Baron-Cohen, 1997). Les expériences de cette étude sont donc construites de façon à évaluer indépendamment les différentes étapes de traitement nécessaires à la réalisation de cette tâche (notamment la vitesse d'encodage, discrimination, mémoire des figures, recherche visuelle des blocs, vitesse psychomotrice). Ceci permettra de mettre en concurrence les modèles cognitifs explicatifs des surfonctionnements perceptifs en autisme en manipulant les dimensions auxquelles chacun d'entre eux attribue la performance des personnes autistes.

CHAPITRE II

PREMIÈRE ÉTUDE

Référence :

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DO HIGH FUNCTIONING PERSONS WITH AUTISM PRESENT SUPERIOR SPATIAL ABILITIES?

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2.1 Abstract

This series of experiments was aimed at assessing spatial abilities in high-functioning individuals with autism (HFA), using a human-size labyrinth. In the context of recent findings that the performance of individuals with HFA was superior to typically developing individuals in several non-social cognitive operations, it was expected that the HFA group would outperform a typically developing comparison group matched on full-scale IQ. Results showed that individuals with autism performed all spatial tasks at a level at least equivalent to the typically developing comparison group. No differences between groups were found in route and survey tasks. Superior performance for individuals with HFA was found in tasks involving maps, in the form of superior accuracy in graphic cued recall of a path, and shorter learning times in a map learning task. We propose that a superior ability to detect [57], match [73] and reproduce [50] simple visual elements yields superior performance in tasks relying on the detection and graphic reproduction of the visual elements composing a map. Enhanced discrimination, detection, and memory for visually simple patterns in autism may account for the superior performance of persons with autism on visuo-spatial tasks that heavily involve pattern recognition, either in the form of recognizing and memorizing landmarks or in detecting the similarity between map and landscape features. At a neuro-anatomical level, these findings suggest an intact dorso-lateral pathway, and enhanced performance in non social tasks relying on the infero-temporal pathway.

Key words : Autism; Cognitive map; Spatial orientation; visual-spatial; "What" pathway, "Where" pathway; Primary visual cortex.

INTRODUCTION

Autism is a neurodevelopemental disability characterized by deficits in several domains, while, in other domains, affected individuals exhibit performance that exceeds that of typically developing individuals. This enhanced performance characterizes individuals with autism as a group, and should therefore be distinguished from the outstanding performances exhibited by "savant" individuals with autism, which are found only in a restricted subgroup of individuals with autism [44].

Superior performance has been demonstrated by individuals with autism in pitch processing and memory [10,25,51,52], pattern discrimination [67], the block-design subtest of the WAIS [73,83], the graphic reproduction of impossible figures [50] and detecting embedded figures [30,72]. An enlarged surface of activation in the occipital primary visual areas and an enhanced activation in the ventral occipito-temporal regions during the embedded figures task was found in individuals with autism in a study using fMRI [68]. In addition, an atypical activation of the primary visual cortex during face perception [65,71] and significantly more dorsal electrophysiological response during visual selective attention task [28] have also been observed. These findings suggest that autistic individuals use different neural structures in the early processing of visuo-spatial stimuli.

The current study represents the first systematic assessment of spatial abilities in individuals with autism. More precisely, it aims to establish if individuals with autism possess a superior ability to learn the spatial layout of the environment built from an explored environment or from a map. Superior spatial ability in high functioning individuals with autism (HFA) may be expected on the basis of empirical evidence for preserved or superior visual spatial abilities [46,59 ,69,36] and from superior recognition memory of topographical landmarks such as buildings, landscapes, and outdoor scenes [9,13]. In addition, anecdotal reports of restricted interest in maps and bus routes, as well as the ability to detect minimal positional changes in the environment [87] suggest that visuo-spatial abilities are enhanced among persons with autism. The visuo-spatial tasks in which persons with autism present enhanced abilities (e.g. block design) consist typically of reproducing a 2 or 3-D model by manipulation of its components and require a high degree of spatio-constructive ability. However, this superiority should not be manifested in those spatial tasks drawing heavily on executive functions, because operations that require conscious manipulation of information, such as planning or switching from one mental set to another, are impaired in autism [4].

Spatial ability can be decomposed into multiple interrelated functions that will be presented from the more complex to the more elementary. Only the spatio-cognitive aspect of spatial navigation tasks, cognitive mapping, will be investigated in the current study. Cognitive mapping is the process by which an individual acquires, codes, stores, recalls, and decodes information about the relative locations and attributes of the spatial environment [15]. A cognitive map may be grouped under two subheadings: survey map and route map [e.g. 6,19,27,80]. These two types of maps differ in the sources from which they are primarily acquired, the aspects of the environment that they represent, and the tasks in which they are most useful. A survey map is characterized by the knowledge of the global spatial layout from an external perspective, such as a standard road map. This knowledge reflects the individual's ability to generalize beyond learned routes and to locate the position of objects within a general and fixed frame of reference [21,27]. One easy way to obtain survey knowledge is to look at a plan that provides an overview of a space otherwise too large to be seen in a glance. Frequent travels on a particular route can also lead to survey knowledge [76,81]. A route map refers to the knowledge of the spatial layout from the ground level observer's perspective. It refers to the knowledge of sequential locations, or sequence of actions, required to follow a particular route. It includes an explicit representation of decision points along the route where turns occur , as well as a representation of the decisions to be taken at each of these points. This knowledge is acquired by navigating through the environment.

FMRI studies during spatial navigation tasks performed in virtual reality environments are informative about the neural networks involved in survey and route map tasks [74,43,29,66]. Route tasks are associated with activation of the bilateral medial temporal lobes, including parahippocampal cortex and posterior hippocampus, as well as the bilateral postcentral gyrus (BA 5, 7), the right superior (BA 7) and inferior (BA 40) parietal cortices. Survey tasks are associated with activation of the bilateral fusiform, inferior temporal Gyri (BA 37, 19), bilateral superior parietal cortex (BA 7) and left insula/claustrum (BA 13). Thus, in both route and survey processing, a common network of brain areas is recruited; the survey mapping is associated with a subset of areas also involved by route encoding, though the former operation results in a greater activation in the inferior temporal cortex, postcentral gyrus and posterior superior parietal cortex. These results do not support the hypothesis that route and survey information rely on different neural systems, but suggest a hierarchical relationship between these two spatial functions.

At a lower integration level, spatio-cognitive processes are under the dependence of visuo-perceptual activity. Neuroimaging studies demonstrate two distinct neural pathways that subserve topographical learning. The ventral, occipito-temporal (or "what") pathways, and more specifically, the inferior temporal cortex in the region of the fusiform gyrus [49] is involved in the recognition of objects. The temporal activation observed in survey knowledge may reflect greater object processing because of the map-like nature of the survey encoding [79]. Accordingly, maps can be treated as physical objects per se, in addition to providing spatial information. The dorso-lateral, occipito-parietal (or "where") pathway, and more specifically, the right inferior parietal lobule in the region of the supramarginal gyrus [49], is involved in the processing of spatial relations between objects and of spatial locations [24]. In addition, the medial temporal lobe is involved in space integration. Specifically, the parahippocampal gyrus is implicated in the encoding of object features and their locations within space [1,38,39,40].

The current research consisted of five spatial tasks. The first set of tasks was performed in a human-size labyrinth and investigated route map learning (experiment 1; route learning), route map manipulation (experiment 2; reversing a route) and survey map learning (experiment 3; pointing toward unseen location). The level of information manipulation required by these three tasks ranged from minimal (route learning) to intermediate (reversing a route) and high (reorganizing spatial information to produce a survey map). In addition, each of these tasks was performed at several levels of difficulty in order to assess how the level of difficulty interacts with the spatial cognitive functions involved. The level of difficulty –and therefore, the performance level- of the task is dependent on the storage and manipulation components of working memory [58].

The scale of represented space was manipulated in the second set of tasks in order to assess the ability to transfer spatial knowledge across different scales of space. When spatial layouts are not perceived all at once (e.g., a human-size labyrinth), the subject is confronted with a macro-scale space. Spatial information has to be experienced by integration of perceptual experiences over space and time through the use of memory and reasoning [48,75,62]. By contrast, spatial cognition at a micro-scale refers to situations where a person can perceive a spatial configuration (e.g.: a map) from a single point of view [see 41 for an overview]. It allows direct access to survey knowledge. Experiment 4 involved transforming knowledge acquired through macro-scale learning into a micro-scale representation, through memorizing a human-size path and then drawing it on a sheet of paper. Experiment 5, a route execution task, required the transfer of spatial knowledge acquired from a micro-scale space where global relationships were simultaneously perceived and learned (a map) toward a macro-scale space (human-size labyrinth).

2.2 - Methods

Participants

Two groups of adolescent and adult individuals participated in the study. The clinical group was comprised of 16 participants with autism (HFA; N=11 males) or Asperger syndrome (N=5, 4 males, 1 female) with IQ scores in the average range, randomly chosen from the database of the Specialized Clinic for diagnosis and evaluation of Pervasive Developmental Disorders of Rivières-des-Prairies Hospital (Montreal, Canada). The diagnosis of autism was made on the basis of the Autism Diagnosis Interview-Revised [ADI-R; 36], a diagnostic instrument operationalizing the DSM-IV [APA] criteria for autism. The ADI-R was administered by one of the authors (LM) who obtained a reliability score of .9 with the creators of the instrument. This diagnosis was confirmed by an explicit assessment of DSM-IV criteria through clinical observation, using the Autism Diagnosis Observation Schedule – Generic (ADOS-G, module 3 or 4) [37]. All participants scored above the cut-offs of the algorithms of the two instruments, except one participant who scored under the communication cut-off of the ADI. This participant was nevertheless included, considering his high score at the other sub-scales of the ADI and at the ADOS-G algorithm.

A pilot study using typical individuals of increasing age was conducted to establish the lowest age at which children could read the map used in the experiment. This resulted in including only participants older than 9 years of age. It should be emphasized that at the time of recruitment of the clinical participants, the experimenters were blind to individuals' ADI-R scores that assess visuospatial abilities (item 106) or to their block design scores, which assess spatio-constructive abilities. Although the clinical group under study presented the classical superiority in block design (see table 1) as compared to the typically developing group [73], this group is representative of the general population of high functioning persons with autism and does not represent a subgroup with "special abilities" in this domain. All participants attended school, were verbal, and were able to read and write. At the time of testing, none of the participants were taking medication. They all had normal or corrected-to-normal vision, tested by a Snoellen Eye Chart prior to the experiment.

The comparison group was comprised of 16 typically developing participants (TD), matched with the clinical group on gender, chronological age, education, performance IQ (WAIS or WISC) and laterality [55]. No statistically significant differences were found between the two groups on these variables. In addition, a posteriori analyses comparing verbal IQ and full scale IQ among these groups did not reveal differences among groups. The typically developing individuals and their first-degree relatives were screened for current or past neurological, developmental, or psychiatric disorder. The experiment was formally approved by a local ethics committee. All participants were given financial compensation for their participation. Table 1 shows the individual values, means and standard deviations for chronological age, PIQ, VIQ, FSIQ, level of education and block design.

TABLE 1

Apparatus

An indoor, life-sized (12 x 8 meters) labyrinth was used for the entire set of experiments. The alleys were one meter wide and bounded by white configuration panels 2 meters high. It was relatively soundproof and diffusely lit. The white, removable panels of the labyrinth enabled the experimenters to 1) control for the dimensions involved in the spatial tasks, 2) control task difficulty, 3) limit extraneous perceptual factors, which might interfere with the measure of spatial-cognitive abilities, and 4) minimize the visual cues used for the build-up of spatial knowledge in natural settings. Close to the experimental labyrinth, a reduced labyrinth (5 x 4 meters) was used for practice trials. The experimental layout has been used in previous research testing spatial orientation and wayfinding abilities of persons with visual impairments [60] and patients with Alzheimer's disease [61].

General Procedure

The nature of the experiment was explained to all participants (or to their representing parent) before signing the research consent. After informed consent was obtained, all participants were individually administered the five tasks in the same order. The instructions relevant to each particular task were presented and practiced in a small labyrinth before the experiment. The entire testing session lasted approximately 1h30 min.

Experiment 1. Route learning

This task was used to assess route mapping skills. The encoding of spatial information in a route learning task is based on the sequential memorization of the starting point, the decision points, and the destination of the route. This cognitive process is considered to be simple [82] because it does not require a reorganization of spatial information. However, it varies in difficulty according to the number of decision points (DP) of the route to be learned [26,56,63, 85,62]. Accordingly, the memory load [58], and the magnitude of spatial interference [11,12,35] are negatively affected by the number of DPs; performance increases when the number of DPs is decreased. Enhanced spatial ability in participants with autism could manifest itself in one of two ways. Participants with autism could exhibit superior performance at each level of difficulty. Alternately, the performance of the participants with autism could exhibit less influence than typically developing participants from increasing the levels of difficulty, being less affected by the increase of spatial memory load.

Stimuli

Three experimental routes of increasing level of difficulty were tested (see example fig.1). Path difficulty was manipulated by varying the total length of the path (37, 41 and 45 m), and number of turns (23, 24 and 26). Regarding the number of decision points, the intersections where the participant has to choose among two or three possible directions, a pilot experiment revealed that paths with less than 6 decision points were memorized without errors. As a result, DP = 8, 10 and 12 were used. The total number of DP with 2 and 3 choices was held constant across paths in order to control for the number of choices, which might have interfered with assessing the impact of the previous variables. Paths were constructed in a manner to avoid salient sequences that could be used as mnemonic cues during the encoding phase. Thus, the paths did not contain repetitions of a sequence of directions (e.g. right-front-left-right-front-left), identifiable gestalts (round, square), or more than two consecutive turns in the same direction. Possible interference between the target path and recently memorized spatial information was minimized by experimental routes beginning and ending at the outer border of the labyrinth.

Figure 1

Procedure

For each path, the testing was comprised of a learning phase, five successive recalls, and a pause during which the configuration panels of the labyrinth were moved. In the learning phase, participants were told that their ability to learn a route in the labyrinth would be assessed. Then, the experimenter guided individual participants along the path from the point of departure to the point of arrival at a fixed walking speed. After completion of the learning phase, participants were accompanied to the point of departure, where they had to execute the path by themselves. The experimenter followed the participants approximately five to seven feet behind. The participants were informed of their errors, within a few steps in a wrong direction, by asking them to backtrack five feet. When they approached the decision point, the examiner pointed in the appropriate direction while saying " the route goes this way". Errors and speed of the participants to reach the end of the path were recorded on-line by the observer.

Results

Route learning performance was analyzed using a Group (HFA, TD) x Condition (8, 10, 12 D.P.) analysis of variance (ANOVA), performed on errors and execution time. The ANOVA revealed a main effect of condition for both variables (errors: $F(2, 60) = 6.61$, $p < .005$; execution time: $F(2, 60) = 33.39$, $p < .00001$), but no main effect of group (errors: $F(1,30) = 0{,}20$, $p = .6553$; execution time: $F(1,30) = 0{,}74$, $p = .3956$). No Group x Condition interaction was found, indicating that increases in difficulty had a similar effects on both the clinical and comparison groups. Both groups displayed similar increases in the number of errors and took more time to complete the task as the difficulty of the path increased ($DP_8 = DP_{10} < DP_{12}$). The mean number of errors ranged from 1.0 errors (s.d.: 0.7) to 1.5 errors (s.d.: 1.0) in the HFA group and from 1.1 errors (s.d.: 0.8) to 1.6 errors (s.d.:1.31) in the TD group. Similarly, the mean execution time ranged from 39.3 sec (s.d.: 11.7) to 48.6 sec (s.d.: 15.4) in the HFA group and from 42.7 (s.d.: 8.7) to 52.8 sec (s.d.: 12.2) in the TD group.

Additional analyses compared the performance of the two groups on each trial (1 to 5) within one level of difficulty (8, 10, 12 DP), and the learning effect across trials. This last variable was examined through a group x trial ANOVA performed on decreases in errors (e.g.: Errors trial 2- Errors trial 1) and relative decreases in execution time [(T trial 2 – T trial 1) / trial 1] between two consecutive trials. The two groups did not differ on these variables.

Discussion

Individuals with HFA performed the route learning task with the same accuracy and at the same speed as the comparison group, indicating that route mapping skills are preserved, but not superior, in individuals with HFA. The variability of performance was large in both groups of participants, ranging from poor to outstanding levels of performance (HFA= 6- 41 errors, TD= 4- 41 errors). This variability, along with the absence of a group x level of difficulty interaction, suggests an identical vulnerability of spatial working memory to memory load and to interference in the two groups, while the lack of a Group x Trial interaction suggests an identical learning curve.

Experiment 2. Reversing a route

Reversing a route requires the manipulation of spatial information by updating this spatial information according to a new sequence of decisions and associated directions. As demonstrated by studies with adults [32] and children [64], reversed recall of a route is at a higher level of complexity than direct route learning. Superior spatial abilities, if revealed only at a high level of complexity, should result in the clinical group performing better than the comparison group in this task. However, inasmuch as manipulation of information is impaired in autism [4], increased manipulation of spatial information may result also result in an inferior performance in this task.

Task, stimuli and procedure

This one-trial task consisted in returning backwards from the arrival point of a path to its departure point and was accomplished at the end of the fifth trial of each route performed in experiment 1 (see Figure 1). Recording procedures were the same as in experiment 1.

Results

A two-way analysis of variance (ANOVA) Group (HFA, TD) X Condition (8, 10, 12 DP) performed on errors and execution time revealed a main effect of condition [errors: $F(2,60) = 5.84$, $p < 0.005$; execution time: $F(2,60) = 12.69$, $p < 0.0001$)], but no main effect of group. Both groups committed similar or more errors and took more time to complete the task as the difficulty of the reverse path increased. The mean number of errors ranged from 1.6 errors (s.d.: 1.4) to 2.2 errors (s.d.: 1.3) in the HFA group and from 2.3 errors (s.d.: 1.6) to 2.7 errors (s.d.: 1.2) in the TD group. Similarly, the mean execution time ranged from 45.7 sec. (s.d.: 13.9) to 52.5 sec. (s.d.: 11.6) in the HFA group and from 51.4 sec. (s.d.: 10.6) to 60.4 sec. (s.d.: 9.9) in the TD group. No group x condition interactions and no group effect were found.

Discussion

This task is a difficult one for the TD group. Accordingly, their error rate increased from 0.5 errors (fifth trial of direct learning) to 2.0 errors (reverse recall), which was almost identical to the first trial of the direct learning route (2.4 errors).

This decline in performance may be attributable to the impossibility of solving this task by merely memorizing the spatial context of each of the DPs, as reversing the route modifies the visual perspective of the DPs. In addition, manipulating memorized spatial information in order to map current (reversed) and previous (forward) routes creates a higher demand on the executive system. Whatever mechanism is involved, this spatial task does not appear to be easier for participants with autism, at least at the various levels of difficulty assessed here. Finally, in accordance with Experiment 1, performance decreased as the difficulty level of the path increased, thus suggesting that the spatial working memory of the participants with HFA is at a comparable level to the comparison group, a finding consistent with recent literature on intact spatial working memory in autism [4].

Experiment 3. Pointing toward an imperceptible direction

The pointing task assesses the survey mapping skill of individuals with HFA. In order to perform this task, individuals must combine and reorganize spatial information learned along the route, and elaborate an integrated representation of the labyrinth. Survey knowledge is typically acquired after repeated navigation in an environment. According to animal studies [84,18,42,88], this task may also rely on path integration (or "dead reckoning"). Path integration is a form of navigation in which perceived self-motion is integrated over time without the elaboration of a cognitive map. This knowledge derives from the cues generated by a point of reference (e.g.: starting point), and subsequent self-movement. There is evidence that this ability depends on the integrity of the right temporal regions [88] and the hippocampal formation [86]. As it does not make use of external cues, this path integration process leads to rapid accumulation of errors involving both the direction and distance of the goal [17]. Consequentially, it should be highly sensitive to an increase in the number of turns and of the segment lengths of the paths.

Task, stimuli and procedure

The task consisted of pointing toward the departure point of a path from the arrival point of this path. This task was performed after experiment 1 & 2. The same configuration panels (except one) used in the 12 DP path of experiment 1 & 2 were used in experiment 3 in order to benefit from the knowledge of the spatial layout acquired in the previous experiment. However, different paths were used in order to maximize the acquisition of information on this configuration. Participants were first asked to memorize the departure point of a new path. Then the participants were asked to follow the experimenter to the arrival point. The participants were told that, in contrast to experiments 1 & 2, the purpose of this experiment was not to memorize the route traveled in the labyrinth. The participants were also told they could not keep track of the target by pointing to the departure point as they walked through the path. Once at the arrival point, the participants had to point as accurately as possible toward the departure point, which was not visible from this position. Four pointing trials of increasing difficulty level (P1, P2, P3, P4) were performed. Trial difficulty was manipulated by increasing the number of turns (8, 14, 11 and 33), and length (15, 23, 17 and 55 meters) of the path taken. The point of arrival on each trial was the point of departure of the subsequent pointing task, except for the last pointing task, where the participant had to point toward the first point of departure (Fig. 2). The examiner stood behind the participant and recorded pointing accuracy.

Figure 2

Results and discussion

The mean absolute error (degrees) was compared across groups using a Mann-Whitney test. Although the participants with autism performed more poorly (mean: 26.3 degrees, s.d.: 31.6) than the comparison group (mean: 15.3 degrees, s.d.: 19.6), the difference did not reach significance. Considering that the error averaging gives an excessive weight to the participant's performance whose pointing was at random, in comparison to those whose pointing is approximate, a binary scoring (passed/failed) was used. We considered a correct answer to lie within a plus/minus 15 degree error margin from the target. A chi-square comparing the proportion of passing participants (HFA=0,516, TD=0,578) among groups did not show significant difference between the groups. This indicates that survey knowledge is acquired at an identical level in the two groups.

In order to assess the possible use of the path integration strategy, pointing performance was analyzed by a Group (HFA, TD) x Condition (P1, P2, P3, P4) ANOVA. No main effect of condition was found between P2, P3, P4, indicating that the increase in segment lengths and number of turns did not significantly decrease the performance of the two groups. Similarly, no group x condition interaction was found, indicating that this effect was similar for the clinical and the comparison group, a result which does not support the use of path integration strategy in the participants.

Experiment 4. Map drawing in cued recall and free recall

Map-drawing tasks involved the graphic recall of spatial knowledge. This task investigated the content and structure of cognitive maps, and required a scale translation from macro to micro scale. As a recall task, map-drawing tasks may be realized in a free recall or a cued recall condition. In the free recall condition, (Experiment 4a) the participant had to draw a path from memory on a blank sheet. This condition assessed the processing of spatial mental imagery when the visual input is no longer present. Performance on such a task is modulated by graphic and planning skills. In the cued recall condition (Experiment 4b), the participant was asked to draw the learned path on a reduced map of the labyrinth. Due to the support of recall cues (see Fig. 3c), this task is less dependent on graphic or planning skills. Participants with autism generally exhibit impaired performance on free recall tasks [4], but preserved performance on cued recall tasks [53]. Therefore, the clinical group should exhibit impaired performance relative to the typically developing participants in the free recall condition unless these findings do not extend to spatial information. For the same reason, they should perform at a normal or superior level in the cued recall condition.

Procedure

Learning phase

Participants were required to learn a path in the labyrinth (see Fig. 3a) and perform five successive recalls of this path, using the same procedure as in Experiment 1. The path to be learned in this experiment included a long straight segment in the middle, in order to simplify the coding of the free recall drawings. A pilot experiment determined that most of the participants should be able to memorize this path errorlessly within 4 or 5 trials.

Recall phase

After the learning phase, the participants where asked to reproduce as accurately as possible the learned path on two 8.5" x 11" sheets of paper containing a 13 by 9 dot matrix (Experiment 4a; free recall; Fig. 3b) or a reduced–scale reproduction of the labyrinth (Experiment 4b; cued recall; Fig. 3c). In both tasks, the departure point was indicated on the sheet. No time limit was imposed on participants for completion of the drawing tasks. The participants were allowed to erase in case of errors until completion of the task. The time required to complete each drawing task was recorded on-line by the experimenter.

Control task

After the recall phase, a timed copying task was performed to control for the motor drawing abilities of the participants. Participants were asked to copy a model of the target path on a blank matrix.

Figure 3a, 3b and 3c

Results

Learning task.

As the purpose of this experiment was to test the graphic production of a well known route, only participants accumulating less than one error for the fourth and the fifth trial of this task (15 HFA, 13 TD) were included in the analyses.

Experiment 4 a. free recall.

In a first analysis, five judges rated the drawings from 1 to 5 on a qualitative basis, according to their global similarity with the target path. For this purpose, the participants' drawings were reproduced on blank paper without the grid. Judges were asked to score the overall gestalt similarity without paying attention to metric properties. The reliability of the mean score was very high, with an intraclass correlation coefficient of 0.94. A t-test performed on average similarity scores did not reveal differences among groups on this measure. In a second quantitative analysis, participant's drawings were converted into a sequence of letters, coding for the direction of turns and length of segments. These sequences were read by software [20] inspired by genome sequencing techniques [23,77]. This software computes a similarity coefficient between the drawing of the participant and the target path from the minimal number of transformations (e.g., deletions) required to transform one into the other. Complete drawings (14 HFA, 12 TD) only were submitted for analysis. Two t-tests were performed, one based on direction similarity alone and the other on direction and metric similarity. Both analyses revealed an equivalent level of performance between groups. Comparison of execution time (HFA = 65.1 sec.; TD = 97.6 sec.) for graphic production of the path revealed that the clinical group was faster in this aspect of the task than the comparison group (Mann-Whitney = 39, $p < 0.05$). Qualitative examination of RT distribution shows that a speed accuracy trade-off is evident in a small number of the "fast" subgroup of individuals with autism. In order to assess possible differences in speed independently of these trade-offs, a secondary analysis was performed on a subgroup of typical participants performing well in this task. High level of performance was defined as graphic production accuracy higher than one standard deviation over average of qualitative (judge) and quantitative scores (software) (HFA=10, TD= 9). This resulted in HFA individuals not being significantly faster than typically developing participants (HFA = 64.7 sec.; TD = 91.2 sec.; Mann-Whitney: $z = 1.80$; p=0,072).

Experiment 4b. Cued recall

In this task, a wrong direction at one decision point results in multiple inaccurate positions on the grid. Therefore, binary scoring (passed/failed) was used, with drawings scored as failing as soon as there was an error at an intersection point. A Chi-Squared analysis comparing the proportion of participants passing the task between groups (HFA: 73.3%; TD: 30.8%) showed that the clinical group exhibited superior performance to the comparison group on this task (Pearson: 5.073; $p < 0.024$). However, the two groups did not differ in the graphic production time (Mann-Whitney: $z = 73$; $p = 0{,}382$).

Control task

Both groups achieved ceiling performance in this task, with identical copy times.

Discussion

The free recall task was aimed at assessing the representation of spatial knowledge when the visual input is no longer present. Individuals with HFA performed this task with the same accuracy and speed than the comparison group. Although the participants in this task were recruited among individuals who performed the learning phase without errors, 50% of the individuals of both groups scored under 2.6 out of a possible 5.0. This may be explained by a spatial knowledge being sufficient to adequately perform a route learning task, but not sufficient to perform the graphic recall, which also requires mental imagery and graphic planning.

The recall of a path in the cued condition assessed the representation of spatial knowledge in the presence of spatial cues. Individuals with autism performed this task at the same speed as the comparison group, but with superior accuracy. In the cued-recall condition, the participants had to recognize the similarity between a graphic representation of the decision points on the one hand, and the environmental features of the corresponding decision points in the labyrinth on the other hand. Therefore, superior performance in this task can first be explained by superior recognition of decision points, and their integration through mental imagery i.e., by a superior cueing effect of the elements composing the plan on retrieved information. A second interpretation of this finding can be explained by participants with autism being superior than the comparison group to manually put together local parts of a path into a coherent whole according to a mental model. In this sense, the superiority of the clinical group in assembling, disposing and ordering segments of a path would be related to a superior spatio-constructive ability. Accordingly, the clinical group presented a significant superiority over the comparison group on a spatial-constructive task, the block-design subtest of the WAIS (see Table 1).

The pattern of results found in tasks 4a and 4b is consistent with the literature for participants with autism exhibiting atypical gain in cued recall condition relatively to free recall condition [4, 53].

Experiment 5. Execution of a route learned on a map

This task was aimed at assessing the transfer of spatial knowledge acquired from a map of the labyrinth (micro-scale space) to a human-size labyrinth (macro-scale space). In this task, the source of survey knowledge is a map, where the integration of spatial features can be directly perceived. This transfer of knowledge requires a capacity to adapt the orientation of the memorized map to the orientation of the labyrinth. Accordingly, after the first turn, map and labyrinth orientation are misaligned. It was expected that participants with autism would perform this spatial task at a superior level than the typically developing group.

Procedure

Participants were told that they would have to learn a path on a reduced–scale reproduction of the labyrinth. The participants were then lead to the departure point of the real-size labyrinth corresponding to the departure point indicated on the map. The map (Fig 4) was presented to the participant with an orientation coinciding with that of the real-size labyrinth. No limitations were applied on subsequent manipulations of the map. Participants were given a maximum of two minutes to study the map, but could move on to the recall phase as soon as they were ready. The same procedure and measures as in Experiment 1 were applied for the recall phase of the path, with the exception that only one trial was performed. The time required to memorize the route during the learning phase, the number of errors and the time required to execute the path were recorded on-line by the observer.

Figure 4

Results and discussion

Comparisons of the number of errors and route execution time revealed identical performance in the two groups (Mann-Whitney). The mean number of errors was 1.4 errors (s.d.: 1.4) in the HFA group and of 0.8 errors (s.d.:1.2) in the TD group. However, the clinical group was significantly faster to the comparison group in learning the map [HFA = 57.7 sec (s.d.: 40.1); TD=79.1 sec (s.d.: 21.9); Mann-Whitney; $z=2.04$; $p=0.042$]. Qualitative examination of RT distribution showed that a subgroup of individuals with autism (9 out of the 16) learned the map faster than the fastest participant in the comparison group (Fig. 5). A speed accuracy trade-off was evident in a small number of the "fast" subgroup of individuals with autism. 4 of the 9 fastest participants with autism presented 3 or 4 errors. In order to assess possible differences in speed independently of this speed accuracy trade-off, a secondary analysis was performed only on participants with 1 or 0 errors (7 HFA, 10 TD). This resulted in HFA individuals demonstrating faster reaction times than typically developing participants (Mann-Whitney: $z = 2.34$; $p= 0.019$). These findings indicate that individuals with autism do not present any difficulty in translating spatial knowledge from micro to macro scale and using abstract mental representation of the environment to navigate efficiently through the maze. In addition, they are more efficient than the comparison group when it comes to the encoding of micro-spatial information.

Additional analysis

The number of individuals exhibiting a consistent success across tasks 4b, 5 and block design was compared in the two groups and was found to be identical. Moreover, the use of non-parametric tests, based on rank rather than raw scores, diminishes the relative weight of subjects displaying extreme scores. In addition, scatter-plots do not show the presence of heterogeneous sub-groups within the experimental group after excluding subjects that display a trade-off. This shows that individuals with HFA are superior to comparison participants as a group on these tasks.

In order to assess the contribution of the block design performance on graphic cued recall (task 4b) and map learning time (task 5), logistic regression analyses were conducted. When block design performance is entered as the first variable in the model predicting the performance at the graphic cued recall (task 4), the effect is significant [Likelihood ratio test: Chi-square(1) =9.08; p=0,003]. When the group (clinical vs. typical) variable is added to the model, the improvement is not significant [Likelihood ratio test: chi-square (1)=2.25; p=0.134]. The consistency among block design task and graphic cued recall task is an expected finding, both tasks being spatio-constructive in nature.

When block design performance is entered as the first variable in the map learning task (task 5), it explains 17% of the variance [F (1,15)=3,13; p=0,097]. When the group variable is added to the model, the explained percentage of the variance is increased to 41% and this increase is significant [F(1,14)=5,78; p=0,031]. In sum, the difference in performance on map learning time between groups remains significant after controlling for differences in performance on block design task.

2.3 General discussion

Data summary

This series of experiments was aimed at assessing spatial abilities in high-functioning participants with autism. In the context of recent findings that this group of individuals is superior to typically developing individuals on several non-social cognitive operations, it was expected that the clinical group would outperform a comparison group matched on full-scale IQ in spatial tasks. Results show that individuals with autism perform all the tasks at a level at least equivalent to a comparison group. No differences were found in route learning, reversing a route or on a pointing task. However, superior performance by participants with autism was found on tasks involving transfer of knowledge between micro and macro-scale, in the form of a superior accuracy in graphic cued recall of a path, and a shorter learning time in a map learning task.

Preserved vs. superior spatial skills

The first finding of this series of experiments is that high-functioning participants with autism possess intact spatial abilities. Experiments 1 to 3 demonstrated that route mapping, route map reversal, and survey mapping are preserved in individuals with HFA. Preserved spatial abilities were expected considering the intact abilities evident in this group in numerous non-social cognitive operations. However, the absence of superior performance in route and survey tasks comes as a surprise, in relation to the often-quoted clinical remark that individuals with autism present remarkable performance in spatial abilities. A similar prediction of superior spatial abilities is predicted by S. Baron-Cohen "extreme-male brain" hypothesis for cognitive profile in autism [5], considering the general superiority of male over female individuals [for a review, see 31].

One explanation would be that the clinical reports of persons with autism performing at a superior level in these tasks results from an implicit comparison of their performance in this domain with their substantially impaired performance in other domains such as language and social cognition. Another possibility would be that this superiority vanishes when individuals with autism reach an adult age. Accordingly, the mean age of the group under study (17 years) and their high level of intelligence, prevents the extension of these findings to younger or lower functioning individuals with autism.

The second finding is that an increase in difficulty within task, as well as in complexity level between tasks, has the same detrimental effect on the two groups under investigation. On the one hand, the increase in memory load (e.g., number of decision points) within route mapping, route map reversal, and survey mapping abilities, is associated with a similar decrease in performance in the two groups. On the other hand, the level of manipulation of spatial information required by these three tasks ranges from minimal (route learning), intermediate (reversing a route), to high (reorganizing spatial information to produce a survey map). This increase in executive loading is plausibly responsible for the increase in error rates between tasks 1, 2 and 3 evident in the two groups, although the three tasks are not directly comparable. Together, these findings indicate that the storage and the manipulation components of spatial working memory are unremarkable in individuals with autism, a result consistent with the notion of intact working memory in autism for different types of material [4].

In addition to preserved spatial skills, the current pattern of findings indicates that a certain number of tasks are realized at a superior level in high functioning persons with autism First, individuals with autism show superior accuracy levels in a cued graphic recall task that assesses spatial representation when spatial cues are available. Second, in a route execution task requiring the transfer of spatial knowledge acquired from a micro-scale space, individuals with autism exhibit a faster learning time of a map. This superior performance cannot be explained by improved route knowledge, which would have resulted in a superior performance in Experiments 1 and 2, or in survey knowledge, which would have also yield superior performance in Experiment 3.

The superior performance of participants with autism in Experiments 4 and 5 may be related to other findings of superior memory for objects, such as superior visual recognition memory in comparison with Verbal IQ-matched individuals, evident for topographical material [9]. More precisely, one explanation for the dissociation between typical performance in Experiments 1, 2 and 3 and superior performance in Experiments 4 and 5 may be the presence or absence of visual perceptual cues. Accordingly, although Experiments 1 through 3 approximate spatial abilities in ecological settings, they differ from real world conditions by a quasi absence of perceptual cues. In contrast, a map is a visually presented (Experiment 5)– or graphically constructed (Experiment 4)- object, composed of elementary visual patterns, which would explain that the clinical group shows superior performance only in the components of Experiments 4 and 5 involving the encoding and retrieval of visual (graphic) components. The superior ability evident in individuals with autism to detect [57], match [73] and reproduce [50] simple visual elements, may represent an advantage in tasks 4 and 5. This advantage would be manifested in easier on-line comparisons of the spatial configuration of decision points with segments of the internal representation of the path.

Consistent with this interpretation, it has been proposed that faster graphic reproduction of impossible geometric figures by individuals with autism, together with unremarkable reproduction of possible figures, may be explained by an ability to ignore irrelevant visual material when accomplishing a visual detection task [50]. The same explanation has recently been proposed for similar speed of detection for a letter embedded within other similar letters [54], whereas a comparison group exhibited a longer detection time for embedded than for isolated letters. This explanation is consistent with the clinical group under investigation showing a clear superiority over the comparison group in the block-design subtest of the WISC/WAIS (see table 1), a task relying on disembedding a segment of the figure to be reproduced from its global appearance, and on matching this segment with the faces of the blocks used in the construction of the figure. Although it has been suggested [7,8] that drawing tasks may be testing a different ability than assembly tasks, other investigators have found high correlations between performance on these two types of constructional tasks [3,14]. The positive correlation found between the individuals' performances on the block design and the cued graphic recall of a path clearly support this second alternative.

Neuro-anatomical implications

The integrity of route and survey knowledge in participants with autism is consistent with the findings of no structural abnormalities reported in the regions typically involved by these processes among persons with autism (up to now, no fMRI studies of route and survey knowledge in autism have been presented, 68). These findings suggest the preservation of the spatial functions served by bilateral medial temporal lobes (including hippocampus and parahippocampal gyrus, postcentral gyrus, and right posterior cingulate) and by the inferior temporal cortex, (including bilateral fusiform gyri, posterior-superior parietal cortex and left medial frontal gyrus). However, this does not preclude that typical performance may be obtained by persons with autism through different brain regions, as it cannot be discarded that non-spatial functions served by the above mentioned regions may be impaired in autism.

The current pattern of preserved vs. enhanced performance may be examined in light of the "where" vs. "what" distinction among processing systems. The spatial functions requiring the integrity of the parietal dorso-lateral regions, or "where" pathway, seem to be preserved according to the current findings. Remarkably, motion perception, a function under the dependence of the magnocellular pathway, a major component of this region, has been reliably found to be abnormal in autism [78,45,6,22], although movement integrated at the level of the primary visual cortex is preserved [6]. Therefore, although the "where" system is not impaired according to the set of experiments presented here, it is premature to make conclusions regarding the integrity of this system in autism.

Regarding the occipito-temporal pathway, or "what" system, the superiority that individuals with HFA exhibit in tasks involving maps is consistent with findings that individuals with autism show more activation in the occipital primary visual cortex and ventral occipito-temporal regions than typically developing individuals during a task of detecting an embedded figure [68]. In addition of being involved in the recognition of objects such as maps, these regions have been reported to be activated by typically-developing individuals performing a topographical representation of a mental image [32]. Accordingly, Tasks 4 and 5 require manipulating the representation of a previously perceived environment and moving mentally from one point to another, an ability that is related to a type of spatial mental imagery.

Superior visual and auditory perceptual performances of persons with autism in laboratory tasks are now evident, using multiple paradigms. An atypical involvement of perception in ecological tasks typically performed by higher order processes is therefore a prospective direction for future cognitive research in this group of individuals, that could be addressed through brain imaging and ERP research.

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TABLE 1

Characteristics of high functioning participants with autism (HFA) and typically developing (TD) participants

Group	Age Mean (SD)	PIQ Mean (SD)	VIQ Mean (SD)	FSIQ Mean (SD)	Education Mean (SD)	Block Design Mean (SD)
HFA	17.6 (6.3)	112.3 (12.9)	102.2 (21.2)	107.7 (13.1)	10.0 (3.2)	15.3 (3.3)*
Range	11-36	93-139	63-141	77-144	6-18	10-19
TD	18.9 (5.7)	107.3 (12.1)	111.1 (10.4)	110.1 (10.5)	10.9 (2.4)	12.6 (2.9)
Range	13-37	87-130	91-128	88-128	8-16	8-18

* Significant difference on this variable (p=0.019)

Figure captions

Figure 1: Example of stimuli used in the route learning task

Figure 2. Example of the pointing task.

Figure 3a. Map drawing task: stimulus

Figure 3b. Map drawing task: free recall response sheet

Figure 3c. Map drawing task : cued recall response sheet

Figure 4. Map learning task: stimulus

Figure 1: Example of stimuli used in the route learning task (8 decision points or DP)

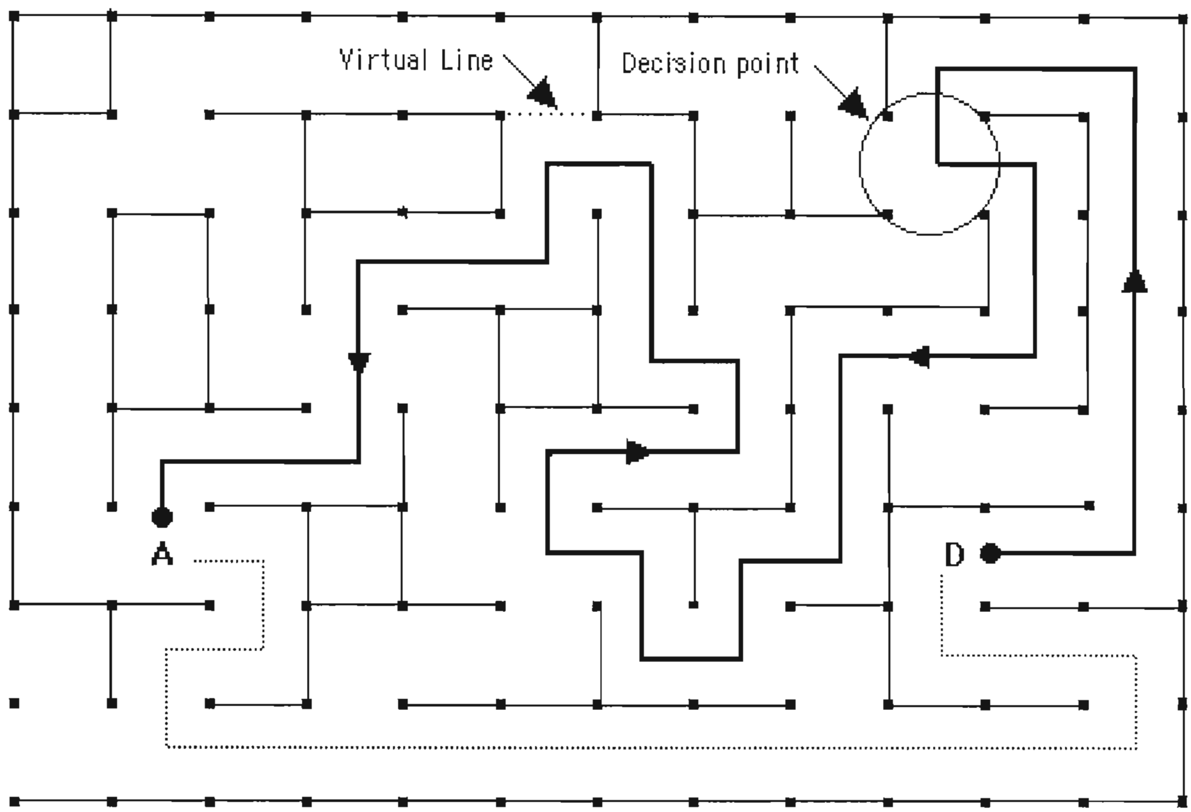


Figure 2. Pointing task. The participant has to point from 1 to D, from 2 to 1, from 3 to 1, and from 3 to D

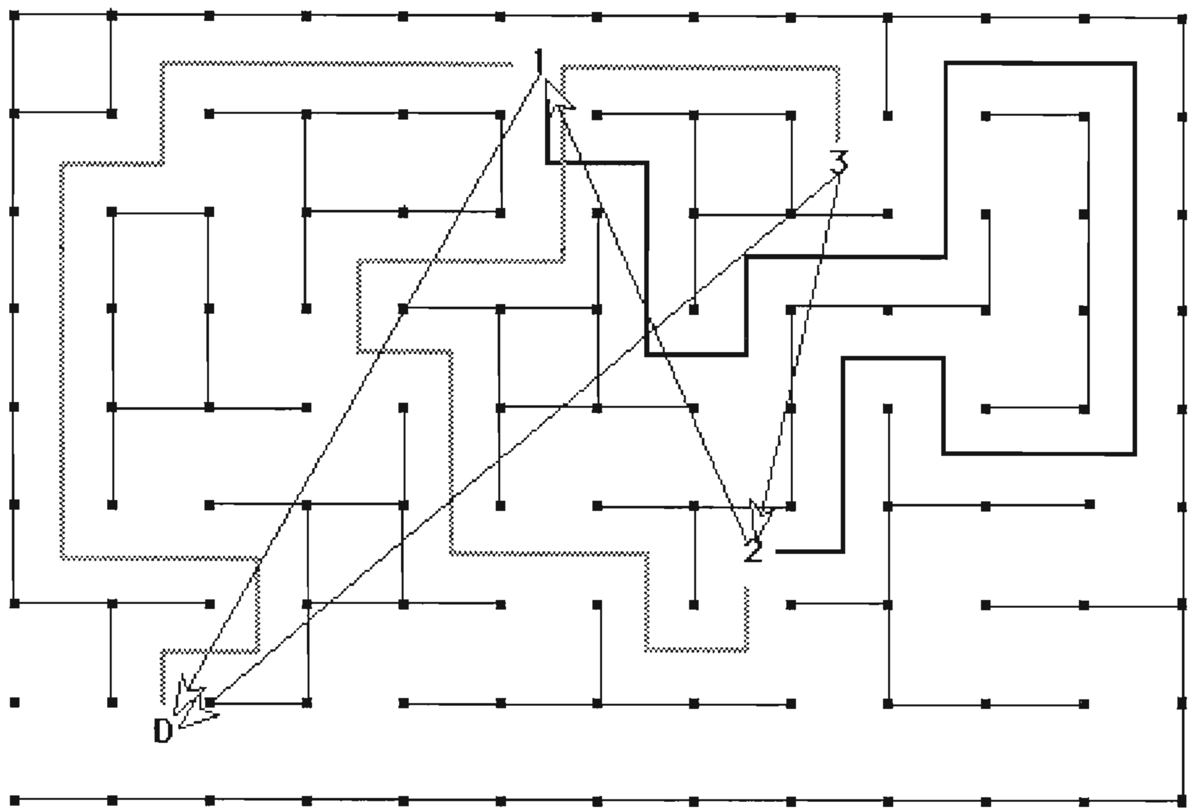


Figure 3a. Map drawing task: stimulus

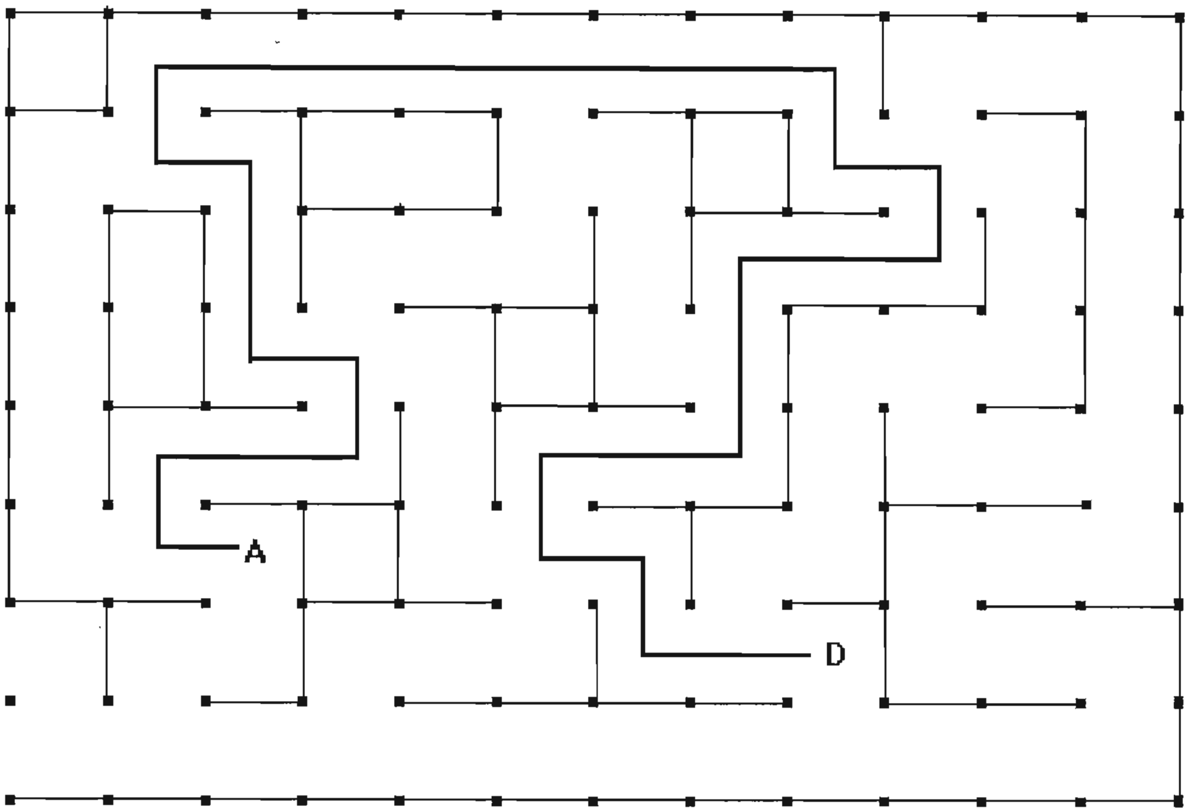


Figure 3b. Map drawing task: free recall response sheet

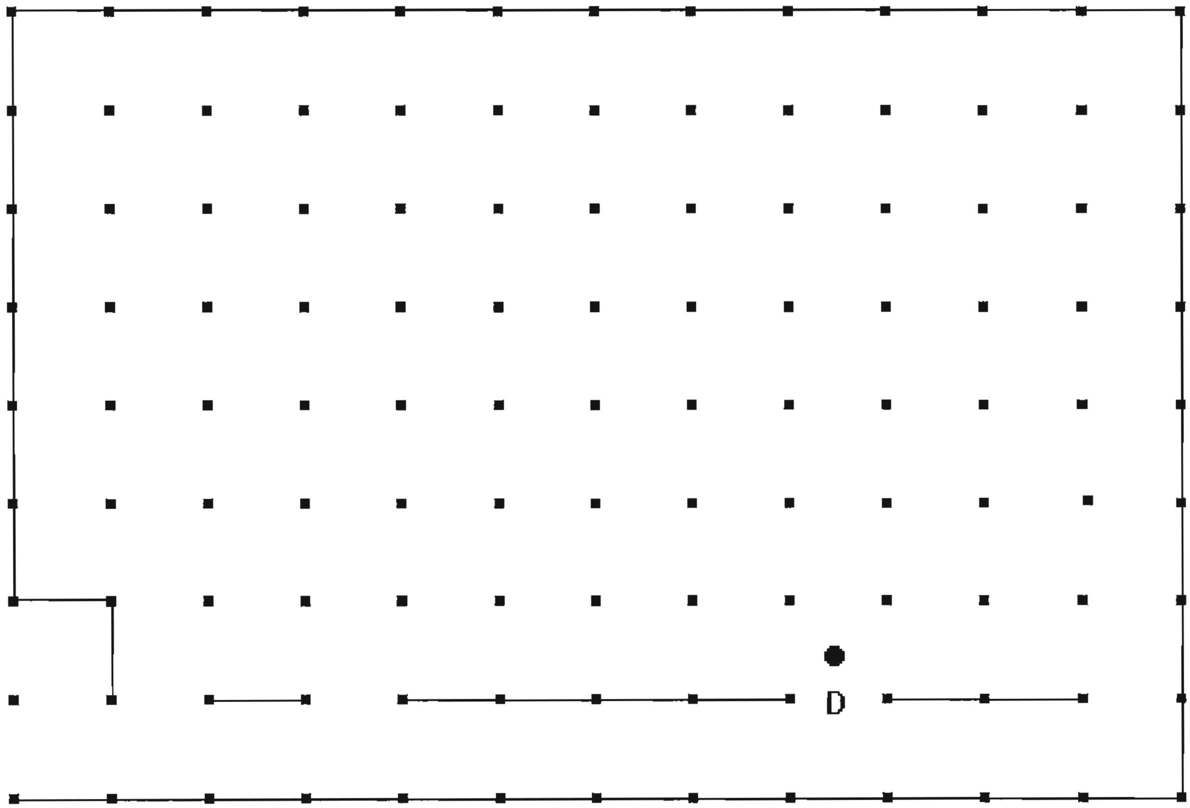


Figure 3c. Map drawing task : cued recall response sheet

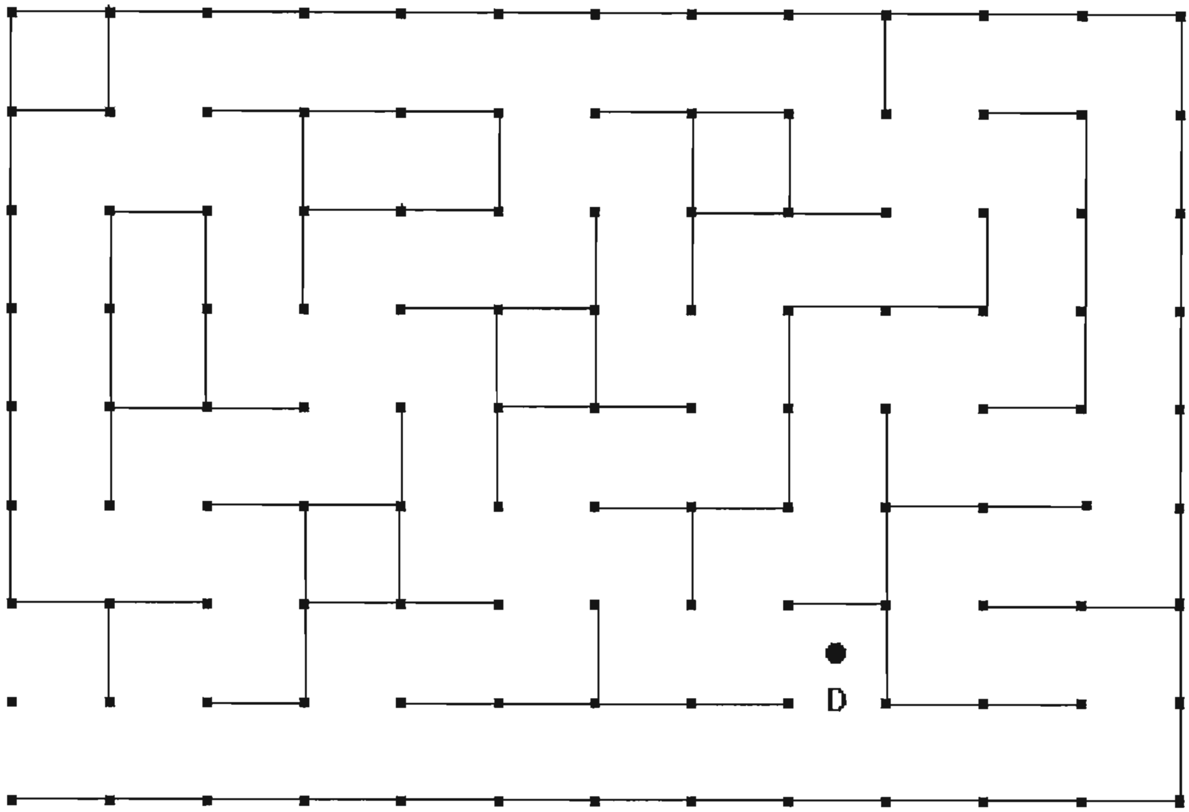
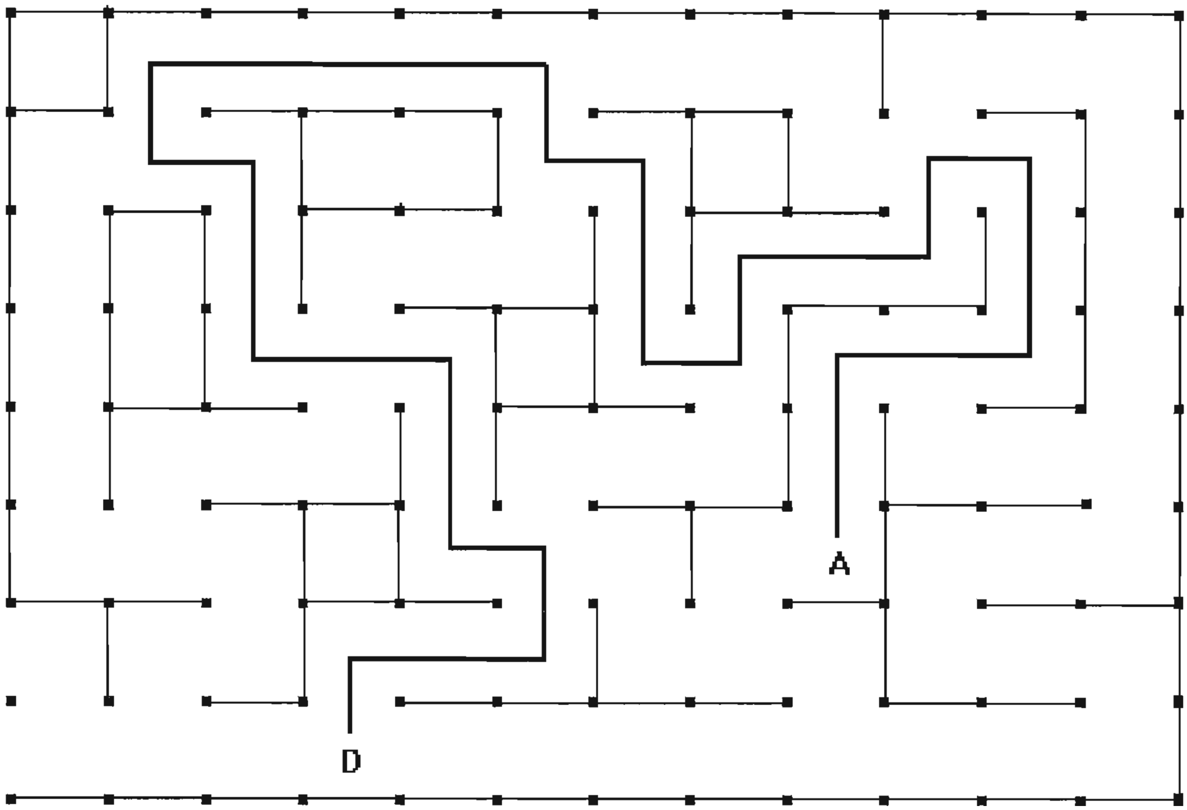


Figure 4. Map learning task: stimulus



CHAPITRE III

DEUXIÈME ÉTUDE

Référence bibliographique :

Caron MJ, Mottron L, Berthiaume C, Dawson M. (2006). Cognitive mechanisms, specificity and neural underpinnings of visuospatial peaks in autism. Brain, 129, 1789-1802

COGNITIVE MECHANISMS, SPECIFICITY AND NEURAL UNDERPINNINGS OF VISUO-SPATIAL PEAKS IN AUTISM

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3.1 Abstract

In order to explain the cognitive and cerebral mechanisms responsible for the visuo-spatial peak in autism, and to document its specificity to this condition, a group of 8 high functioning individuals with autism and a visuo-spatial peak (HFA-P) performed a modified block-design task (BDT; subtest from Wechsler scales) at various levels of perceptual cohesiveness, as well as tasks tapping visuo-motor speed, global perception, visual memory, visual search, and speed of visual encoding. Their performance was compared to that of 8 autistics without a visuo-spatial peak (HFA-NP), 10 typically developing individuals (TD), and 8 gifted comparison participants with a visuo-spatial peak (TD-P). Both HFA-P and HFA-NP groups presented with diminished detrimental influence of increasing perceptual coherence compared to their BDT-matched comparison groups. Neither autistic group displayed a deficit in construction of global representations. The HFA-P group showed no differences in performance level or profile in comparison to the gifted BDT-matched (i.e., higher FSIQ) group, apart from locally oriented perception. Diminished detrimental influence of perceptual coherence on BDT performance is both sensitive and specific to autism, and superior low-level processing interacts with locally-oriented bias to produce outstanding BDT performance in a subgroup of autistic individuals. Locally oriented processing, enhanced performance in multiple tasks relying on detection of simple visual material, and enhanced discrimination of first order gratings (Bertone et al., 2005) converge toward an enhanced functioning and role of the primary visual cortex in autism. In contrast, superior or typical performance of autistics in tasks requiring global processing is inconsistent with the global-deficit-driven Weak Central Coherence hypothesis and its neurobiological magnocellular deficit counterpart (Milne et al., 2002).

Key words: Autism, visuo-spatial peak, occipital cortex, parvocellular pathway, magnocellular pathway

Abbreviations:

ADI = Autism Diagnosis Interview; BDT = block-design task; CT = construction time; EPF = enhanced perceptual functioning; FSIQ = full-scale IQ; HFA-NP = high-functioning individuals with autism and without a visuospatial peak; HFA-P = high-functioning individuals with autism and a visuospatial peak; TD = typically developing individuals; ISI = interstimulus interval ; PC = perceptual cohesiveness; PIQ = Performance IQ; RT = reaction times; TD-P = typically developing individuals with visuospatial peak; TU = task uncertainty; VIQ = Verbal IQ, WCC = Weak Central Coherence; WISC = Wechsler Intelligence Scales for Children; WAIS = Wechsler Adult Intelligence Scales.

INTRODUCTION

There is accumulating evidence that atypical perception plays a prominent role in the autistic behavioural and cognitive phenotype. Within the visual modality, the performance of persons with autism on tasks necessitating the detection of visual elements embedded in larger fields has been found to be either more locally oriented (Shah and Frith, 1983; Jolliffe et al., 1997; Mottron et al., 2003; Lahaie et al., 2006; see Happé, 1999; and Happé and Frith, 2006 for reviews) or enhanced (Plaisted et al., 1999; O'Riordan et al., 2001; Caron et al., 2004; Pellicano et al., 2005; see Mottron et al., 2006 for a review) when compared to typically developing individuals. This is the case in the embedded figures task (Jolliffe et al., 1997; Shah and Frith, 1983), the impossible figures task (Mottron et al., 1999) and the maze-map task (Caron et al., 2004). Superior performance has also been demonstrated in tasks relying on low-level perceptual processing like pattern (Plaisted et al., 1998b) or grating (Bertone et al., 2005) discrimination tasks, in discrimination of elementary stimuli differing at the featural level (Plaisted et al., 2003), and in featural and conjunctive visual search tasks (Plaisted et al., 1998a; O'Riordan et al., 2001; Jarrold et al., 2005; O'Riordan, 2004).

Among the large number of visual tasks in which autistic individuals display superior performance, one of the most replicated is the "block design" subtest of the Wechsler intelligence scales (WISC, WAIS: Wechsler, 1981, 1994). In the block design task (BDT), the individual is shown a two-dimensional red and white geometric design. The task consist of reproducing this design by assembling a set of blocks composed of 6 colour surfaces (2 red, 2 white and 2 diagonally oriented half-red and half-white surfaces). Relative BDT peaks, i.e. high level of performance in the BDT as compared to other verbal and non-verbal subtests, is a robust and early finding in autism (Asarnow et al., 1987; Shah and Frith, 1983, 1993; Tymchuk et al., 1977; Happé, 1994; Siegel et al., 1996). However, high level of performance is observed only in a subgroup of individuals satisfying the behavioural criteria for autism. While estimating incidence of the BDT peak as 22% to 38 % in the autistic population of normal intelligence, Siegel et al., (1996) concluded that this result could not be used for diagnostic purposes, due to lack of sensitivity. However, this conclusion has been drawn from performance in the standard Wechsler BDT. This task may not be the most sensitive to autistic particularities, if it does not manipulate the specific dimension which reveals autistic superiority.

Regarding the cognitive mechanisms explaining BDT superiority, a study from Shah and Frith (1993) has shown that the superiority of the autistic group in this task vanishes when the figure to be reproduced is segmented. The authors concluded that BDT superiority in autistic individuals was due to the advantage conferred by spontaneous segmentation, which was evidence for locally oriented processing. This important finding became the cornerstone of Weak Central Coherence (WCC), developed by Frith and Happé (Frith and Happé, 1994; Frith, 2003; Happé and Frith, 2006). In this hypothesis, locally oriented processing is derived from a deficit in the tendency to integrate local elements into a coherent whole. An alternative account attributed BDT superiority to a combination of superior disembodying ability and superior discrimination, within general superior low-level perceptual functioning (Mottron et al., 2006b). In the latter explanation, superior performance and locally oriented processing in the BDT would be one among many manifestations of superior performances reflecting overall enhanced perceptual functioning (EPF). However, this model has not been empirically applied to the BDT. In particular, no study has directly tested how EPF may explain the BDT peak, and to date, Shah and Frith's (1993) account for the BDT peak in autism remains without alternative.

Although the WCC model has no explicit neurobiological counterpart, it has been proposed (Milne et al., 2002; Greenaway and Plaisted, 2005) that a putative deficit in perceiving the global aspect of visual information may derive from abnormal functioning of the magnocellular pathway. However, this hypothesis has been criticized on the basis of typical performance in first-order motion perception (Bertone and Faubert, 2005), and overall typical performance in the construction of global visual representations (Mottron et al, 2003, 2006).

This study aims to determine how locally oriented processing and overall superiority in perceptual functioning interact to produce the BDT peak. For this purpose, a BDT allowing manipulation of the variables favouring local (segmentation) and global (perceptual cohesiveness) processing was constructed. In addition, autistic and non-autistic participants were assessed in a large sample of visual perception tasks (visuo-motor speed, global processing, short and long term visual memory, visual search, low-level discrimination). In order to disentangle the effects of giftedness, autism and general intelligence in the BDT, this series of tasks was assessed in two groups of autistics: one randomly selected among individuals with a relative BDT peak (HFA-P), and another among individuals without a BDT peak (HFA-NP). Their performance was compared to that of two comparison groups of typically developing individuals, one representative of the general population (TD), and one composed of individuals presenting with an absolute BDT peak (TD-P), i.e. exceeding IQ baseline by more than 1.5 SD. This strategy provides two different matching variables for the autistic group, one on general intelligence (HFA-P and HFA-NP vs. TD) and one on visuo-spatial ability, when it differs from general intelligence due to autistic or non-autistic giftedness (HFA-P vs. TD-P). However, it does not allow for a factorial design (Group X BDT peak), which would require identical criteria for both autistic and control groups. Whereas the TD group is representative of the entire population of typically developing individuals, the TD-P group is defined on the basis of the presence of an absolute BD peak only. A relative peak is exceptional in typically developing people, but always accompanies the presence of an absolute peak within the autistic population of normal intelligence. Although BD ability cannot be isolated from autism unequivocally in this design, it detects patterns of performance sensitive to autism when the HFA-P and HFA-NP groups differ from the baseline of the TD sample, and specificity to autism when TD-P and TD behave similarly in this regard.

WCC (and magnocellular) accounts of the BDT peak predict an absence of influence of perceptual cohesiveness (Exp. 1) on performance, a larger impairment of the HFA-P group in a task tapping holistic processing (Exp. 2), and a superior memory for block patterns deprived of perceptual cohesiveness (Exp. 3) in the HFA-P group. In contrast, the EPF model applied to the BDT predicts an overall superiority of the HFA-P group in Exp. 1 to 5, in addition to predictions similar to WCC in Exp. 1, but opposite in Exp. 2.

3.2 Methods

Participants

Four groups of adolescents and adults participated in this study: high functioning autistics with (HFA-P) and without (HFA-NP) a BDT peak, typically developing individuals (TD) and a group of non-autistic gifted individuals with a BDT peak (TD-P). Both groups of HFA participants had full scale IQ (FSIQ) scores in the average range (IQ>80). Participants were obtained from the database of the Pervasive Developmental Disorders Specialized Clinic of Rivière-des-Prairies Hospital (Montreal, Canada). The diagnosis of autism was made on the basis of the Autism Diagnosis Interview-Revised (ADI-R; Lord et al., 1994). This diagnosis was confirmed by an explicit assessment of DSM-IV criteria through clinical observation, using the Autism Diagnosis Observation Schedule – Generic (ADOS-G, module 3 or 4, Lord et al., 1999). All participants scored above the cut-offs in the algorithms of the two instruments, except for one of the HFA-NP group who scored at 6 (cut off: 10) in the ADI communication area, but was included as he scored at 5 (cut off = 3) at the ADOS communication area, had a presentation of classical autism, and no other Axis 3 diagnosis. In order to exclude individuals with an attenuated phenotype who may still be positive to these instruments in our experience, the participants were limited to those presenting at least a delay in one or two-word development. This had the effect of excluding clinical diagnoses of Asperger syndrome in this study, except one who was included due to a clerical error. Among HFA-P participants, one was taking risperidone, one risperidone and clonidine, and one paroxetine. Among HFA-NP participants, one was taking methylphenidate. Autistic participants were verbal, between 12 and 33 years of age, and all had normal or corrected-to-normal vision, tested by Snoellen Eye Chart prior to the experiment.

The HFA-P group included 8 individuals with autism presenting a BDT scaled score superior to 15, i.e. satisfying the .05 threshold provided by Wechsler's manual guide to determine an informative difference between the BDT and the average of the other WAIS-III or WISC-III scaled scores (the differences being 3.2 and 2.7 respectively). The HFA-NP group included 8 individuals with autism but without a BDT absolute or relative peak as previously defined.

The TD group comprised 10 typically developing participants. One TD participant presented an absolute BDT peak, which corresponds approximately to the incidence of BDT absolute peak in our database of TD individuals. The TD-P group included 8 typically developing individuals with a BDT scaled score equivalent or superior to 15. The typically developing individuals and their first-degree relatives were screened for current or past neurological, developmental, or psychiatric disorders. The experiment was formally approved by a local ethics committee. All participants were given financial compensation for their participation. Table 1 shows the characteristics of the 4 groups.

TABLE 1

No statistically significant differences were found between the HFA-P, HFA-NP and TD groups on chronological age, gender, laterality, verbal IQ (VIQ), full scale IQ (FSIQ), nor in average scaled scores of the different WAIS or WISC subtests minus BDT. The unique difference was in performance IQ (PIQ) (HFA-P=108, TD=96; p=0.048) due to the standard score of the BDT being significantly higher in the HFA-P and in the TD-P group. Relative BDT peaks being practically nonexistent in the typical population, TD-P individuals were found only among subjects with overall high IQ. Therefore, the TD-P group had an IQ significantly higher (approximately 20 points) than the three other groups. The TD-P group was also significantly younger than the HFA-P group.

An overall difference in ADI scores has been reported to falsely produce apparent qualitative differences among subgroups of pervasive developmental disorder (PDD) (e.g. Asperger vs. autism: Macintosh & Dissanayake, 2004). Therefore, we assessed differences between individual ADI items and summary scores between the two autistic groups. We did not find differences between groups in any of the summary scores, including the cumulative score for restricted interests and repetitive behaviours. Among the ADI items composing the diagnostic algorithm, only unusual preoccupations (# 71) and unusual sensory interests (# 77) at the 4-5 years period differed (exact Fisher test, p=0.041), which confirms the hypothesis (see Mottron et al., 2006b) that visuo-spatial peaks and perceptually-oriented repetitive behaviour may be related to a low-level perceptual mechanism.

In order to obtain information about the incidence of HFA-P individuals within the autistic population, we examined the proportion of individuals with relative BDT peak in the entire sample of individuals with autism (n=92) and of typically developing (n=112) individuals listed in Rivière-des Prairies' database. A relative BDT peak occurred in 47% of individuals with autism. We therefore consider that the combination of the HFA-P and HFA-NP groups is a representative sample of the autistic population. In contrast, a relative BDT peak was found in only 2% of the non-autistic population (see figure 1).

Figure 1

General procedure, tasks and apparatus

The nature of the experiment was explained to all participants at the occasion of signing the research consent. After informed consent was obtained, all participants were individually administered the five tasks in the same order (1- Perceptual cohesiveness in BDT, 2- Segmentation vs. integration in BDT, 3- Long term visual memory in BDT, 4- Visual search in BDT, 5- Perceptual discrimination, encoding and retention of visual pattern). The instructions relevant to each particular task were presented and practiced before the experiment. The stimuli for computerized tasks were generated by a PC Vectra Pentium II and displayed on a 17-inch colour monitor. Participants were seated 2 feet from the monitor. The entire testing session lasted approximately 1h30 min.

Experiment 1: Effect of perceptual cohesiveness on performance in a BDT

Exp. 1 manipulates the perceptual cohesiveness (minimal, intermediate, maximum) and the presentation form of the design (unsegmented, segmented). Perceptual cohesiveness (PC) is a global property of the figure to be reproduced. Figures with high PC require mental segmentation in order to divide them into block-sized units, allowing matching between a part of the design and one of the three possible surfaces of the blocks. PC can be manipulated by varying the number of 'adjacencies' of opposite-coloured edges for the block, or edge cues. The higher the number of edge cues, the lower the PC and the easier / faster a successful completion occurs (Royer et al., 1984; Royer and Weitzel, 1977; Schorr et al., 1982). Other variables relevant for task difficulty are task uncertainty (TU), and matrix size. TU expresses the number of possible decisions required to reproduce a figure. The first level of TU (TU=1) consist of determining if a required part is red, white or bicolour. If a bicolour part is required, an additional choice (TU = 2) among the 4 different bicolour face orientations has to be made. The sum of the TUs for each block composing the target figure provides a measure of the total TU involved in constructing this figure. Matrix size expresses the number of blocks (4, 9 or 16) composing the figure. Lastly, the segmentation of the target figure suppresses the detrimental effect of PC on figure construction, leaving only the local-local matching and motor components of the task.

Experimental task and stimuli

The task was constructed following a PC (minimum, intermediate, maximum) x Task uncertainty (min, max) x Size (4, 9, 16) design, resulting in 18 figures, presented in unsegmented, then in segmented conditions. The segmentation space was 1/3 of the width of one block (0. 9 cm). For each matrix size, a control condition measuring the motor velocity component involved in BDT construction was added, in the form of a monochromic square presented in the segmented and the unsegmented condition. Examples of stimuli are presented in figure 2.

Figure 2

Procedure

Task procedure followed Wechsler's instruction guide. The participants were first shown the different faces of a block, and were informed that all blocks were identical and composed of 2 red, 2 white and 2 bicolour surfaces (see figure 2). A 2 x 2 example (not included in the task) was performed by the examiner and then reproduced by the participant. Between each construction, the examiner placed the blocks in front of the participants in order that an equivalent variety of block surfaces was facing up. Instructions emphasised speed as well as accuracy. Performance was timed from the moment the design card was placed in front of the participant until the design was completed or the time limit elapsed. Because the designs used in this experiment were more difficult than those in the WISC or WAIS, the maximum allowed time before the construction of a design was considered 'failed' was increased, based on a pilot study. The time limits for the 4, 9 and 16-block designs were respectively 120, 180 and 240 seconds. One point was credited for each of the correctly reproduced designs. Presentation order of the designs was identical for all participants. Trials were ordered by increasing level of uncertainty within each matrix size, and PC level within each level of uncertainty. The unsegmented condition was presented before the segmented condition to avoid a facilitation effect.

Hypotheses

Following experimental findings demonstrating a generalized local bias in autism and consistent with Shah and Frith's seminal study (1993), the detrimental effect of PC on performance should be inferior in the HFA-P compared to the TD group. In addition, the superiority of the HFA-P group should disappear in the segmented condition, which allows all participants to use a local strategy. Predictions arising from WCC and EPF models would be identical in this regard. No predictions were made for the HFA-NP and the TD-P group.

Results

Average construction time ranged between 15 and 126 s., i.e. within task limits. Construction time (CT). A Group (HFA-P, HFA-NP, TD, TD-P) x Segmentation (segmented, unsegmented) x PC (minimum, intermediate, maximum) repeated measures ANOVA, with CT as the dependent variable, revealed an interaction of Group x Segmentation x PC, $F(6,60)=3,673$; $p=0.004$ in the unsegmented condition and an interaction of PC x Group $F(6,60)=5,173$; $p=0.000$. The planned comparison of the Group x PC interaction in the unsegmented condition revealed significant interactions when comparing TD to HFA-P ($F(2,32)=12.908$; $p=.000$) and TD-P to HFA-P $F(2,28)=6.183$; $p=.006$ whereas the interaction is not significant when comparing HFA groups to each other ($F(2,38)=2.728$; $p=.083$). Therefore, TD and TD-P individuals were slowed by increased PC whereas HFA-P participants were not. In the segmented condition, the detrimental effect of increasing PC disappeared. However, post hoc comparisons (Tukey HSD) shows that whereas the TD-P group was faster than the HFA-NP ($p=0.000$) and TD ($p=0.000$) groups in the segmented condition, it was not faster than the HFA-P group ($p=0,126$).

Figure 3

Visuomotor baseline speed. CTs in the segmented and unsegmented condition of the visuo-motor control task were pooled, as no hypotheses predicted a difference at this level. Average CTs were respectively 11.63, 15.60, 13,25 and 9,92 seconds for the HFA-P, HFA-NP, TD and TD-P groups and revealed a significant difference between groups $F(3,33)=5,631$, $p=0,003$. The finding of a significant difference between groups in the visuo-motor control task led to verification by ANCOVA of whether this variable explained differences in CT found between groups. This analysis pulled out the variance in CT resulting from the visuo-motor component. Conclusions pertaining to the Group x Segmentation x PC and the Group x PC interaction in the unsegmented condition were not modified by adding the visuo-motor variable.

Accuracy. Overall number of errors was very low, resulting in a non-normal distribution of data which, combined with the relatively small number of participants per group, precludes statistical analysis. However, qualitative examination of the error curves show the same pattern as CT, with the HFA-P and TD-P groups being the most accurate, the HFA-NP group falling closely behind and the TD group presenting with a larger number of errors. The TD group was the least accurate in the minimum PC condition, where they displayed 15 to 20 % "local" errors.

In sum, the influence of PC on BDT construction time is diminished in gifted and non- gifted autistic individuals, when compared with BDT-matched typical participants, and within groups, in gifted participants, when compared to non-gifted participants. This indicates that diminished influence of PC on BDT in autism is neither dependent on diagnosis, nor on general intelligence, nor on visuo-spatial giftedness only. The autistic superiority in the BDT is revealed only at the maximal level of PC, which conflicts with the local analysis required to perform the task for TD individuals, and confirms Shah and Frith's (1993) interpretation that locally oriented processing contributes to superior BDT performance.

Experiment 2: Holistic visual processing through a "reversed" computerized BDT

This matching task directly assessed the construction of a global representation in a BDT, to document the role of a deficit at the global level in the local bias evident in Exp. 1.

Experimental task and stimuli

This computerized task consisted of matching an unsegmented figure to a corresponding segmented target figure presented among three segmented distractors. In the condition of minimal PC, the participant can use a local by local strategy which is induced both by the large number of edge cues and by the segmented presentation of the figure. In the condition of maximal PC, matching at the global level requires only one operation, whereas matching at the local level requires as many operations as there are blocks in the figure. 18 stimuli-target pairs of increasing level of PC, TU and matrix size, corresponding to the same characteristics as those of Exp. 1, were constructed. The distractors used in this task differed from the target by colour inversion, local difference and target rotation. Examples of stimuli are presented in figure 4.

Figure 4

Procedure

Subjects were instructed that they would see some designs similar to those used in Exp. 1 at the top of the screen (target stimulus). They were also instructed that they would have to choose, as quickly as possible, from among four segmented designs displayed on the lower part of the screen, the design that corresponds to the target stimuli at the top of the screen. Responses were given by indicating verbally the letter corresponding to the presented items. The experimenter manually recorded the answer by pressing one of 4 keys of a keyboard recording accuracy and RT.

Hypotheses

Whereas WCC explicitly predicts a deficit in processing the configural aspect of the target figure, EPF predicts a general perceptual hyper-functioning should be manifested by a superiority in processing isolated visuo-spatial components, even configural ones.

Results

Average reaction times per individual ranged between 5 and 11 sec.

Reaction times (RT). A Group (HFA-P, HFA-NP, TD, TD-P) x PC (minimum, intermediate, maximum) repeated measures ANOVA with CT as the dependent variable revealed main effect of Group, $F(3,30)=4,111$, $p=.015$ and PC, $F(2,60)=118,622$, $p=0,000$, but no Group x Condition interaction ($p=0.952$). The facilitation effect on RT of increasing PC was identical across groups, thus demonstrating that global advantage is preserved in autistic participants, whatever their BDT performance. The HFA-P group was faster than the TD group across all levels of PC (p=.029), and was similar to the TD-P group, demonstrating that perceptual matching is superior in this group, independent of the hierarchical level at which it occurs: local, but also global processing is faster in HFA-P participants (see figure 5).

Figure 5

Accuracy. Overall number of errors was very low which, combined with the small number of participants, precluded statistical analysis. However, qualitative examination of the error curves showed the same pattern as the accuracy measured in Exp. 1, with HFA-P and HFA-NP groups being the most accurate, and TD and TD-P groups being least accurate in the minimal PC condition, where they displayed 15 to 25 % "local" errors. No speed-accuracy trade-off was found in this task (Spearman Correlation).

The integrity – and a fortiori, the superiority - of performance in a task relying on the construction of a global representation for the HFA groups discards the existence of an integration deficit in autism, and more specifically, its putative role in BDT peak.

Experiment 3: Long term visual memory for block design figures

This task was devised to test the EPF hypothesis that all operations involving simple patterns, from detection up to and including identification and memory, are superior in autism.

Task, stimuli and procedure

The purpose of Exp. 3 was to test if the group of participants showing superior BDT ability in Exp. 1 and 2 were also superior in memorizing the local and global aspects of figures involved in a BDT. An incidental long term visual recognition task was administrated after Exp. 2 (30 minutes after Exp. 1) to all participants. The participants had to identify the 18 unsegmented designs of Exp. 1 among a set of 18 distractors corresponding to the same characteristics (PC, TU, and Matrix size) as the target designs used in Exp. 1, but different from the stimuli used in Exp. 1 and 2. The series of 18 target figures intermingled with 18 distractors was presented randomly, one at a time. Yes-no responses were recorded on response keys. Accuracy was the dependent variable. Responses on the recognition task were considered correct if the participant accepted an old stimulus or rejected a new stimulus.

Hypotheses

The EPF model predicts a superior memory performance for all figures. EPF and WCC predict that this superiority should be larger for low PC figures, due to local bias. The WCC model has the same prediction for minimal PC figures (local bias), but this superiority should vanish for high PC figures (global deficit).

Results

Accuracy. A group (HFA-P, HFA-NP, TD, TD-P) x PC (minimal, intermediate, maximum) ANOVA with accuracy as the dependent variable revealed a group x PC interaction (F (6, 60) =4,917, p=0,000). The planned comparison of the group x PC interaction revealed that diminishing PC has a detrimental effect on memory in each group, the classical (Schacter et al., 1990) "global advantage" in memory. However, this effect was inferior in the HFA-P (P=0,023) and the TD-P (p=0,014) groups than in the HFA-NP and TD groups (p= 0.000), due to a superior performance of the two former groups in recognizing previously encountered, minimum PC figures (i.e. comprising local details).

Figure 6

In summary, both autistic groups were better at memorizing high PC (global) figures than low PC (local) figures, showing that the global advantage in long-term memory is not impaired in HFA participants. The fact that the HFA-P group equals the TD-P group in this task indicates that visuo-spatial peaks extend to the memorization of visual material in both groups.

Experiment 4: Visual Search using block design components

Autistic individuals present a characteristic pattern of performance in visual search tasks (O'Riordan and Plaisted, 2001; O'Riordan et al., 2001; Plaisted et al., 1998a). In a featural visual search task, the target differs from a unique set of distractors by a single feature. In a conjunctive visual search task, the target shares one feature with one set of distractors and another feature with another set of distractors. Therefore, the target is defined by a combination of features. Autistic individuals are more effective than typically developing individuals in conjunctive visual search tasks. Individuals with autism are also superior to typically developing individuals in featural tasks when featural tasks become more difficult (O'Riordan, 2004). In addition, autistics are less affected by increases in the number of distractors. According to Plaisted (2001), superior ability to discriminate among presented elements (the highly similar blocks required for a construction in BDT, the target and distractors items in a visual search task) may account for superior performance in both types of tasks. In order to facilitate the comparison and the generalisation in performance between the two tasks, a visual search task where targets and distractors were identical to block surfaces in the BDT was constructed.

Experimental task and stimuli

Stimuli were constructed by manipulating the structure (bitriangular, birectangular) and the orientation (red angle on right top, left top, right bottom, left bottom; see Fig. 7) of the presented "blocks". Birectangular blocks were identical to one of Kohs' blocks (1923), used by Shah and Frith (1993). In the featural condition, the distractors differed from the target by structure and orientation. In the conjunctive condition, distractors were either of identical structure as the target but with different orientation, or different in structure but identical in orientation. Therefore, distractors shared either structure or orientation with the target.

Figure 7

In each condition (featural, conjunctive), level of difficulty was manipulated by varying the number of items displayed (4, 9, 16) and the presence vs. absence of the target (50/50) resulting in 6 possible combinations per condition (see figure 8 for example). Two different targets were presented in each condition for a total of two sets of 60 trials, separated by a pause. Each set of trials was presented in an individually randomised sequence. Hence, the participant knew in advance the target to search for in each display, but did not know in advance if the target would be present, nor the number of distractors to be searched among for the target. In both conditions, each stimulus display occupied an unmarked 16.8 by 16.8 cm square at the middle of the screen. Target or distractors measured 1 cm by 1 cm. The minimum distance between elements was 0.7 cm (rows and columns).

Figure 8

Procedure

Prior to each set of test trials, participants were given 12 practice trials. Before starting the test trials, participants were instructed to respond by pressing one of two response keys as quickly and accurately as possible. Each trial was composed of the following sequence: white screen (1 s.) central fixation point (1 s.), search display (10 s., or until the participant's response). The digital timer was initiated by the presentation of the search display. If the subject did not responded within 10 s., a small clock appeared on the middle of the screen (1 s.) followed by a white screen (1 s.) and a central fixation point (1 s.) announcing the onset of the next trial. If an incorrect response was made, an inverse "smile" was shown on the screen (1 s.). Finally, if a participant pressed on the response key before the search display appeared on the screen, a running "bunny" was displayed at the middle of the screen (1 s.).

Hypotheses

WCC predictions about impaired ability to combine two features have already been contradicted by findings of not only preserved, but superior performance of autistics in conjunctive conditions. However, according to the EPF model, lower target detection time and superior accuracy in the autistic group extends also to difficult featural visual search tasks (O'Riordan, 2004).

Results

The four variables (Group: HFA-P, HFA-NP, TD, TD-P; Condition: featural, conjunctive; Display size: 4, 9, 16; Presence of the target: yes / no) could not be entered in the same analyses. Therefore, absent and present condition were pooled together in order to document the differential effect of display size among groups and condition. For the same reason, analyses were performed using pooled average RTs and errors across display size (4,9,16).

Group x condition x display size

Reaction times. A Group (HFA-P, HFA-NP, TD, TD-P) x Condition (featural, conjunctive) x Display size (4,9,16) repeated measures ANOVA, with RT as the dependent variable, revealed a main effect of Group, $F(3,30)=3,877$, $p=.019$, and a Condition x Display size interaction, $F(2,60)=92,073$ ($p=0.000$) (see Figure 9). RT increase between featural and conjunctive conditions and detrimental effect on RT of increasing display size in the conjunctive condition were identical across groups, thus replicating O'Riordan's (2001) and Plaisted's (1998b) results for similar display size; however, the HFA-P and TD-P groups were the fastest in all conditions.

Figure 9

Accuracy. Overall number of errors was small (around 5% in all conditions / display sizes, except 15 % in the conjunctive condition for the display size 16), and no differences were observed between groups. No speed-accuracy trade-off was found in this task (Pearson Correlation).

Group x condition x target presentation: Results were similar to the previous analyses, with HFA-P behaving like TD-P and HFA-NP like TD participants for present or absent targets.

The observation that the same autistic individuals present with a BDT peak and superior performance in a visual search task confirms Plaisted et al. (1998b) and O'Riordan and Plaisted's (2001) suggestion that some factor, implicated in a high level of perceptual performance, is shared by these two tasks. It also confirms that the ability to merge two perceptual criteria (conjunctive visual search) is unremarkable in autism.

Experiment 5 : Perceptual encoding speed and persistence in iconic memory.

This task assesses discrimination threshold and perceptual encoding speed for meaningless visual patterns. Whereas the contribution of local and global perceptual processing to superior BDT performance is assessed in Exp.1-2, to visual long term memory in Exp. 3, and to attention / perception interactions in Exp. 4, Exp. 5 tested the possibility that the input of perceptual information is atypically superior in a subgroup of persons with autism. Information in sensory storage typically transfers to short term visual memory within 100 - 250 ms after stimulus onset (Phillips, 1974; Purdy et al., 1984).

Stimuli

The stimuli were identical to those used by Phillips (1974) and consisted of 9x9 grids, each containing 81 square cells (40 red, 41 white randomly distributed) without borders (see figure 11 for example). The difficulty index (proportion of cells differing between a pair of stimuli) qualifies the level of similarity between 2 stimuli.

Procedure

Exp. 5 consisted of the determination of individual discrimination threshold (phase 1) followed by a delayed matching-to-sample task, at various exposure times and inter-stimulus intervals (phase 2). Participants were instructed that they would see a geometrical figure on the screen (the probe), followed by a pair of figures (one target, one distractor differing by having some red cells whitened or vice-versa). Responses were recorded by pressing the right or left key, depending on the side on the screen where the target was located.

Phase 1: The purpose of phase 1 was to determine the individual discrimination threshold, expressed in minimum proportion of differing cells allowing discrimination. This was done in order to compare the two groups on this variable, and to separate its role from encoding speed by equating participants on discrimination competency. Probe exposure time and ISIs were both fixed at 1 sec. A descending staircase procedure (step = 1 differing cell) was used, beginning by maximum level of difficulty, i.e. 1/81 cell differing between targets and distractors. Phase 1 was interrupted when the participant successfully discriminated 16 out of 20 stimuli of a given difficulty level.

Phase 2: The second phase was tested at the difficulty level individually determined during phase 1. Participants were told that exposure time and delay period were modified in phase 2. A sequence of 90 stimuli randomly combining 3 probe exposure times (200, 500 or 1000 ms) and 3 ISIs (17, 250 or 8000 ms.) was constructed. All ISIs were filled by a neutral grey texture with a fixation cross in the middle of the screen.

Figure 10

Hypotheses

WCC does not entail predictions regarding low-level processing in isolation. The EPF model predicts that discrimination threshold (phase 1) performance as well as encoding speed, and persistence of iconic trace (phase 2) should be enhanced in the HFA-P group.

Results

1) Discrimination. Groups were virtually identical in terms of average difficulty index: HFA-P: 89 % (SD= 4%), HFA-NP: 91% (SD= 4%), TD: 89% (SD= 4%), TD-P: 90 (SD=5%). Between 1 and 16 differing cells were required to discriminate two displays.

2) Group x Exposure time ANOVA. A Group (HFA-P, HFA-NP, TD, TD-P) x Exposure time (200, 500, 1000 ms) repeated measures ANOVA with Accuracy as dependent variable revealed a Group x Exposure time interaction $F(6,60) = 4{,}000$ ($p = 0.002$). Post hoc analyses revealed a clear superiority in accuracy for the HFA-P and TD-P groups at 200ms of exposure $F(3,30)=5{,}485$ ($p=0.004$), as compared to HFA-NP and TD participants. The HFA-

P and TD-P groups required less exposure time to obtain a comparable performance in discrimination.

Figure 11

3) Group x ISI ANOVA. A Group (HFA-P, HFA-NP, TD, TD-P) x ISI (17, 250, 8000 ms) repeated measures ANOVA with accuracy as dependent variable did not reveal a difference between groups.

The fact that HFA-P participants perform like TD participants with a FSIQ approximately 20 points higher indicates that availability of visual information is superior to what FSIQ could predict in autism (see also Scheuffgen et al., 2000), but indicates that this is true only for the endophenotype characterized by an overall superiority in perceptual tasks. These results also suggest that not all dimensions of early stage visual processing are superior in the HFA-P group (see also Bertone et al., 2005).

3.3 Discussion

With the purpose of explaining the mechanisms responsible for the BDT peak in autism, and to document its sensitivity and specificity to autism, a group of HFA individuals with a BDT peak of ability performed a BDT in conditions orienting toward local (segmentation) or global (increasing PC) processing, and 4 tasks tapping different levels of visual perception. The performance of the HFA-P group was compared to that of autistics without a BDT peak, typical individuals of similar general intelligence, and typical individuals matched in BDT peak, but with a superior general intelligence measured with Wechsler scales. The two HFA groups displayed diminished sensitivity to perceptual cohesiveness, and three results indicate that their ability to integrate features into a coherent whole was preserved: a typical advantage in matching block patterns at the global level, in memorising figures with high PC and in detecting conjunctive pattern in a visual search task. The HFA-P group displayed a consistent superiority to FSIQ matched participants but an equivalent performance to that of BDT-matched participants, in one or several aspects of the entire range of tasks. We shall now examine how these findings allow for the disentangling of factors that have been proposed to account for the BDT peak in autism, to which extent

BDT peak and overall superiority in perceptual tasks are sensitive to autism, and how this may be explained at the neural level.

Understanding BDT peak in autism

Disembedding ability. The limitation of BDT superiority of the autistic group to the unsegmented condition, as reported by Shah and Frith (1993), is replicated. Segmentation of the figure to be reproduced considerably reduces the difficulty of the task, but is at risk of producing a ceiling effect, which obscures effects more specific to each of the groups under study. This is not the case for the manipulation of perceptual coherence, which reveals an increase of difficulty which interacts with group and level of performance. For TD individuals, both gifted and non-gifted groups display an increase of construction time following increase in PC. However, this increase is more important for non-gifted people than for gifted people, autistic or not, and more important for non-autistics than for autistics, gifted or not. In the autistic group, only the non-gifted group displays a cost of increasing PC. However, when autistic and non autistic groups of similar level of performance in a standard BDT are compared, autistics are consistently less slowed by maximal level of PC. Therefore, diminished influence of PC plays a role in BDT peak in autism, although it interacts with task difficulty and abilities in perceptual tasks.

Global deficit. Could a deficit in the ability to combine elements in a higher-order representation be responsible for superior BDT performance, as initially proposed by the WCC model (Frith, 2003; Happé and Frith, 2006)? Combined findings of experiments 2, 3 and 4, based on intact or superior construction of a visual perceptual representation, indicate that this is not the case. The autistic participants without BDT peak are comparable to IQ-matched participants in these tasks, and those with a BDT peak are also superior to IQ-matched typical participants in these tasks. Taken together, these findings indicate that the "default setting" of autistic perceptual analysis toward local elements, demonstrated in Exp. 1, may be bypassed either when the construction of a global perceptual representation optimizes performance (Exp. 2) or when it is mandatory to a successful performance (Exp. 4, conjunctive condition). The autistic group appears to be more cognitively versatile than the TD group: they may use a locally oriented (Exp. 1, maximum PC) or a globally oriented

(Exp. 2, maximum PC) strategy. Normalcy of global level analysis has also been reported following explicit instruction in a Navon-type task (focused attention condition, Plaisted, 1999, Exp. 1). Likewise, an ability of autistic participants to reconfigure their default setting according to task demands has recently been demonstrated by Iarocci et al. (2006), who showed that autistic participants (regardless of their BDT performance) adapt more easily to modification of frequency of target occurrence at the local and global level than comparison individuals, although they are superior for local targets.

Enhanced perceptual functioning. In an updated version of the EPF model (Mottron et al., 2006b), we proposed that superior perceptual functioning could be involved in BDT peak. A contribution of EPF to an absolute BDT peak is plausible, as the HFA-P group also displays superiority in 5 other perceptually related tasks. Conversely, superior disembedding ability has to be combined with overall superior perceptual performance to produce a high BDT performance in autistics. Accordingly, the HFA-NP group, by definition, does not reach the level of absolute and relative BDT peak, and performs at an unremarkable level in experiments 2 to 5, everything else (ADI scores, FSIQ, VIQ, PIQ) being equal. Locally-oriented processing being found in the entire autistic population and superior perceptual performance being found only in half of them, locally oriented processing may be a necessary, but not sufficient, condition for the development of BDT peak. An indication that visuo-spatial peaks are a developmental ongoing process has been proposed by Joseph et al. (2002), who found greater visuo-spatial peak vs. base line discrepancy in autistic children aged 8 years 11 months than in children aged 5 years 5 months. The fact that the HFA-P group presents with a greater level of unusual preoccupations and sensory interests than the HFA-NP group suggests that locally oriented visual processing might be causally related to these behaviours in a fraction of autistic individuals, thereby overtraining low-level perception in this subgroup. However, a reverse causality (e.g. absence of development of peaks of ability in a subgroup of autistics due to environmental suppression of repetitive behaviours) is also possible.

Specificity and sensitivity to autism of locally-oriented processing and of enhanced perceptual functioning.

Diminished sensitivity to perceptual coherence is found in both HFA-P and HFA-NP groups. In contrast, absolute BDT peak is not specific: its estimated incidence in TD participants from our database is 19 % (FSIQ : mean =107, s.d.= 16, range:=65-137), whereas it is found in 21 % of the autistic population (FSIQ : mean = 84, s.d.= 21, range 40-120). However, relative BDT peak is clearly more frequent in autistic (47%) than in typical individuals (2 %). Although frequently 1 to 3 SD above IQ baseline, BDT performance in autism is highly correlated with FSIQ (.613, P <.000; Mottron 2004). Less than 10 % of autistic individuals perform at an inferior level in BDT compared to their IQ baseline, whereas this happens in 50 % of typically developing individuals. However, although BDT performance of HFA-P and NP groups is unremarkable for minimal level of PC, they become superior to the TD group for intermediate and maximal levels of PC. This suggests that the standard BDT of the Wechsler scales, on which our initial division of HFA-P vs. -NP was grounded, was not difficult/sensitive enough to reveal the superiority of the HFA-NP participants. In consequence, the poor sensitivity of BDT peak (38%) reported by Siegel et al. (1996), also based on a standard BDT, represents a clear underestimation of the incidence of relative BDT superiority to other Wechsler subtests. In summary, a relative BDT peak appears as relatively sensitive to autism, inasmuch as high level of perceptual coherence in the figure to be reproduced reveals an autistic superiority in this task, and that performance of autistic participants is compared to that of non-autistic participants of similar FSIQ measured by Wechsler scales.

Regarding perceptual superiority of the HFA–P group in other visual tasks, it could also be seen as poorly specific, as this superiority vanishes when performances of the HFA-P group are compared to that of typically developing participants with similar BDT performance, the TD-P group. However, the specificity of EPF increases considerably if one considers the relation between perceptual performance and average FSIQ. Accordingly, the TD-P group was on average 20 points higher in FSIQ than both the TD and the HFA-P group. Therefore, the relative performance of the HFA-P group, i.e. having higher perceptual strength than their FSIQ predicts, appears as unique to the HFA-P group.

Neural models for BDT peak and visual enhanced perceptual functioning

Typical or superior performances in a series of tasks relying on binding of local features do not support a magnocellular involvement in autism. The association of locally oriented processing with enhanced performance in a wide range of visual tasks relying on the detection and discrimination of simple visual material instead suggests an enhanced functioning and role of V1. In typical individuals, feed-forward visual processing follows a double hierarchical pattern. More posterior regions of the occipital lobe are devoted to extraction of unique dimensions and to small areas of the visual field, and more anterior regions both to large areas of the visual field and increasingly abstract, higher-order operations like global processing and categorisation (Grill-Spector and Malach, 2004). According to this view, both superior performances in extracting one-dimensional aspects of visual information and locally-oriented processing would therefore result from superior functioning of the same region of the posterior-central visual cortex, V1.

Within V1, the enhanced functioning of the early parvocellular pathway may be a candidate to account for both locally oriented and superior low-level performances in autism. The parvocellular pathway conducts high-resolution visual information and is involved in processing fine-grained stimulus configurations, initial detection and segregation of objects from the background, and object identification (Merigan et al., 1993, Steinman et al., 1997). It is optimised for encoding information about colour/wavelength and stationary stimuli and is also more sensitive to details of objects (high spatial frequency; Merigan et al., 1991; Merigan et al., 1993; Kaplan, 1991). The detection of form contours from individually oriented line elements may be achieved though lateral interaction of orientation selective cells operating in V1, in addition to integrating feedback from higher levels (see Hess et al., 2003, for a review). Therefore, local structure can be encompassed by single neurons in V1 (Dakin and Frith, 2005). The "blocks" used in experiments 1 to 4 and in the visuo-motor control task share the property of being static, contour and plain colour - defined, and simple (squares and triangles). Most of their detection should plausibly be accomplished at the earliest part of the parvocellular pathway. Although Exp. 5 involves apparently more complex stimuli, these are also composed of coloured squares at the local level, and their processing relies mostly on lateral and anterior occipital sulci and the occipito-temporal sulcus (Ciesielski et al., 2005). Other converging arguments for the implication of a V1 "overfunctioning" in enhanced visual functioning evident in autism come from a recent study by Bertone et al. (2005), which investigated a group of 13 HFA individuals, 5 of whom were also in the current HFA-P group. Bertone et al. (2005) measured first and second order information processing along the parvocellular pathway in autism. Their HFA group was superior for identifying the orientation of simple, first-order gratings, processed in V1, but inferior for identifying the orientation of second-order gratings when compared to typically developing participants. 83% of the autistic participants in Bertone et al.'s study presenting superior discrimination of first order gratings also had a relative BDT peak.

Such a specific dissociation between first- and second-order stimuli could result from from diminished (or different, e.g. non-mandatory) long-range feedback from higher order cognitive processes (Frith, 2003). It could also result from non-mandatory regional feedback, here between V2-V3 and V1. In the same direction, a superior activation of right lateral occipital cortex (Brodmann Area –BA- 17, 18 and 19) during an EFT was reported by an fMRI study exploring pattern detection in autism (Ring et al., 1999). However, the absence of a control perceptual task in this study prevents the attribution of this finding to disembedding or enhanced performance per se. Considering that V1 typically reduces activity when elements form coherent shapes, and that greater activity in V1 indicates that a collection of lines cannot be resolved into shapes (Murray et al., 2002), this superior activity may be explained by atypical spatiotemporal dynamics of V1 during object features binding or to an atypical functional dedication of V1 in autism. Currently, the only argument for a reduced synchrony between V1 and another level of processing is derived from the finding of diminished functional synchrony between V1 (BA 17) and frontal area 44 in a task involving the observation of visual material(Villalobos et al., 2005).

We therefore propose that in a significant proportion of autistic individuals, a superior visual input issuing from early stages of visual processing increases the level of performance of subsequent feed-forward flow of visual information, as local - global hierarchical processes (Exp. 1 & 2), long term visual memory (Exp. 3) visual selective attention (Exp. 4) and texture discrimination (Exp. 5). If confirmed, V1 overfunctioning itself calls for explanation, and various candidates are currently available: overall diminished crosstalk between brain regions (Just et al, 2004; McAlonan et al., 2004); atypical neural connectivity, in the form of enhanced lateral inhibition, more beneficial to "simple" visual tasks (Bertone et al., 2005); diminished feedback of higher-order mechanisms (C. Frith, 2003) or within low-level visual areas (from V3-V2 to V1; Bertone et al., 2005); local overconnectivity combined with long-range underconnectivity (Belmonte et al., 2004); less specified mechanisms dedicated to high and low spatial frequencies (Boeshoeten et al., sub.); and long term effects of the "optional" use of higher –order processes (Mottron et al., 2006). Whatever existing or emerging explanation prevails, we contend that overall skewing of visual processing toward postero-central occipital brain regions represents an adequate description of the autistic endophenotype, regarding low-level visual perception. Moreover, the finding of similar superior performances in functions accomplished by the primary auditory cortex (Bonnel et al., 2003; see Samson et al., 2005, for a review) indicates that perception per se may be reorganised in autism.

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TABLE 1

Characteristics of high functioning participants with autism with (HFA-P) and without (HFA-NP) block design peak, typically developing participants (TD) and control participants with block design peak (TD-P).

	HFA-P Mean (SD)	HFA-NP Mean (SD)	TD Mean (SD)	TD-P Mean (SD)
N	8	8	10	8
Age	23,28 (7,4)	18,88 (4,4)	18,6 (3,5)	16,88 (2,0)
V.IQ	98,9 (21,5)	98,4 (11,8)	103,8 (8,1)	115,13 (8,2)
P.IQ	108,9 (10,0)	99,4 (10,6)	96,5 (9,6)	123,88 (7,9)
FS. IQ	103,1 (15,0)	98,5 (10,8)	101,2 (7,2)	121,00 (7,1)
Averaged P s.s.	11,23 (1,3)	9,83 (1,6)	9,4 (1,5)	13,53 (1,2)
BDT s.s.	16,6 (2,0)	10,8 (1,8)	10,1 (2,7)	17,0 (1,4)
Averaged (FS – BDT) s.s.	9,98 (2,0)	9,43 (1,5)	9,77 (0,9)	12,49 (1,1)
Averaged (P – BDT) s. s	10,01 (1,4)	9,64 (1,6)	9,28 (1,6)	12,66 (1,2)

s.s: scaled score; V: verbal; P: performance; FS: Full scale; BDT=block design task

Figure captions

Figure 1. Relative BDT peak (standard deviation in comparison to FSIQ) distribution in autistic (n=92) and typically developing (TD) individuals (n=112).

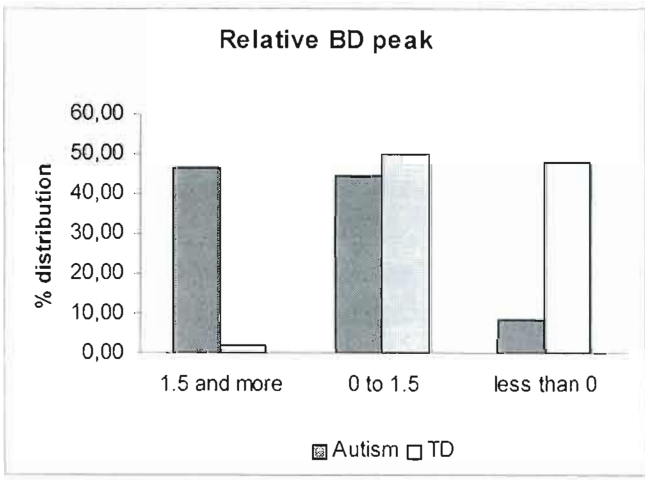


Figure 2. Examples of the block design task: unsegmented and segmented designs of PC min and PC max patterns. The design is to be constructed from 6 surfaces blocks.

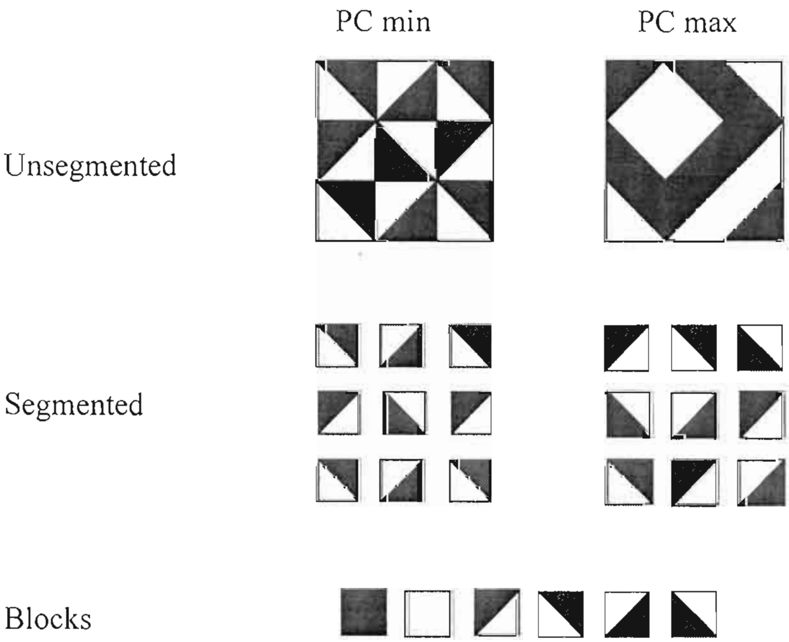


Figure 3. Construction time for unsegmented and segmented designs for different levels of PC (minimum, intermediate, maximum).

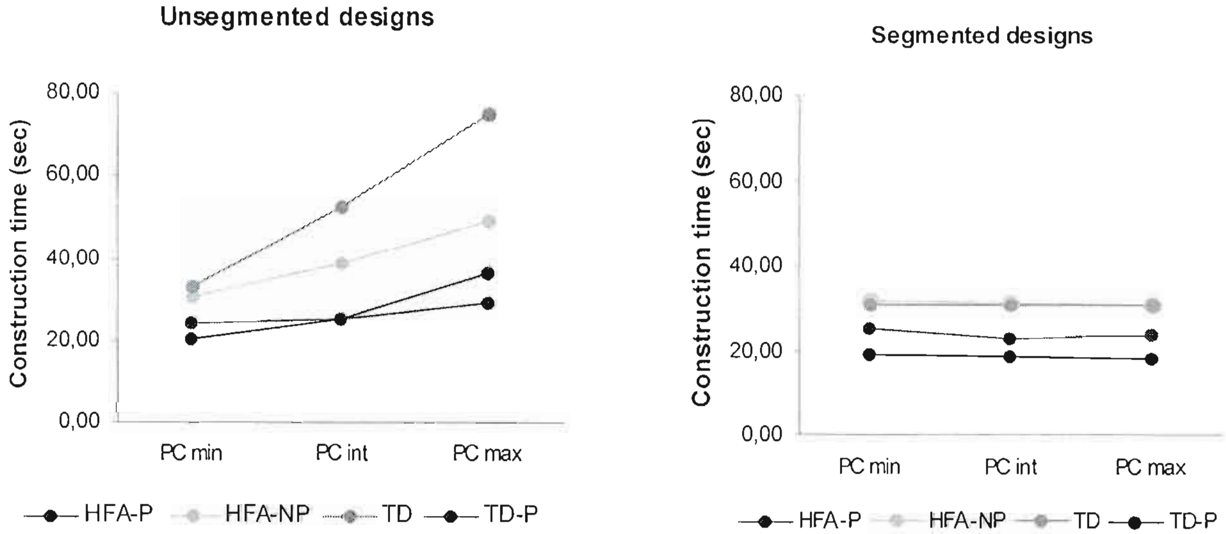


Figure 4. Example of stimuli (top left: local figure, top right: global figure) and distractors (bottom) used in task 2.

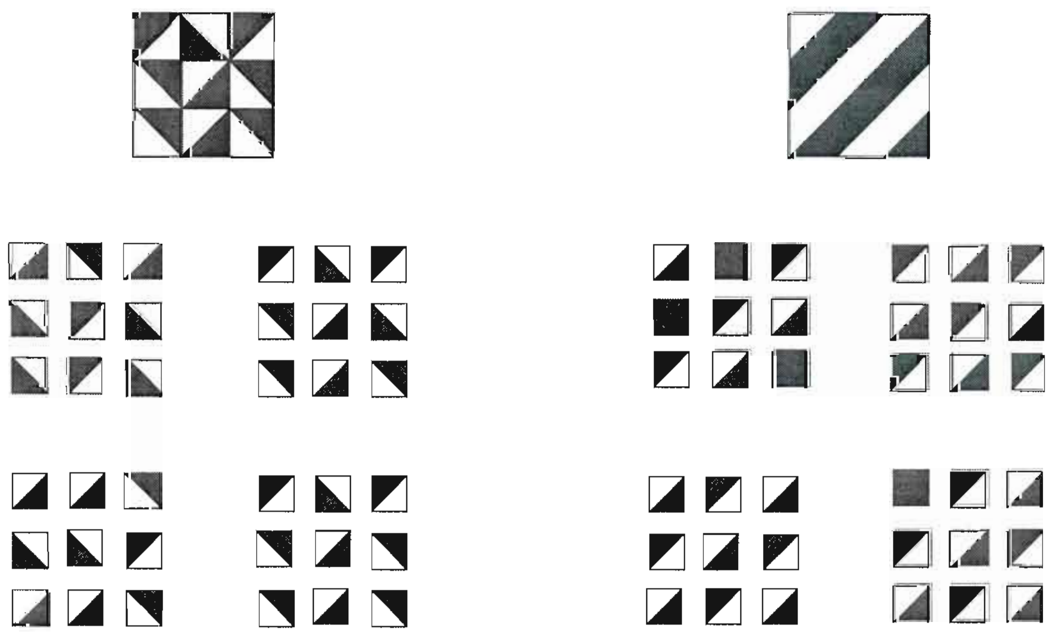


Figure 5. Local (PC min) vs global (PC max) processing matching speed.

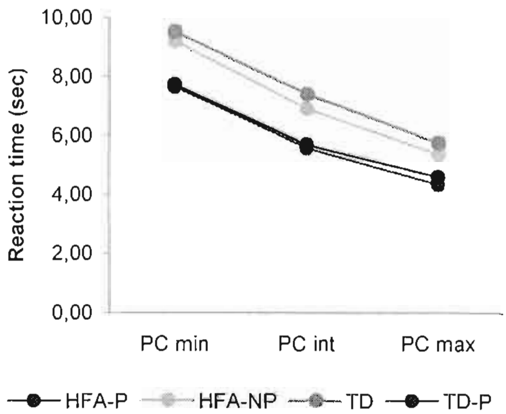


Figure 6. Long term visual memory for local (PC min) and global (PC max) BDT figures.

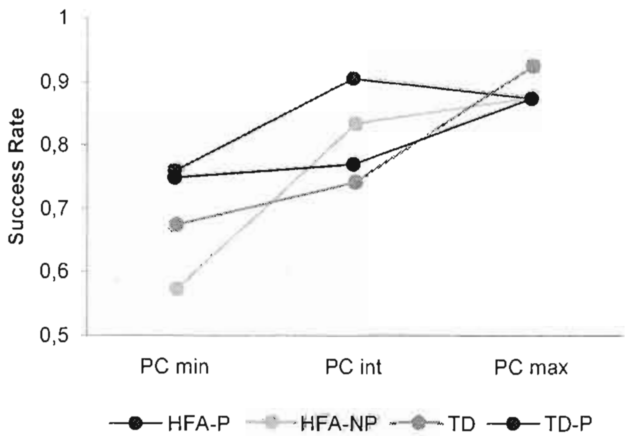


Figure 7. Targets and distractors used in the 'featural' and 'conjunctive' visual search task.

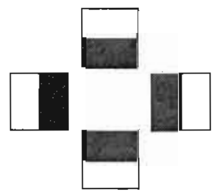
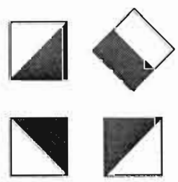
Visual Search Task	Target	Distractors
Featural		
Conjunctive		

Figure 8. Visual search task: stimulus (top); featural search (bottom left); conjunctive search (bottom right). The left frame shows an example of a 'featural' search display in which the target is present in a 16 item display. The right frame shows an example of a 'conjunctive' search display in which the target is present in a 16 item display.

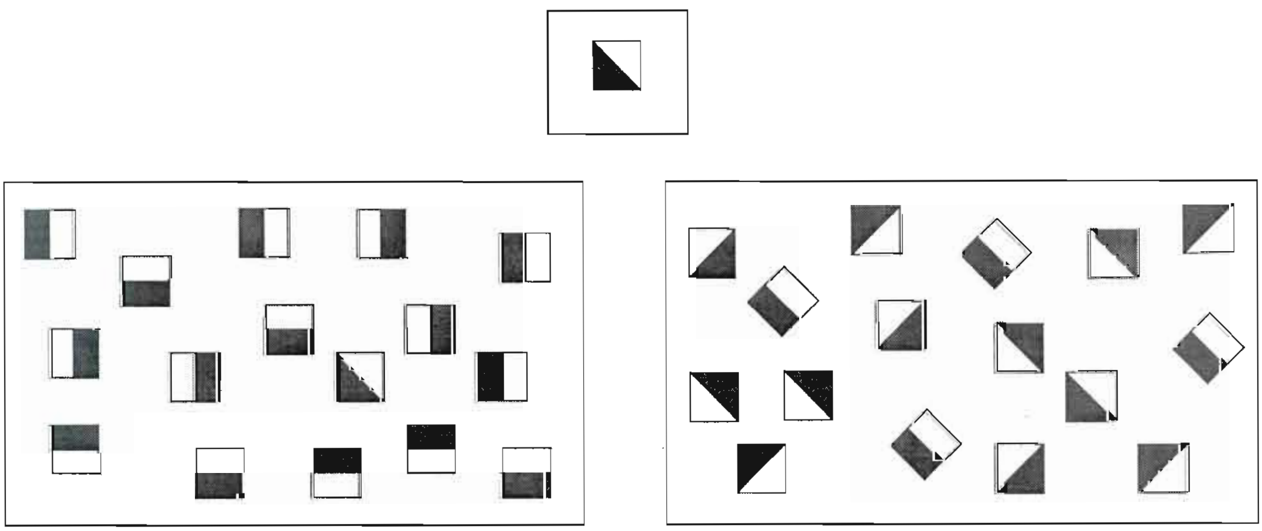


Figure 9. Average reaction time to detect target among displays of 4, 9 and 16 distractors by group and type of search trial. (C=conjunctive search; F= feature search)

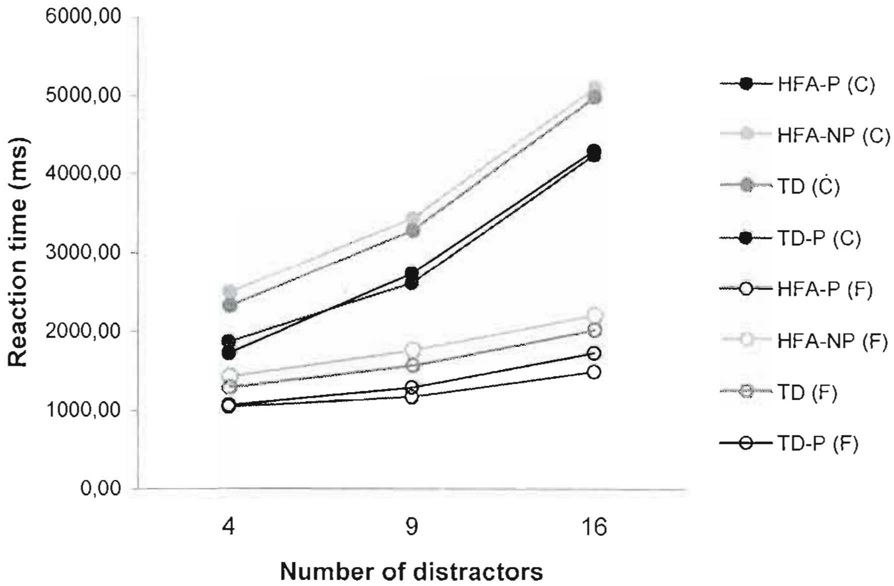


Figure 10. A, Sample target stimulus (probe), consisting of 9 x 9 grid of cells, half of which are darkened in a random fashion and exposed for 1000 ms in phase 1 and for 200, 500 or 1000 ms in phase 2. B and C, Two test stimuli, which are displayed 1000 ms after presentation of the probe in phase 1 and after a delay of 17, 250 or 8000 ms seconds during phase 2. The test stimulus on the le (B) matches the probe, whereas the test stimulus on the right (C) differs by 4 cells.

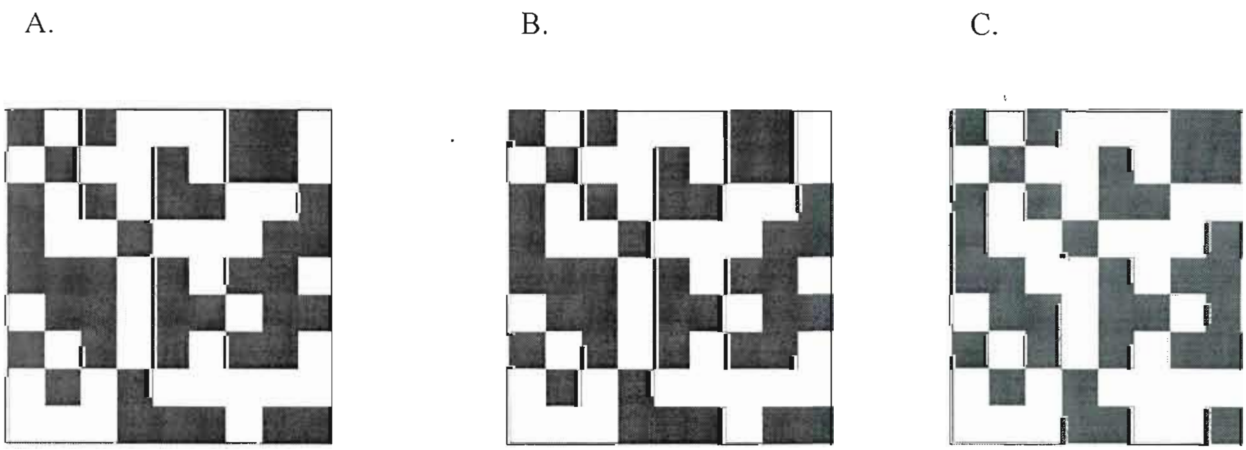
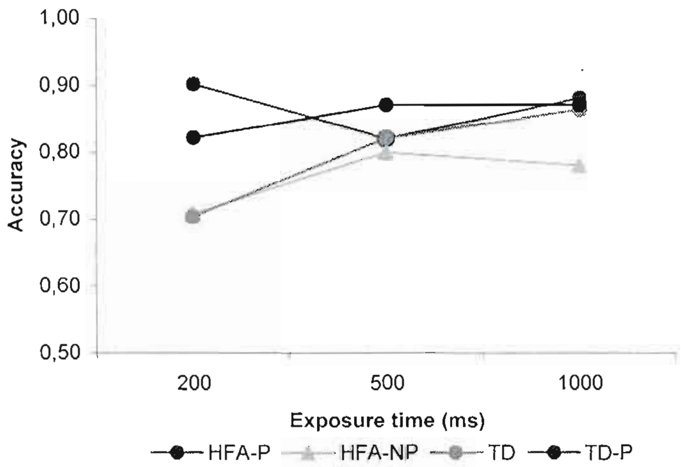


Figure 11. Accuracy at different exposure times in experiment 5.



CHAPITRE IV

DISCUSSION GÉNÉRALE

DISCUSSION

La présente thèse avait pour premier objectif d'établir une possible dissociation entre traitement cognitivo-spatial et visuo-perceptif chez les autistes de haut niveau, en investiguant séparément orientation spatiale et perception visuelle. En présence d'éventuelles supériorités chez la population autiste, la thèse avait comme second objectif d'en investiguer les mécanismes responsables, en manipulant les variables pertinentes dans chaque série de tâches. Toutefois, comme les deux séries d'expériences ont été faites de façon successive sur 6 années, que la deuxième série d'expériences a été fait à partir du résultat du premier article, et étant donné les différences méthodologiques liées au matériel investigué dans les deux tâches, l'information issue de chacun des deux domaines fonctionnels ne peut pas être mise en parallèle de façon stricte.

4.1 Première étude: traitement spatial

La première série de tâches de cette étude (exp. 1, 2 et 3), réalisée dans un labyrinthe grandeur humaine exempt d'indices perceptuels, a investigué les compétences spatio-cognitives chez les individus autistes. Les tâches spatiales ont été élaborées de façon à évaluer les compétences des sujets à divers degré d'exigence de manipulation de la carte spatio-cognitive. Cette première série de tâches n'a pas permis de mettre en évidence de supériorité dans la mise en place de carte cognitive de type 'trajet' (ex : apprentissage de trajet direct) et de type 'survol' (ex : pointage dans des directions imperceptibles exigeant une réorganisation de l'information spatiale). Ces résultats vont à l'encontre des impressions cliniques suggérant une meilleure orientation spatiale chez cette population. Ils n'appuient pas non plus la théorie du 'cerveau mâle-extrême' proposée par Baron-Cohen (2002) qui prédit une supériorité générale chez les personnes autistes des aptitudes pour lesquelles les hommes sont supérieurs aux femmes - et donc notamment de l'orientation spatiale (pour une revue, voir Jones, Braithwaite, & Healy, 2003).

Au cours de la seconde série de tâches (exp. 4 et 5), l'échelle de l'espace représenté a été manipulée (ex : labyrinthe grandeur humaine vs carte de la configuration interne du labyrinthe). Les résultats de l'expérience 4 indiquent que les individus HFA réussissent mieux dans la représentation spatiale graphique en condition indicée. Enfin, les résultats de l'expérience 5 révèlent que les individus autistes nécessitent moins de temps que les sujets contrôles pour encoder les informations nécessaires à l'apprentissage d'un trajet à partir d'un plan. Ces supériorités ne peuvent être expliquées par une meilleure carte cognitive de type « trajet » ou « survol », étant donné l'absence d'une supériorité des autistes sur le groupe contrôle évaluant ces dimensions dans les trois premières tâches de l'étude.

Une explication plausible de cette dissociation entre compétences typiques (exp. 1,2 et 3) et supérieures (exp. 4 et 5) concerne la présence ou absence d'indices visuels perceptuels dans la tâche. En effet, les expériences 1 à 3 évaluent les compétences spatiales dans un environnement expérimental qui diffère des conditions offertes dans le monde 'réel' par l'absence d'indices perceptuels (panneaux de configuration blancs). Inversement, une carte visuellement présentée ou graphiquement construite (exp. 4 et 5) représente un 'objet' composé d'éléments visuels simples, ce qui peut constituer un avantage pour la population autistique, étant donné leur supériorité dans l'encodage et la récupération des composants visuels et graphiques. En effet, les cartes peuvent être traitées en tant qu'objets, en plus de fournir une information spatiale. Or, la supériorité établie des personnes autistes à mémoriser le matériel topographique (Blair et al., 2002), à détecter (O'Riordan, Plaisted, Driver, & Baron-Cohen, 2001), apparier (Shah & Frith, 1993) et reproduire (Mottron et al. 1999) des éléments visuels simples peut constituer un avantage dans la réalisation de tâches manipulant un matériel visuo-spatial. Il apparaît donc qu'une apparente supériorité clinique en orientation spatiale peut provenir de ce que les autistes sont simplement normaux dans ce domaine, par contraste avec une adaptation faible au monde des non-autistes (telle que par exemple mesurée au Vineland). Si on se réfère à la base de données d'où a été extraite la population à l'étude, une population autistique qui réussit au 35e percentile en moyenne au

Wechsler est en moyenne inférieure au 5e percentile au Vineland. Il est donc possible que ce soit cette divergence (si on admet que leurs performances spatiales sont à leur niveau d'intelligence mesurée au Wechsler, puisqu'ils réussissent au même niveau que des contrôles appariés avec cet instrument) qui crée l'impression de supériorité de l'orientation spatiale.

Toutefois, contrairement à la seconde étude, nous n'avons pas comparé des groupes choisis selon un test préalable. Notre résultat « négatif » (soit le fait que les autistes réussissent en moyenne selon leur QI en orientation spatiale) n'exclut donc pas que certains autistes présentent des pics d'habiletés dans ce domaine. Notre résultat indique seulement que si c'est le cas, ces forces sont trop rarement représentées pour influencer la moyenne d'un groupe choisi au hasard, représentatif de la population.

4.2 Deuxième étude : traitement visuo-perceptif

Le but de la deuxième étude était de comprendre les mécanismes responsables de la supériorité déjà établie au sous-test 'Dessins avec blocs' (BD) du test d'intelligence de Weschler. Trois modèles ont été proposés pour rendre compte de la supériorité visuo-perceptuelle en autisme; le modèle de la FCC, le modèle d'hyper-discrimination et le modèle d'hyper-perception. Cette deuxième étude a mis en concurrence ces modèles en manipulant les dimensions auxquelles chacun d'entre eux attribue la performance des personnes autistes dans la tâche de dessins avec blocs de Weschler. Les individus autistes et contrôles (avec ou sans pic au BD) ont donc été soumis à une variété de tâches perceptuelles, incluant des tâches locales versus globales, de recherche visuelle, de discrimination, d'encodage perceptuel et de mémoire visuelle. Les résultats confirment l'absence d'effet de l'augmentation de la cohérence perceptuelle des figures à reproduire chez les personnes autistes (le temps d'exécution est double chez les contrôles). Ce résultat appuie de façon plus contrôlée que dans les études disponibles, et sans effet plancher / plafond possible- l'hypothèse de la présence d'un biais local chez les autistes. Toutefois, la supériorité démontrée par les individus autistes dans le traitement holistique des dessins avec blocs élimine l'hypothèse que ce biais local soit la conséquence d'un déficit dans l'analyse des aspects globaux de la figure.

Cette étude démontre que malgré un biais local, les HFA ne sont pas rigides dans l'utilisation de cette stratégie locale quand la tâche n'avantage pas ce type d'approche. Dans les expériences de l'article 2, des performances supérieures ont aussi été démontrées dans les tâches qui évaluent d'autres fonctions perceptuelles, la recherche visuelle, la discrimination et la reconnaissance à long terme. Le grand éventail de tâches perceptuelles dans lesquelles les autistes avec pic sont supérieurs appuie donc de manière forte le modèle EPF. Supériorité perceptive et biais local contribuent donc tout deux à la supériorité des autistes à la tâche de dessins avec blocs.

4.3 Implications générales pour les modèles cognitifs et neuronaux de l'autisme.

La principale convergence entre les deux études est que les supériorités objectivées en autisme appartiennent aux fonctions perceptuelles. L'association des deux articles, ajoutée à l'importante masse de littérature convergente à ce sujet montrent que la perception des informations visuelles chez les HFA oppose un surfonctionnement de la détection et de la discrimination des éléments visuels simples, un traitement local préférentiel et un traitement global préservé et un déficit de la discrimination des stimuli complexes (ex : textures et mouvements de deuxième ordre). Nous proposons que les zones perceptives primaires du canal parvocellulaire puissent être associée à ces deux aspects, efficacité de ce canal variant selon un niveau de complexité postéro-antérieur.

Au niveau des hypothèses neuronales concernant les surfonctionnements en autisme, mentionnons d'abord que la cartographie des régions fonctionnelles est profondément modifiée dans l'autisme, même pour des tâches qui n'ont apparemment peu à voir avec la symptomatologie autistique (Ex : finger tapping, Muller et al. 2001). Il est donc vain de vouloir donner une liste exhaustive de différences entre régions d'activation chez autistes et contrôles étant donné qu'à peu près toutes les régions cérébrales montrent des différences, même si celles-ci ne correspondent pas forcément à des déficits. Certains résultats semblent faire consensus. En fait, dans une revue récente des différents résultats obtenus en imagerie cérébrale chez les individus autistes, C. Frith (2003) conclut que l'activation cérébrale est tantôt normale, tantôt augmentée dans les zones perceptives striées ou extra-striées (régions postérieures), alors qu'elle est réduite dans les régions dédiées à des processus de plus haut niveau comme les aires langagières ou le cortex frontal. Dans sa revue de littérature, C.Frith démontre que la moitié des études (sur une trentaine) montrait cette particularité, faisant du surfonctionnement perceptif un phénomène général en autisme. Depuis cette date, des résultats très clairs dans ce sens ont été rapportés, notamment dans l'étude de Manjaly (2007) qui démontre à nouveau une activation postérieure supérieure lors d'une tâche de détection de figures cachées. Ces résultats suggèrent que les individus avec autisme utilisent différents réseaux neuronaux dans le traitement primaire des stimuli visuo-spatiaux. Il faut souligner que dans la plupart de ces études, la performance comportementale n'est pas inférieure chez les autistes. Il s'agit donc d'un fonctionnement à la fois différent et adapté.

Plus spécifiquement, l'hyperfonctionnement pourrait se limiter aux régions primaires de la voie parvocellulaire du cortex occipital en association avec une diminution relative de l'activité de la voie magnocellulaire. Cette hypothèse est basée sur la démonstration que la voie parvocellulaire est sensible aux stimuli statiques définis par les hautes fréquences spatiales (i.e., sensible aux informations locales ou aux détails des images), alors que la voie magnocellulaire est davantage responsable de traiter les informations dynamiques (ex : mouvement) et les informations définit par de basses fréquences spatiales (i.e. informations globales ou configurationnelles). Une activation plus grande de la voie parvocellulaire pourrait expliquer le biais local chez les autistes qui sont supérieures dans le traitement des informations à haute fréquence spatiale. De façon contraire, un déficit de la voie magnocellulaire prédit un déficit du traitement global et du mouvement biologique, qui a d'ailleurs été rapportée en autisme. Toutefois, l'intégrité du traitement de stimuli simple de premier ordre du mouvement (Bertone et al. 2003) qui reflète le fonctionnement magnocellulaire est un argument en défaveur de la théorie d'un déficit de la voie magnocellulaire. De plus, un déficit du traitement des informations à basse fréquence spatiale résultant d'un déficit de la voie magnocellulaire devrait occasionner un déficit du traitement des propriétés globales des représentations visuelles. Ceci a notamment été démontré par les résultats démontrant une performance typique chez les individus autistes dans le traitement des informations globales (Étude 2). Ainsi, certaines données convergent vers un surfonctionnement de la voie parvocellulaire mais les études plaidant en faveur d'un déficit de la voie magnocellulaire demeurent peu détaillées, et méritent une évaluation plus exhaustive.

Parallèlement, plusieurs hypothèses d'une connectivité cérébrale atypique dans l'autisme ont été avancées dans la littérature. Une mention particulière doit être faite du modèle dit de sous-connectivité cérébrale. Ce modèle, introduit par Castelli et al (2002) et surtout par Just et ses collaborateurs (2004) tire son argument de la diminution de la synchronie d'activation en fMRI lors de tâches cognitives. Ces derniers proposent une sous-connectivité entre les différentes régions cérébrales dans l'autisme. Prises isolément, chacune des régions cérébrales pourrait fonctionner normalement ou même parfois de façon plus efficace chez les individus autistes. Par contre, la coordination entre différentes régions cérébrales (nécessaire pour des tâches plus complexes nécessitant l'intégration de plusieurs informations et/ou des processus d'abstraction) serait moins bien réalisée que chez les individus non autistes. Bien qu'il soit répliqué par plusieurs groupes et avec des tâches de nature variable, il n'existe pas de consensus sur son interprétation. Spéculativement, Just a pu parler de diminution de connectivité physique en le reliant à la diminution volumétrique du corps calleux. Muller (2006) et Mottron et al. (2006) critiquent cette position en faisant de la sous-connectivité un résultat plutôt qu'une cause. Selon ces auteurs, une entrée perceptive différente, associé à une expérience de vie profondément différente, entraîne une série de divergences en cascade (et aboutissent à une « distributivité exponentielle », selon Muller). Ce terme désigne que même un nombre limité de différences dans l'état initial d'un organisme en développement aboutit, par leu jeu de l'interaction entre les systèmes et de l'interaction entre cerveau et comportement, à ce que « tout soit différent » une fois que l'organisme atteint l'âge adulte. Selon une variante de cette critique, qui est incluse dans le modèle EPF (Soulière et al., 2007) la sous-connectivité traduirait en fait une plus grande autonomie fonctionnelle des fonctions cérébrales de bas niveau dans l'autisme. On peut donc penser que dans l'autisme, les régions cérébrales perceptives fonctionneraient davantage isolément, ne recevant pas de rétroactions des régions antérieures pour moduler et coordonner leur activité. Un exemple important pour l'interprétation des résultats obtenus dans l'étude 2 de cette thèse est ainsi rapporté par Villalobos (2005). Ce dernier a examiné la connectivité entre le cortex visuel (V1) et d'autres parties du cerveau pendant des tâches visuo-motrices.

Ils ont trouvé une diminution de la connectivité (synchronie) entre V1 et le cortex frontal. Si on rapproche ce résultat de la sur-activation des aires visuelles striées et extra-striées rapportées plus haut, ceci indiquerait que les autistes traitent l'information de manière plus perceptive que les sujets typiques, soit à la fois en utilisant davantage leurs aires visuelles, et de manière plus autonome que les contrôles. Toutefois, le mécanisme spécifique qui permettrait d'unifier cette hypothèse et les performances supérieures dans les tâches perceptives visuelles, bien qu'intuitivement possible, reste à déterminer.

4.4 Répercussions cliniques et rééducatives

Ce projet a des implications importantes pour la compréhension de l'autisme en permettant de mieux comprendre les particularités que ces personnes présentent au niveau perceptif. L'hypothèse perceptive dans l'étiologie de l'autismé semble donc solidement appuyée par un ensemble de données provenant de domaines de recherche connexes. Toutefois, au niveau diagnostic dans le DSM-IV, l'autisme se définit par des critères comportementaux incluant des déficits de la socialisation, de la communication et la présence d'intérêts restreints. En surface, aucun de ces symptômes ne semble inclure des anomalies perceptives. Toutefois, même si cela ne se reflète pas encore dans la sémiologie de l'autisme, la place de la perception (auditive et visuelle) dans l'autisme revêt une grande importance sur le plan diagnostique puisque les surfonctionnements de certaines dimensions perceptives sont directement liés à certains des symptômes les plus invalidants de l'autisme. Par exemple, l'hypersensibilité auditive a généralement pour conséquence que les enfants autistes qui en sont porteurs arrêtent tout comportement social ou d'acquisition de connaissances lorsqu'ils sont en présence d'un bruit gênant et s'automutilent fréquemment dans ces circonstances. De plus, plusieurs signes d'appel suggèrent un fonctionnement perceptif visuel anormal. Ces indices incluent la fixation de lumières vives et d'objets en mouvement rotatif, une fixation visuelle plus longue des objets avant l'âge d'un an (Zwaigenbaum et al. 2005), l'exploration des objets par déviation du regard, l'autostimulation visuelle avec les doigts, l'évitement du regard et le manque de spontanéité à regarder le visage d'autrui. D'autres études montrent des particularités en vision périphérique des personnes autistes (Mottron et al. 2007). Toutes ces observations sont compatibles avec l'hypothèse d'un fonctionnement visuel atypique qui pourrait rendre compte, en partie du moins, du tableau autistique (Dakin & Frith, 2005). Quoi qu'il en soit, si les surfonctionnements perceptifs sont retrouvés dans une proportion substantielle de participants, ils pourront permettre, en association avec d'autres surfonctionnements déjà établis, d'obtenir un profil de performance caractéristique au niveau diagnostic. Parallèlement, ce projet peut aussi modifier profondément la façon dont on leur transmet de l'information en situation rééducative. En effet, dans une optique où l'on s'appuie sur les forces pour compenser les faiblesses, il est essentiel de connaître les fonctions cognitives intactes et supérieures qui peuvent servir de levier pour la réadaptation. Ainsi, la mise en évidence d'un pic d'habiletés perceptives justifie d'utiliser ce domaine pour la transmission de contenu académique.

CONCLUSION

Les données de cette thèse ont permis d'établir que les surfonctionnements perceptifs visuels se généralisent à l'ensemble des processus de bas niveau. La première étude montre que c'est dans la composante perceptive que l'on trouve les surfonctionnements en orientation spatiale et élimine l'hypothèse d'un surfonctionnement dans cette modalité, du moins dans un environnement exempt d'indices perceptuels. L'ensemble des données de la deuxième étude indique que les personnes autistes présentent non seulement un biais local et mais aussi un hyperfonctionnement du traitement perceptif de bas niveau (encodage, pairage perceptuel, discrimination, trace mnésique, ...). Cependant, et contrairement à la première interprétation du modèle de 'faiblesse de la cohérence centrale' expliquant les performances supérieures, il est démontré que ces particularités ne découlent pas d'un déficit du traitement des aspects globaux de l'information. Des études ultérieures, notamment en imagerie et en psychophysique, seront nécessaires afin de mieux comprendre la nature exacte des anomalies perceptives chez cette population.

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