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Lo sviluppo e le basi neurali della cognizione sociale: studi sull'attribuzione di stati mentali e sulla valutazione di azioni distributive

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Indice

Introduzione

Gli studi sulla cognizione sociale si occupano dei processi attraverso cui gli individui acquisiscono informazioni, le interpretano, le immagazzinano in memoria e le recuperano al fine di comprendere il proprio mondo sociale ed organizzare di conseguenza i propri comportamenti**.** La cognizione sociale e l'abilità di formare metarappresentazioni sono processi cognitivi strettamente associati. Per la psicologia dello sviluppo cognitivo è di centrale interesse comprendere come si sviluppano tali abilità, per comprendere i processi cognitivi presenti nella vita sociale della prima infanzia. Lo sviluppo cognitivo della conoscenza fisica (*naïve physics*) e biologica (*naïve biology*) è basato sulla capacità di formare rappresentazioni reali primarie. Diversamente, lo sviluppo della conoscenza psicologica (*naïve pshychology),* è associato allo sviluppo della capacità di formare specifiche rappresentazioni i cui contenuti sono gli stati mentali altrui (Leslie, 1994).

Leslie (1994) ha sostenuto che le meta-rappresentazioni hanno la forma generale e speciale di "Agente-Relazione Informazionale-espressione", in cui l'agente è una o più persone e l'espressione è una rappresentazione definita 'distaccata' perchè ogni riferimento alla realtà esterna viene sospeso. La Relazione Informazionale si riferisce a qualsiasi stato intenzionale, cioè qualsiasi stato mentale *circa* qualcosa, come: pensare, credere, conoscere, aver intenzione di, ecc. La Relazione Informazionale precede l'espressione e la rende "opaca", sospendendo le implicazioni di verità. Secondo questa prospettiva, la meta-rappresentazione è il meccanismo sottostante alla capacità di rappresentare stati mentali.

La capacità d'inferire gli stati mentali altrui è il cuore della vita sociale, perché tale abilità permette di comprendere i comportamenti degli altri, codificandoli in termini di stati mentali, come scopi, desideri e credenze.

Allo stato presente, molti ricercatori asseriscono che l'interpretazione dello scopo delle azioni altrui sia fondamentale per la comprensione della 'causalità psicologica', intesa come origine della capacità di inferire gli stati mentali altrui, nota come Teoria della Mente. Un importante studio affronta questo argomento, discutendo la possibilità che il ragionamento sugli stati mentali possa determinare la comprensione delle azioni altrui (Kuhlmeier, Wynn e Bloom, 2003)[1]. Kuhlmeier e al. (2003), usando un paradigma di preferenza visiva, hanno creato una situazione in cui una scena avrebbe dovuto essere, seguendo uno specifico ragionamento psicologico, preferita ad un'altra scena. Gli infanti di 12 mesi guardavano un cerchio rosso tentare di salire su per un pendio, senza riuscire ad arrivare in cima. A questo punto l'animazione continuava in due maniere differenti. In una familiarizzazione, dopo il fallimento del cerchio, un triangolo verde si spostava verso il cerchio e spingeva il cerchio verso la cima. In un'altra prova di familiarizzazione, dopo il fallimento del cerchio, un quadrato giallo si spostava verso il cerchio e lo spingeva giù. Nella fase successiva di test i bambini osservavano un altro evento in cui il triangolo e il quadrato erano posizionati ai due lati opposti del display, mentre il cerchio stava al centro. Nella scena non era rappresentato alcun pendio. Il cerchio dopo alcuni movimenti diretti verso entrambi i lati, come per decidere la direzione, alla fine si avvicinava verso uno dei due agenti, il triangolo o il quadrato. Uno studio pilota, condotto sugli adulti dagli stessi autori, ha dimostrato che l'evento in cui il cerchio sceglie l'agente che lo ha aiutato (il triangolo), era giudicato dagli adulti come coerente con gli eventi di familiarizzazione, visti precedentemente. Kuhlmeier e al. (2003) hanno trovato che i bambini guardavano di più l'evento di avvicinamento all'helper. Questi risultati sono coerenti con l'interpretazione "ricca", basata sull'inferenza degli stati mentali, intesi come credenze, desideri, intenzioni e anche disposizioni. Il cerchio rosso sembra aver mostrato una preferenza per l'agente "aiutante" (triangolo) piuttosto che per l'altro

“ostacolante” (quadrato), così i bambini hanno prestato maggior attenzione all’evento in cui il cerchio si avvicina al triangolo, ovvero all’agente che lo aveva aiutato a raggiungere lo scopo. Tuttavia, i risultati sono coerenti anche con un’interpretazione ‘povera’, per cui rimane non chiaro il processo cognitivo adoperato dai bambini.

Un studio successivo ha indagato con un compito simile la valutazione sociale nei bambini di 6 e 11 mesi, rivelando un precoce ragionamento sugli stati mentali, mediante la violazione dell’aspettativa (Hamlin, Wynn e Bloom, 2007). Gli studi di Kuhlmeier et al., (2003) e di Hamlin et al. (2007), pur usando lo stesso metodo hanno ottenuto diversi risultati, che però sono stati interpretati in maniera coerente con la conclusione per cui i bambini nel primo anno di vita hanno la capacità di inferire le disposizioni comportamentali altrui in contesti sociali complessi, coerentemente con altri studi specifici di Teoria della Mente (Onishi e Baillargeon, 2005; Surian, Caldi e Sperber, 2007).

In merito allo sviluppo dell’abilità d’inferire gli scopi delle azioni altrui si è consolidata una “ricca” interpretazione, la quale sostiene che l’infante percepisce lo scopo di un’azione quando inizia ad interpretare i comportamenti degli agenti in termini di stati mentali. I bambini sono abili a capire gli scopi degli altri agenti, perché sanno che gli altri possiedono stati mentali che li conducono ad agire (causano l’azione) per la realizzazione di uno scopo. Questa interpretazione psicologica “ricca” viene messa in discussione da un’altra interpretazione, detta “povera”, avanzata da Gergely e Csibra (2003), i quali hanno sostenuto che l’abilità d’inferire gli scopi delle azioni non implica l’attribuzione degli stati mentali. Essi sostengono che i bambini di 12 mesi applicano un principio teleologico (*teleological stance*) quando devono interpretare le azioni altrui, inferendone gli scopi. Secondo quest’assunzione le azioni sono rappresentate considerando questi elementi:1) scopo; 2) azione, come tesa a raggiungere lo scopo; 3) aspetti della realtà fisica, come impedimenti per l’azione. In questo ragionamento teleologico, gli stati mentali degli agenti non vengono considerati. Gli autori aggiungono che l’inferenza degli stati mentali non è sempre necessaria nella comprensione dello scopo di un’azione altrui. Questa spiegazione teleologica, dunque, dipende dagli aspetti della realtà e non dalla percezione della causalità relativa agli stati mentali. Essa estende i risultati di alcuni studi precedenti che hanno rivelato, nei bambini di 12 mesi, la capacità di attribuire *teleologicamente* uno scopo alle azioni degli agenti, seguendo un principio di razionalità (Gergely, Nadasdy e Bìrò, 1995). Questa assunzione inerente alla razionalità è stata dimostrata anche in uno studio sull’imitazione (Gergely, Bekkering e Kiraly, 2002). Quindi, secondo questa interpretazione, detta “povera”, gli infanti interpretano l’azione di un agente come protesa verso uno scopo. Per stabilire quale delle due interpretazioni, “ricca” e “povera”, guidi gli infanti nella comprensione delle azioni altrui, sono necessari ulteriori studi in differenti contesti e situazioni. Lo scopo generale del seguente lavoro è indagare la natura del ragionamento inferenziale nella prima infanzia, utilizzando differenti *contesti sociali e volti a stimolare le valutazioni sociali* dove gli agenti compiono varie azioni. A tal proposito, sono stati condotti vari esperimenti in cui gli infanti devono inferire gli stati mentali degli agenti: false credenze; preferenze e disposizioni; intenzioni. Il presente lavoro si suddivide in due aree d’indagine: a) Teoria della Mente; b) Valutazione sociale. Le due parti affrontano diversi quesiti su due importanti temi dello sviluppo della cognizione sociale. Nella sessione relativa alla Teoria della Mente, sono stati indagati anche i correlati neurali e il ruolo della precoce esperienza conversazionale, come fattore esperienziale.

Il primo obiettivo è saper*e quando* e *come* emerge il ragionamento psicologico, inteso come l’abilità di inferire gli stati mentali altrui. In questo lavoro, gli esperimenti studiano l’origine e la natura del ragionamento inferenziale nel secondo anno di vita, indagando, nello specifico,

l'attribuzione delle false credenze negli infanti attraverso lo sguardo anticipatorio (misure implicite) e anche negli adulti, attraverso compiti verbali (misure esplicite). Per studiare l'interazione tra la Teoria della Mente e il linguaggio sono stati condotti altri due studi. Il secondo studio ha indagato il ruolo della precoce esperienza conversazionale nello sviluppo del ragionamento sugli stati mentali. Sono stati condotti due esperimenti e confrontate due popolazioni di infanti, udenti e sordi. I risultati di questo studio hanno dimostrato il ruolo della precoce comunicazione, verbale o dei segni, sullo sviluppo della Teoria delle Mente. Il terzo studio è stato condotto confrontando le prestazioni dei bambini prescolari monolingui e bilingui. I risultati hanno messo in luce le migliori abilità di ragionamento inferenziale e pragmatico nei bambini bilingui (Siegal, Surian, Matsuo, Geraci, Iozzi, Itakura, 2010). Il quarto studio ha indagato il substrato neurale, sottostante la Teoria della Mente, per verificare l'ipotesi modulare, analizzando le prestazioni a compiti di Teoria della Mente di pazienti neurologici, con lesione prevalentemente focale nella corteccia prefrontale, e controllando la *co-azione* di altri processi cognitivi, come le funzioni esecutive e l'intelligenza generale (Geraci, Surian, Ferraro e Cantagallo, 2010). Il quarto studio ha indagato l'ipotesi modulare e del dominio specifico della Teoria della Mente, esaminando una delle regioni neurali, ritenuta specializzata nelle rappresentazione degli stati mentali altrui: la corteccia prefrontale ventromediale. Individuare un'area specifica per il ragionamento inferenziale, vuol dire sostenere ulteriormente, la teorie del dominio specifico della Teoria della Mente.

Il secondo obiettivo è indagare nella prima infanzia la valutazione sociale delle azioni distributive. A tal proposito, gli esperimenti proposti sulla valutazione sociale hanno lo scopo di approfondire negli infanti la capacità di inferire le disposizioni degli agenti, quando queste sono successive ad un processo di valutazione sociale dei comportamenti altrui. In questi due studi sono state indagate le inferenze delle disposizioni altrui anche in seguito a giudizi su comportamenti distributivi operati da diversi agenti.

Capitolo I: La Teoria della Mente, i modelli evolutivi e neuropsicologici

1.1 Il ragionamento sulle false credenze negli infanti

Il termine *Theory of Mind* è stato introdotto da Premack e Woodruff (1978) per riferirsi all'abilità di imputare stati mentali a se stessi e agli altri. Chiaramente, possedere una teoria della mente è importante nella cognizione sociale. Comprendere gli stati mentali degli altri permette di predire i comportamenti propri ed altrui, in termini di desideri e credenze.

Negli ultimi venticinque anni, la ricerca si è focalizzata sullo sviluppo della teoria della mente e, nello specifico, sulla comparsa del ragionamento inferenziale e dell'attribuzione delle false credenze agli altri. Questo argomento è importante per due ragioni: a) la comprensione delle false credenze rappresenta l'evidenza dell' abilità di considerare le informazioni disponibili ad un agente, nell'interpretare e predire le sue azioni, anche se queste informazioni sono incompatibili con le proprie (Call e Tomasello, 2008; Wimmer e Perner, 1983); b) quando i bambini iniziano ad attribuire le false credenze il ragionamento psicologico necessario per inferire stati mentali diventa attivo (Leslie, 1994; Scott e Baillargeon, 2009).

I primi studi condotti sui bambini in età scolare e prescolare hanno utilizzato *misure esplicite*, ossia compiti che richiedevano risposte esplicite, a domande dirette sulle false credenze di un agente (Wimmer e Perner, 1983; Baron-Cohen, Leslie e Frith, 1985; Wellman e Bartsch,

1988). In un compito classico (Baron-Cohen, e al., 1985), i bambini ascoltavano la seguente storia: Sally nasconde una pallina in un cesto e poi esce. Anna sposta la pallina in una scatola. Ai bambini veniva chiesto dove Sally avrebbe cercato la sua pallina al suo rientro. A 4 anni i bambini con sviluppo tipico rispondevano correttamente e indicavano il cesto (il posto di falsa credenza), mentre i bambini di 3 anni indicavano la scatola (posto reale), mostrando una mancata comprensione della falsa credenza di Sally. Questa tendenza evolutiva è stata riscontrata in altri studi (Gopnick e Astington, 1988; Perner, Leekam, e Wimmer, 1987). Questi risultati hanno portato alla conclusione che l'abilità di attribuire false credenze agli altri non emerge prima dei 4 anni (Perner, 1991; Flavell, Green e Flavell, 1990). Alcuni ricercatori hanno suggerito che l'origine delle difficoltà riscontrate nei bambini più piccoli possa esser riconducibile alla complessità delle richieste dei compiti verbali di Teoria delle Mente sulle false credenze (Bloom e German, 2000; Leslie, 1987).

Gli studi più recenti hanno usato le *misure spontanee,* rivelando la precoce abilità nei bambini del primo anno di vita di attribuire false credenze. In questi compiti, la comprensione degli stati mentali e, nello specifico l'attribuzione delle false credenze agli altri, sono rivelate dai comportamenti che spontaneamente emergono negli infanti dopo aver osservato le azioni degli agenti. Queste misure spontanee includono i compiti basati sulla *violazione dell'aspettativa* e quelli sullo *sguardo di anticipazione*. Il primo tipo di compito testa se i bambini guardano più a lungo l'evento in cui l'agente agisce in maniera non coerente con le false credenze, i secondi indagano se i bambini anticipano con lo sguardo il posto dove l'agente con una falsa credenza cerca un oggetto. Le metodologie implicite hanno 'rivoluzionato' la recente psicologia evolutiva, rivelando nel bambino del primo anno di vita il possesso di abilità socio-cognitive complesse. Il comportamento sociale del bambino risulta sin dalle prime fasi organizzato e biologicamente predisposto.

I risultati hanno rivelato che i bambini possono attribuire ad un agente una falsa credenza sulla posizione di un oggetto (Onishi e Baillargeon, 2005; Song, Onishi, Baillargeon, e Fisher, 2008; Southgate, Senju, e Csibra, 2007; Surian, Caldi e Sperber, 2007), una falsa percezione di un oggetto (Song e Baillargeon, 2008) e una falsa credenza sull'identità dell'oggetto (Scott & Baillargeon, 2009). In merito all'attribuzione delle false credenze, il noto esperimento di Onishi e Baillargeon (2005) ha indagato se i bambini di 15 mesi possono attribuire a un agente una falsa credenze relativa alla posizione di un oggetto. Il primo evento di familiarizzazione mostrava un giocattolo (una fetta di anguria) tra due scatole, una gialla e una verde. L'attore entrava, giocava con il giocattolo e poi lo deponeva dentro la scatola verde, per poi riprenderlo con la mano dopo una breve pausa. In seguito il bambino riceveva l'evento test, che variava tra i soggetti per condizione. Nel test di falsa credenza, nella 'condizione verde', il giocattolo si sposta dalla scatola verde alla scatola gialla in assenza dell'attore, mentre nella 'condizione gialla' il giocattolo si sposta nella scatola gialla in presenza dell'attore, e poi ritorna nella scatola verde in sua assenza. In ciascuna condizione gli infanti si aspettano che l'attore cerchi il giocattolo dove lui crede che sia nascosto. Dai risultati, i bambini hanno guardato più a lungo quando l'attore ha cercato l'oggetto nell'altro posto, ovvero la posizione reale.

Altre ricerche hanno esteso i risultati di Onishi e Baillargeon (2007), usando le misure implicite. Surian e al.(2007) hanno dimostrato che a 13 mesi i bambini possono attribuire a un agente, anche non umano, una falsa credenza sulla posizione di un oggetto. Nelle prove di familiarizzazione, un bruco vedeva la mano dello sperimentatore nascondere una mela dietro un muro e un pezzo di formaggio dietro un altro muro. Il bruco poi si dirigeva verso la stessa direzione, mostrando una preferenza specifica per un cibo. Nell'evento test, la mano sistemava i

due alimenti nelle posizione opposte, prima dell'ingresso del bruco. I bambini guardavano più a lungo la scena in cui il bruco si dirigeva verso la nuova posizione (posto reale) del suo alimento preferito. Questo ha dimostrato l'aspettativa dei bambini di vedere il bruco dirigersi verso la vecchia posizione (posto di falsa credenza), coerentemente con la sua falsa credenza. In seguito, Song, Onishi, Baillargeon e Fisher (2008) hanno mostrato che i bambini a 18 mesi arrivano alla comprensione che la falsa credenza di un agente sulla posizione di un oggetto può cambiare, e può esser corretta in maniera appropriata, mediante la comunicazione. In un esperimento un agente nascondeva una palla in una scatola, e poi, in sua assenza uno sperimentatore la spostava, nascondendola in una tazza. Quando l'agente riappariva, i bambini si aspettavano che avrebbe cercato la palla nella tazza se lo sperimentatore lo avesse informato verbalmente: "La palla è dentro la tazza!", e invece dentro la scatola, se lo stesso gli avesse detto: "Mi piace la tazza!". I risultati hanno mostrato la comprensione dei bambini della relazione tra l'informazione e la falsa credenza dell'agente sulla posizione della palla.

Per quanto riguarda la seconda tipologia di misura implicita, relativa allo sguardo di anticipazione nell'attribuzione della falsa credenza a un agente, i primi hanno dimostrato la capacità nei bambini di 3 anni di attribuire false credenze attraverso lo sguardo anticipatorio (Clements e Perner, 1994; Garnahm e Ruffman, 2001). In uno studio più recente, Southgate e al. (2007) hanno dimostrato che i bambini di 25 mesi possono anticipare correttamente la destinazione finale verso cui un agente potrebbe dirigersi per cercare un oggetto, coerentemente con la sua falsa credenza. Nelle prove di familiarizzazione un pupazzo nascondeva un giocattolo in una delle due scatole, mentre l'attore osservava. Dopo che il pupazzo poneva il giocattolo dentro la scatola, le due finestre s'illuminavano; in seguito l'attore apriva correttamente la finestra posizionata sopra la scatola che, correttamente, conteneva il giocattolo. Nell'evento test, l'attore vedeva nascondere il giocattolo in una scatola, e dopo, lo squillo di un telefono, si voltava indietro. In questa fase il pupazzo ritirava l'oggetto portandoselo via con sé fuori dalla scena. Quando il telefono finiva di squillare, l'attore si rigirava verso lo stage e dopo aver visto le scatole le finestre si illuminavano. A partire da questo momento venivano codificati gli sguardi anticipatori dei bambini, i quali hanno anticipato correttamente il comportamento dell'attore in merito all'apertura della finestra corretta. Inoltre i bambini hanno guardato più a lungo la finestra corrispondente alla scatola che era coerente con la falsa credenza dell'attore relativamente alla posizione del giocattolo. In conclusione, i risultati degli studi più recenti hanno dimostrato la presenza nel secondo anno di vita del possesso di una matura e complessa abilità di attribuire false credenze agli altri, usando diverse misure implicite, varie situazioni e differenti agenti naturali, umani e non umani.

1.2 Misure esplicite e misure implicite della Teoria della Mente

Dalle recenti scoperte, sorge spontaneo chiedersi il motivo del fallimento dei bambini di 3 anni nei compiti espliciti di falsa credenza. Secondo Baillargeon, Scott e He (2010), i compiti espliciti coinvolgono tre processi: 1) un processo di rappresentazione della falsa credenza; 2) un processo di selezione della risposta coerente; 3) un processo di inibizione della risposta non coerente.

I compiti impliciti, basati sulle misure spontanee, implicano solo il processo relativo alla rappresentazione della falsa credenza. I bambini piccoli fallirebbero nei compiti espliciti per il coinvolgimento di altre funzioni cognitive che potrebbero non esser loro ancora disponibili, o perché le connessioni neurali tra le varie regioni cerebrali coinvolte in queste funzioni, potrebbero

esser ancora insufficienti. Inoltre, una possibile spiegazione potrebbe esser fornita dagli studi recenti di neuroscienze, i cui risultati hanno rivelato che: la giunzione temporo-parietale gioca un ruolo importante nel processo di rappresentazione delle false credenze (Saxe e Wexler, 2005); la regione della corteccia cingolata anteriore e la corteccia prefrontale sono coinvolte nel processo di selezione della risposta (Obhi e Haggard, 2004); le connessioni tra le regioni frontali e temporali maturano in un secondo momento (Lebel, Walker, Leemans, Phillips, e Beaulieu, 2008). Questi risultati suggeriscono che i bambini piccoli potrebbero avere maggiori difficoltà nei compiti espliciti sulle false credenze a causa del coinvolgimento di altre abilità cognitive, i cui substrati neurali potrebbero esser ancora immaturi. Quando invece vengono utilizzate le misure implicite, dirette, gli infanti si rivelano capaci di attribuire agli agenti le false credenze.

1.3 'Subsystem-1' e 'Subsystem-2' nel ragionamento psicologico degli infanti

Il recente modello teorico sullo sviluppo della teoria della mente assume che i bambini nascono con un sistema di ragionamento psicologico che provvede all'interpretazione delle azioni altrui (Leslie, 1994; Gergely e Csibra, 2003; Premack e Premack, 1995; Baillargeon, Scott e He, 2010). Le assunzioni comuni sostengono che tale sistema operi senza una percezione cosciente (Song e al., 2008), si applica ad agenti umani e non umani (Onishi e Baillargeon, 2005; Surian e al., 2007), implica un principio di razionalità (Gergely, Bekkering e Kiràly, 2002). Baillargeon, Scott e He (2010) sostengono che questo sistema sia composto da due sotto-sistemi, *Subsystem-1*(SS1) e *Subsystem-2* (SS2).

Il primo, l' SS1, permette ai bambini di ragionare su due tipi di stati mentali: stati motivazionali, che riguardano la motivazione dell'agente in termini di scopi, disposizioni; stati informativi che sono congruenti con la realtà, che colgono l'informazione necessaria e disponibile dalla scena, attraverso la percezione, la memoria o l'inferenza (attribuendo agli agenti conoscenza o ignoranza). Quando nella scena la rappresentazione dell'agente è incompleta e manca di informazioni rispetto a quella dell'infante (l'agente non può vedere un oggetto), un meccanismo di *masking* blocca l'informazione che non è disponibile e permette all'infante di interpretare e predire le azioni dell'agente, condividendo con lui la sua informazione. SS1 è attivo nel primo mese di vita, ed è completamente maturo già alla fine del primo anno di vita (Csibra, 2008; Hamlin, Wynn, e Bloom, 2007; Luo e Baillargeon, 2007; Luo e Johnson, 2009; Premack e Premack, 1997; Song e Baillargeon, 2007; Tomasello e Haberl, 2003).

Il secondo sistema, SS2, estende le funzioni dell' SS1 permettendo agli infanti di attribuire agli agenti stati informativi incongruenti con la realtà, che includono le false credenze o le finzioni (Leslie, 1994; Onishi, Baillargeon, e Leslie, 2007). Quando la rappresentazione di un agente è incoerente con quella degli infanti , SS2 permette l'inferenza di queste credenze altrui divergenti. Un meccanismo *decoupling* permette ai bambini di maturare una separata rappresentazione mentale della scena che include le false credenze e le finzioni dell'agente, rendendo possibile l'interpretazione delle azioni dell'agente (Leslie, 1994).

Coerentemente con i risultati degli studi più recenti sulla teoria della mente e sull'attribuzione delle false credenze, il sistema SS2 risulta esser attivo e disponibile già nel secondo anno di vita (Onishi e Baillargeon, 2005; Southgate, Senju e Csibra, 2007; Surian, Caldi e Sperber, 2007).

1.4 Modelli non innatisti sulla Teoria della Mente

Due diverse interpretazioni alternative sono state avanzate in merito ai dati che sostengono

la capacità degli infanti di attribuire false credenze, messa in luce dagli studi che hanno adoperato il paradigma della violazione dell'aspettativa.

La prima, l'interpretazione *associazionista* proposta da Perner e Ruffman (2005), sostiene che i bambini formano delle associazioni che codificano le conoscenze degli altri, guidando le risposte degli infanti. Secondo questa teoria, nei compiti di falsa credenza che utilizzano la violazione dell'aspettativa, i bambini formerebbero delle associazioni tra l'agente, l'oggetto e la posizione dell'oggetto nascosto. Queste associazioni permetterebbero ai bambini di guardare più a lungo l'evento che non è coerente con questa associazione, ovvero quando l'agente cerca l'oggetto in un altro posto. Questa interpretazione non è confermata dagli studi recenti sul sistema SS1, poiché gli infanti in una condizione hanno guardato più a lungo l'evento che non è coerente con gli eventi di familiarizzazione, ma in un'altra condizione simile non lo fanno (Csibra, 2008; Luo e Baillargeon, 2007: Song e Baillargeon, 2007). Infatti, in molti studi, dopo aver guardato un evento di familiarizzazione che mostra un agente cercare un oggetto A, gli infanti guardano a lungo l'evento test in cui l'agente cerca l'oggetto B, ma solo se l'oggetto B è presente e visibile all'agente nelle familiarizzazioni, così che possa esser chiaro ai bambini che l'agente preferisce l'oggetto A (Luo e Baillargeon, 2005; 2007; Luo e Beck, 2010; Luo e Johnson, 2009) . Questa differenza di *looking time* indica che i bambini non formano nessuna associazione, ma considerano gli stati motivazionali e conoscitivi che guidano le azioni dell'agente (Baillargeon, Scott e He, 2010).

La seconda interpretazione dell' *evento insolito*, avanzata da Buttelmann, Carpenter e Tomasello (2009) sostiene che gli infanti non attribuiscono false credenze agli agenti, ma prendono in considerazione che l'evento è insolito (Haith, 1998). I bambini guarderebbero più a lungo l'evento non atteso perché gli eventi risultano ai bambini insoliti e strani. Questa interpretazione non trova conferma in molti studi basati sulla violazione dell'aspettativa (Onishi e Baillargeon, 2005; Surian e al., 2007), in cui l'evento inatteso, in una condizione di falsa credenza, è lo stesso atteso in un'altra condizione di falsa credenza. In tutte le condizioni gli eventi sono inattesi solo perché essi mostrano gli agenti che falliscono ad agire coerentemente con le loro false credenze.

Sono state avanzate due possibili spiegazioni relative all'attribuzione degli stati motivazionali e informativi del SS1. La prima interpretazione, detta dell'*ignoranza*, sostiene che i bambini si creano l'aspettativa considerando l'ignoranza dell'agente. Questa interpretazione si presenta in due versioni. La versione dell'*errore* suggerisce che i bambini si aspettano che l'ignoranza induca gli agenti a sbagliare (Southgate, Senju e Csibra, 2007): se l'agente è assente durante lo spostamento di un oggetto da un posizione A ad un'altra B, i bambini si aspettano che l'agente cerchi l'oggetto nel posto sbagliato. La versione dell'*incertezza* sostiene che i bambini si aspettano che l'ignoranza induca gli agenti all'incertezza, così i bambini sono sorpresi, se l'agente ignorante si dirige nel posto giusto (Wellman, 2010). Le due versioni della spiegazione dell'ignoranza non vengono confermate dagli studi recenti, basati sulla violazione dell' aspettativa, dove gli agenti sono ignoranti. Nello studio di Scott e Baillargeon (2009) due oggetti, di cui uno diverso perché composto da due pezzi, erano nascosti dietro due muri opachi negli eventi test. I bambini guardavano alla stessa maniera gli eventi in cui l'agente cerca l'oggetto nell' una o nell'altra direzione (condizione di ignoranza). In questo modo i bambini mostravano di capire la condizione di ignoranza dell'agente, relativamente alla posizione dell'oggetto, composto da due pezzi. Questi risultati indicano che i bambini, nei compiti di falsa credenza, non si aspettano che l'agente cerchi l'oggetto nel posto sbagliato (diversamente dall'interpretazione dell'errore), o sono sorpresi quando l'agente cerca l'oggetto nel posto corretto (diversamente

dall'interpretazione dell'incertezza).

La seconda interpretazione basata sulle regole comportamentali, proposta da Perner e Ruffman (2005), sostiene che i bambini comprendono le regole comportamentali del compito che l'agente ignorante dovrebbe seguire in specifiche situazioni (come nella ricerca di un oggetto). In merito alla veridicità di questa interpretazione, i ricercatori stanno esaminando la comprensione delle false credenze in varie circostanze. Stanno indagando in quali circostanze i bambini si aspettano che un agente non segua una regola comportamentale, perché in possesso di informazioni (anche false), per cui nessuna regola si applica alla situazione. Se per questa interpretazione è possibile che i bambini si aspettino qualche volta che gli agenti agiscano su false informazioni, allora essa non provvede a fornire una spiegazione alternativa ai risultati sulle false credenze negli infanti.

1.5 Il ruolo del linguaggio nello sviluppo della Teoria della Mente

Le capacità di ragionare e di attribuire metarapprensentazioni costituiscono la base dello sviluppo della cognizione sociale e delle comunicazione (Frith, Happè e Siddons, 1994). Sulla comunicazione verbale un deficit di Teoria della Mente potrebbe causare una difficoltà nel riconoscimento delle intenzioni comunicative, demotivazione alla conversazione e una difficile produzione di enunciati contestualmente appropriati (Frith, 1991; Surian, Baron-Cohen e Van der Lely, 1996).

In merito all'importanza dei contenuti della comunicazione, in accordo con il modello teorico di Vygotsky (1978), Bretherton e Beeghly (1982) hanno sostenuto che la comunicazione attraverso il linguaggio gioca un ruolo importante nello sviluppo della cognizione sociale, ipotizzando che l'abilità di acquisire conoscenze psicologiche sul se e sugli altri dovrebbe esser facilitata dalla comunicazione basata sulle intenzioni. Quest'ipotesi è stata confermata dallo studio longitudinale di Dunn, Browm e Beardsall (1991), che ha indagato la relazione tra il dialogo in famiglia sugli stati mentali e la comprensione delle emozioni altrui. I risultati hanno rivelato una continuità tra i precoci discorsi familiari sugli stati mentali (sentimenti), fatti già a 36 mesi, e la comprensione delle emozioni altrui dimostrata dagli stessi bambini all'età di 6 anni. In un altro studio, Dunn, Brown, Slomkwsky, Tesla e Youngblade (1991) hanno aggiunto che le conversazioni precoci familiari sulla causalità permettevano ai bambini piccoli di riflettere, domandarsi e capire i comportamenti altrui.

Astington e Jenkins (1999) hanno rivelato il ruolo importante del linguaggio nello sviluppo della teoria della mente, dimostrando che le abilità linguistiche possono prevedere un miglioramento di teoria della mente. Ad un campione di bambini normali di tre anni sono stati somministrati compiti di linguaggio che valutavano le competenze ricettive e produttive della semantica e della sintassi, mentre per la teoria della mente sono stati adoperati compiti di comprensione della falsa credenza e di distinzione tra realtà e apparenza. Lohmann e Tomasello (2003) hanno riportato che i bambini di tre anni mostravano miglior comprensione delle meta-rappresentazioni se era stato impartito loro un precedente training basato su discorsi che richiedevano il ragionamento sugli stati mentali e sulle prospettive altrui. Le loro conclusioni sostenevano che l'esposizione ad un linguaggio sugli stati mentali era necessario per migliorare la comprensione delle false credenze. Queste scoperte sono coerenti con gli studi condotti sui bambini sordi e sul ruolo della comunicazione, anche attraverso il linguaggio dei segni, nello sviluppo della teoria delle mente (Peterson e Siegal, 2000; Woolfe, Want e Siegal 2002).

Il linguaggio sembra aver un ruolo indiscusso nello sviluppo del ragionamento sugli stati

mentali. Recentemente è stato sostenuto che il bilinguismo precoce abbia un effetto positivo nello sviluppo delle competenze linguistiche e comunicative dei bambini, in particolare nella capacità di giudizi grammaticali, sostituzione di simboli, nelle risposte inibitorie, nei compiti che richiedono distinzione tra realtà e apparenze e nella comprensione delle massime di conversazione (Bialystock e Martin, 2004; Kovacs, 2009; Siegal, Iozzi e Surian, 2009).

Kovacs (2009) ha confrontato le prestazioni dei bambini monolingui e bilingui di tre anni usando tre compiti: due di teoria della mente che prevedevano l'inferenza degli stati mentali, e uno di controllo, basato sull'inferenza non mentale. I risultati hanno rivelato una migliore prestazione nei bambini bilingui nel ragionamento sugli stati mentali, dovuti alle loro migliori abilità esecutive di monitoraggio e d'inibizione della risposta.

Sull'effetto positivo del bilinguismo nello sviluppo delle abilità pragmatiche, Siegal e al. (2009), hanno condotto uno studio sui bambini dai 3 ai 6 anni, adoperando un compito per determinare l'abilità di identificare le risposte corrette a delle domande secondo le massime di conversazione di Grice, messo a punto da Surian e al., (1996). I risultati hanno rivelato che i bambini con bilinguismo hanno delle prestazioni migliori dei monolingui italiani o sloveni nelle abilità pragmatiche. Il bilinguismo sembrerebbe favorire lo sviluppo di una capacità migliore nel cogliere le risposte comunicative più efficaci, a causa delle abilità esecutive coinvolte nel processo di selezione e di inibizione della lingua.

1.6 I correlati neurali della Teoria della Mente

Sull'acquisizione della Teoria della Mente sono state avanzate teorie modulariste e costruttiviste. Nella proposta modularista, Alan Leslie (1994), sostenendo l'ipotesi dell'esistenza di sistemi di meccanismi specializzati nel cervello che rappresentano il substrato per lo sviluppo cognitivo, ha presunto per la Teoria della Mente l'esistenza di conoscenze innate e di un meccanismo specializzato di elaborazione e di acquisizione di informazioni. La proposta costruttivista, avanzata da Gopnik e Meltzoff (1997), sostiene che lo sviluppo della Teoria della Mente sia dovuto allo sviluppo di capacità generali di costruzione e di revisione teorica, anche partendo da una base di conoscenze innate. L'idea che possa esserci una regione neurale specializzata per la rappresentazione delle false credenze è diventata un'area di ricerca di grande interesse per le neuroscienze e per rivelare se lo sviluppo della Teoria della Mente sia determinato dall'azione di un meccanismo specializzato, come sostenuto dai teorici modularisti, o dall'intervento di varie capacità generali di costruzione ed elaborazione, come ipotizzato dai teorici costruttivisti..

Considerando i risultati di alcuni studi prestigiosi, emerge come sia difficile concludere con un'unica teoria che identifichi l'area cerebrale specifica coinvolta nell'attribuzione delle false credenze (Frith e Frith, 2006; Gallagher e Frith, 2003). La specificità neuroanatomica della teoria della mente è un prerequisito molto importante per il supporto della teoria relativa alla specificità di dominio. Ci sono due diversi approcci che stanno indagando i correlati neurali del ragionamento sulle false credenze: 1) gli studi neuropsicologici basati sullo studio delle lesioni cerebrali; 2) gli studi con tecniche di neuro-immagine e di stimolazione cerebrale.

La tradizione degli studi neuropsicologici ha rivelato che i lobi prefrontali mediali sono necessari per questa abilità. Baron-Cohen e Goodhart (1994) hanno individuato nella regione orbito-frontale di destra una maggior attivazione nei compiti con parole riferite a stati mentali. Fletcher, Happé, Frith, Baker, Dolan, e Frackowiak (1995) hanno scoperto un aumento dell'attivazione del giro prefrontale sinistro e della corteccia paracingulata durante i compiti di

teoria della mente. Per quanto riguarda la lateralizzazione emisferica, una serie di studi ha mostrato il coinvolgimento dell'emisfero destro nella capacità di teoria della mente. Winner, Brownell, Happe, Blum e Pincus (1998) hanno scoperto che le performance nei compiti TOM di secondo ordine dei pazienti con un danno all'emisfero destro erano deficitarie rispetto a quelle del gruppo di controllo, mentre le performance ai compiti TOM con meno richieste verbali dei pazienti con danno all'emisfero sinistro non erano deficitarie. Da questi risultati si potrebbe dedurre il maggior coinvolgimento del lobo frontale destro nei compiti di Teoria della Mente. Questa ipotesi è stata sostenuta da altri studi. Tranel, Bechara e Denburg (2002) hanno scoperto che la lesione alla corteccia prefrontale ventromediale destra comporta deficit nei processi sociali ed emozionali. Non c'è però un accordo sul ruolo dell'emisfero destro. Infatti altre ricerche sostengono un ruolo più importante per l'emisfero sinistro (Channon e Crawford, 2000; Fletcher e al. 1995; Goel, Grafman, Sadato e Hallett, 1995). Surian e Siegal (2001) hanno scoperto che i pazienti con lesione all'emisfero destro hanno performance peggiori nei compiti di teoria della mente rispetto a quelle dei pazienti con danno a sinistra. Nonostante gli studi abbiano attribuito alla corteccia mediale frontale un ruolo importante nel TOM, rimane aperta la possibilità che la lesione ad una specifica regione neurale non possa essere sufficiente a causarne un deficit.

Siegal e Varley (2002) hanno sostenuto che la teoria della mente sia supportata da un esteso sistema neurale. Alcune componenti di questo sistema, come il linguaggio relativo all'emisfero sinistro, i lobi frontali e la corteccia temporo-parietale destra, non sono dedicate solo al ragionamento degli stati mentali. Il sistema comunque ha un centro, una componente specifica per dominio che è localizzata sul circuito dell'amigdala. In questo sistema il deficit della teoria della mente può esser interpretato come un'anormalità del centro di questo sistema o il fallimento di uno dei componenti del sistema necessario per il successo in alcuni compiti di teoria della mente. Avrebbe un ruolo anche l'assenza di esperienze sociali necessarie allo sviluppo del TOM.

Amodio e Frith (2006) propongono un modello teorico in cui attribuiscono alla corteccia prefrontale mediale diverse funzioni, delineandone una mappa. Innanzitutto il lobo prefrontale si occupa di determinare i futuri comportamenti, pianificandoli, basandosi su valutazioni anticipate. La parte caudale è associata alle azioni, mentre la parte orbitale ai risultati delle azioni (esiti). La parte anteriore è associata alle rappresentazioni metacognitive, che consentono di ragionare sui significati e i valori associati ed attribuiti alle azioni.

Gli studi condotti con le tecniche neuroimmagine, attribuiscono invece, alla giunzione temporo-parietale un ruolo importante nei compiti di cognizione sociale, di comprensione dei pensieri e delle credenze altrui. (Saxe e Powell, 2006). Secondo Saxe e Powell (2006) i risultati provenienti dalle immagini della risonanza magnetica funzionale, fMRI, identificano cinque componenti della cognizione sociale, cui sarebbero associate diverse aree cerebrali. La corteccia posteriore temporale sarebbe deputata alla percezione dei corpi degli altri; il solco posteriore superiore temporale all'abilità di interpretare le azioni degli altri in termini di scopi; la giunzione temporo-parietale alla capacità di ragionare sui contenuti degli stati mentali e la corteccia prefrontale sarebbe divisa in due regioni, la parte ventromediale per l'empatia e la parte dorsomediale per le rappresentazioni triadiche.

Differenti risultati provengono dagli studi sul *mirror neuron system*, in cui Rizzolatti e Craighero (2004) sostengono l'esistenza di un sistema speciale di neuroni che si attivano durante l'imitazione dell'azione degli altri e la comprensione delle intenzioni altrui. I neuroni specchio sono stati individuati in primo momento nella corteccia frontale premotoria. Rizzolatti e Craighero(2004) scoprirono l'attivazione di tali neuroni quando la scimmia operava un'azione diretta ad uno scopo o quando la stessa osservava qualcuno compiere la stessa azione. Iacoboni,

Molnar-Szakacs, Gallese, Buccino, Mazziotta e Rizzolatti (2005) hanno usato un paradigma con adulti in cui era presente una stessa azione (l'afferrare), ma in un due differenti contesti, che si differenziavano per la presenza di briciole e torte parzialmente consumate. L'attivazione dei neuroni era diversa per i due contesti, nonostante il movimento fosse uguale. Questi dati suggeriscono che il sistema dei neuroni specchio è coinvolto nella codifica delle azioni e nella comprensione dell'intenzionalità altrui.

Nonostante questi risultati, pare che ci sia un accordo nel ritenere che la comprensione degli stati mentali richieda un'attivazione neuronale complessa, *ma* sono ancora necessari molti studi prima di definire quale sia il substrato neurale relativo al ragionamento sugli stati mentali.

Capitolo II: La valutazione sociale negli infanti

2.1 Lo sviluppo del senso morale secondo i modelli classici

Nel panorama scientifico della psicologia evolutiva ci sono pochi studi che indagano lo sviluppo della valutazione sociale negli infanti. Le persone adulte valutano gli altri rapidamente e automaticamente sulla base delle loro azioni in un contesto sociale. L'origine e le prime fasi dello sviluppo di queste abilità non sono ancora note. La valutazione dei comportamenti altrui implica un processo di giudizio che spesso avviene in un contesto morale. Per comprendere lo sviluppo cognitivo del giudizio morale, non si possono escludere i modelli classici di Piaget (1932) e Kohlberg (1981). Entrambe le teorie sono accomunate dal ritenere lo sviluppo del giudizio morale dipendente dallo sviluppo cognitivo e che segue delle tappe in un percorso obbligato e tracciato dalle leggi dello sviluppo.

Secondo Piaget (1932), lo sviluppo del senso di giustizia rappresenta un aspetto primario del passaggio da una morale eteronoma ad una morale autonoma, ed è strettamente legato all'esperienza col gruppo dei pari. Piaget ha delineato lo sviluppo della comprensione delle due nozioni classiche di giustizia: distributiva e retributiva.

La giustizia distributiva mira a promuovere un'equa ripartizione delle risorse comuni cioè una società materialmente giusta, nella quale non vi sia posto per invidie o risentimenti per le fortune altrui. La giustizia retributiva promuove la distribuzione delle sanzioni e delle ricompense per le azioni compiute: il delitto merita una pena equivalente, la buona azione, il premio corrispondente. La giustizia retributiva compare precocemente, ha una natura più individuale e prende in considerazione il rapporto fra sanzioni e ricompense. La comprensione della giustizia distributiva sembra emergere in un secondo momento, quando si evolve la morale autonoma: ha una natura sociale ed è dominata all'inizio da un principio di uguaglianza e poi di equità. Nei suoi studi Piaget ha indagato anche la nozione di sanzione espiatoria che domina nella fase del realismo morale: essa è legata all'idea che ad ogni trasgressione debba seguire una punizione severa, che appare conseguenza naturale e necessaria dell'atto punitivo e che in ogni caso verrà da qualche parte, magari non dalle persone ma dai fatti naturali (giustizia immanente). In seguito alla cooperazione e all'esperienza del rispetto reciproco, viene eliminato il carattere espiatorio della sanzione e prevale l'aspetto della riparazione o dell'osservanza dell'obbligo reciproco. Questa reciprocità ha inizialmente un carattere semplicistico e gradualmente assume un carattere più universalistico. Inoltre, Piaget ha ritenuto che il ragionamento morale esplicito, espresso verbalmente dal bambino, sia una sorta di presa di coscienza dell'attività morale, supportata dalle capacità cognitive che si sono sviluppate.

Kohlberg (1981) ha esteso e completato la teoria piagettiana, con la quale condivide l'aspetto stadiale, la considerazione centrale dei processi di tipo cognitivo e l'interesse prevalente per il pensiero morale. L'estensione consiste in un'articolazione degli stadi che arrivano all'età adulta e in una definizione precisa dei criteri che consentono di collocare le varie forme di giudizio morale nei successivi stadi. Per Kohlberg è fondamentale il parallelismo tra gli stadi dello sviluppo intellettivo e quelli dello sviluppo del pensiero morale. Il possesso delle competenze cognitive di uno stadio è una condizione necessaria ma non sufficiente perché siano presenti le corrispondenti caratteristiche del giudizio morale. Servendosi di interviste analoghe a quelle adoperate da Piaget, Kohlberg ha proposto ai soggetti dei dilemmi morali, rappresentati da vicende nelle quali il protagonista può prender diverse decisioni; in seguito ha delineato una serie di stadi di sviluppo morale dall'infanzia all'età adulta. La nozione di stadio è strettamente legata a quella di Piaget: lo sviluppo degli stadi va da un livello inferiore ad un livello superiore ed ogni

individuo passa da uno stadio a quello successivo (principio di invarianza della sequenza). La sequenza ideata da Kohlberg prevede 3 livelli di giudizio morale, ognuno dei quali è diviso in 2 stadi.

Livello preconvenzionale: in questo livello (sotto i 9-10 anni), si considerano le norme che possono comportare una punizione. La motivazione sulla quale si basa la valutazione è legata al rischio di ricevere una punizione e quindi all'obbedienza all'autorità. La prospettiva socio-cognitiva è quella egocentrica.

- Stadio 1: orientamento premio-punizione non si tiene conto di possibili differenze nei punti di vista dai quali si valuta un dilemma morale, né si considerano adeguatamente le intenzioni che determinano un comportamento.
- Stadio 2: orientamento individualistico e strumentale:ciò che è giusto o sbagliato diventa più relativo, e non dipende più così radicalmente dalla sanzione dell'autorità.

Livello convenzionale: questo livello (dai 13/14 anni fino ai 20 anni) è caratterizzato dal rispetto di norme che sono state socialmente approvate, e non più dalle conseguenze immediate dell'azione individuale.

- Stadio 3: orientamento del "bravo ragazzo": assume importanza il rispetto delle norme in modo da rispondere alle aspettative positive della comunità della quale si condividono i valori.
- Stadio 4: orientamento al mantenimento dell'ordine sociale: le relazioni interindividuali vengono considerate nel contesto di un sistema, le cui regole non devono essere infrante. Le norme morali non valgono soltanto in quanto legate ad un gruppo con il quale si hanno legami affettivi ma connesse con il proprio ruolo all'interno della società, le cui leggi vanno rispettate in quanto garantiscono l'ordine sociale.

Livello post-convenzionale (regolato da principi):le norme morali vanno al di là della società nella quale si vive, sono legate ad un sistema di principi astratti e di valori universali.

- Stadio 5: orientamento del contratto sociale: le regole morali non sono fisse e immutabili, ma sono create e quindi modificabili in base ad una sorta di contratto sociale.
- Stadio 6: orientamento della coscienza e dei principi universali,che possono non essere scritti nelle leggi e dei quali ognuno risponde alla propria coscienza.'

Non tutti gli studiosi hanno accettato e condiviso le conclusioni della teoria di Kohlberg. La critica più importante ha interessato soprattutto la presunta universalità delle tappe dello sviluppo morale. In particolare sono state criticate:

a) Esclusiva attenzione ai valori della civiltà occidentale;
b) Rigidità nella suddivisione degli stadi;
c) Campione formato quasi esclusivamente da soggetti di sesso maschile.

2.2 Le nuove proposte teoriche sullo sviluppo del 'senso morale'

Piaget e Kohlberg hanno il merito di aver richiamato l'attenzione sulla psicologia dello sviluppo morale e di aver osservato il modo in cui si modifica il ragionamento morale nel corso dello sviluppo. Negli ultimi anni, lo sviluppo del senso morale è diventato un'area di grande interesse, nonché di dibattito per le scienze cognitive. Alcune recenti proposte teoriche hanno esteso la prospettiva rawlsiana sull'origine e sullo sviluppo del giudizio morale (Hauser, 2006; Rawls, 1971), basata sull'analogia tra il senso morale e la facoltà del linguaggio descritta da Chomsky. In questa prospettiva si ipotizza l'esistenza di "una grammatica morale universale", dotata di conoscenze innate che forniscono i fondamenti per lo sviluppo delle capacità di giudizio

morale. La mente umana sarebbe dotata di principi universali che guidano lo sviluppo delle competenze morali. Questa dotazione biologica non determina in modo endogeno un sistema morale, altrimenti tutte le culture dovrebbero sviluppare lo stesso sistema di valori. Il contesto culturale specifica il contenuto dei principi, fissando dei parametri. In questo modo il meccanismo dei principi e dei parametri spiegherebbe la componente biologica e culturale del sistema morale. Hauser (2006) ha presentato tre possibili spiegazioni allo sviluppo del "senso morale"mediante tre modelli esplicativi: il modello *kantiano, humeano e rawlsiano*.

Il modello "*kantiano"* è basato sul costruttivismo epigenetico (Kohlberg, 1981), sostenendo che il soggetto formula i giudizi a partire da un ragionamento razionale ed esplicito. Questo processo prevede una fase di apprendimento delle norme convenzionali. La letteratura recente concorda nel ritenere poco plausibile il modello kantiano, che per Hauser, presenterebbe i seguenti limiti: inadeguata spiegazione del processo di apprendimento e ruolo eccessivo attribuito al ragionamento esplicito.

Decisamente più plausibile è il modello "*humeano"*, basato sulla tesi dell'innatismo del senso morale, senza postulare una competenza dominio-specifica, riconducendo le capacità morali ad un meccanismo emozionale che codifica una risposta positiva/negativa a situazioni sociali e produce come output un giudizio morale. Si tratta di un sistema automatico studiato dalla psicologia sociale (Haidt, 2001), e coerente con l'ipotesi di Damasio, basata sui risultati del marcatore somatico (Damasio, 2005).

Infine, il modello "*rawlsiano"*, prevede tre tipi: debole, moderato e forte. Il tipo debole per l'apprendimento delle norme è dotato di un meccanismo che non nasce da alcun principio generale; il tipo moderato è dotato di principi e parametri per costruire un sistema morale; il tipo forte nasce con principi morali specifici, indipendentemente dall'ambiente culturale. Hauser (2006) sostiene che il secondo fenotipo, quello moderato, sia il più plausibile e che la ricerca attuale non permette di decidere quale sia il modello esplicativo migliore per cui la questione rimane aperta.

Dupoux e Jacob (2007) hanno avanzato una critica all'analogia tra la facoltà morale e il linguaggio proposta da Hauser (2006). Essi hanno sostenuto che: 1) le credenze morali esplicite appartengono alla facoltà morale; 2) la competenza morale manca di strutture grammaticali; 3) le strutture dei principi e dei parametri non possono spiegare la diversità morale. Sulla base di simili considerazioni, Rorty (2006) ha negato che la moralità possa aver un'origine biologica e innata. In contrapposizione a quest'assunzione, Dupoux e Jacob (2007) hanno sostenuto che molti processi cognitivi, come la percezione del colore, non hanno alcuna struttura grammaticale e dipendono dal nostro bagaglio biologico. Pur non concordando sul parallelismo tra la facoltà morale e il linguaggio, la loro posizione non ha escluso l'origine innata del senso morale, ipotizzando che il giudizio morale emerga dalle risposte emotive automatiche e che le complesse computazioni tengano conto delle intenzioni nelle interazioni sociali.

2.3 I precursori del giudizio morale nell'infanzia

A differenza della ricca letteratura sul giudizio morale dei bambini prescolari e scolari, sugli infanti non ci sono molti studi relativamente al ragionamento morale, nonostante sia di grande interesse scoprire l'origine del senso morale mediante le misure implicite.

Un prima indagine sulla capacità dei bambini di 12 mesi di attribuire una valenza sociale alle azioni, ha mostrato che gli infanti attribuiscono un valore positivo alle azioni degli agenti, come aiutare e accarezzare, ed un valore negativo ad altre, come impedire e litigare (Premack e Premack, 1997). In un altro studio è stato rivelato che bambini di 12 mesi associano le azioni

positive alle facce piacevoli e le azioni negative alla facce non piacevoli (Taylor-Pertridge, Griffin, Rosen, Langlois e Principe, 2006). Questi primi studi sui bambini di 12 mesi hanno dimostrato che la semplice osservazione dei comportamenti altrui è sufficiente a generare una valutazione sociale.

Uno studio recente ha rivelato che gli infanti di 11 mesi giudicano l'azione di un agente verso gli altri, valutandola come solidale o avversa (Hamlin, Wynn e Bloom, 2007). In questo studio, i bambini hanno dimostrato di preferire l'agente che aiuta un altro a raggiungere uno scopo a quello che invece ostacola.. In questo studio viene adottato il paradigma della violazione dell'aspettativa che valuta se un bambino anticipa una certa azione sulla base degli eventi che ha visto precedentemente. Nel primo esperimento i bambini guardavano degli eventi messi in scena utilizzando piccoli oggetti di legno in forme geometrica (quadrato, triangolo e cerchio) a cui erano applicati un paio di occhi. In ogni evento un agente, il 'climber', cercava di risalire un pendio. Nella fase di familiarizzazione i bambini potevano vedere uno dei due eventi seguenti. Nell'evento con 'agente solidale' il climber veniva aiutato a salire dal secondo agente. Nell'evento con agente avverso, il 'climber' non riusciva a salire perché l'altro lo aveva ostacolato. Nella fase test, i bambini vedevano due tipi di eventi: in uno il 'climber' si avvicinava all'agente solidale, nell'altro evento invece sceglieva di avvicinarsi all'agente ostacolante. I risultati hanno mostrato che i bambini di 10 mesi hanno guardato di più quando hanno visto che il 'climber' si dirigeva verso l'agente ostacolante. Inoltre, i bambini, quando in un test successivo sono stati messi di fronte ad entrambi gli agenti (in assenza del 'climber'), hanno preferito afferrare o toccare per primo l'agente solidale. Persino i bambini di 6 mesi hanno manifestato una preferenza significativa per l'agente cooperativo nel compito di scelta. Hamlin e al., (2007) hanno concluso che le abilità precoci, messe in luce nel loro studio sono coerenti con le recenti teorie dello sviluppo del senso morale e sono in contrasto con i modelli classici.

Usando gli stessi stimoli, Hamlin, Wynn e Bloom (2010) hanno indagato la valutazione sociale nei bambini più piccoli, prima dei 6 mesi di vita. I risultati hanno rivelato che i bambini di 3 mesi valutano gli agenti per i loro comportamenti verso terzi.

Jacob e Dupoux (2008) hanno commentato i risultati di Hamlin e al. (2007), dimostrando come questi dati suggeriscano una cognizione morale e sociale basata su *core systems,* cioè su sistemi computazionali e specializzati che elaborano le informazioni sociali ed emozionali in maniera inconscia e automatica. Jacob e Dupoux (2008) sostengono che gli studi precedenti sugli altri domini dello sviluppo cognitivo, come le ricerche sulla cognizione numerica, non suggeriscono l'ipotesi della specificità di dominio della cognizione morale umana. Sono necessari ulteriori studi per approfondire l'origine e i precursori del senso morale, dal momento che il mondo morale e sociale dell'infanzia sono ancora *terra incognita*, come hanno sostenuto gli stessi Jacob e Dupoux (2008).

Capitolo III: Studi sperimentali

3.1 Studi di Teoria della Mente

Studio 1. '*Where will the triangle search? Attributing False Beliefs to a Geometric Shape at 17 months'*. L'obiettivo è stato indagare se i bambini prima del secondo anno di vita attribuiscono false credenze ad agenti, rappresentati da figure geometriche, mediante la rilevazione dello sguardo anticipatorio (misure implicite). Sono stati confrontati bambini appartenenti a due fasce d'età: 11 mesi e 16 mesi. I risultati hanno rivelato nei bambini di 16 mesi la capacità dei bambini di applicare il ragionamento psicologico ad agenti non familiari, attribuendo ad essi stati mentali, come le false credenze. Queste conclusioni contribuiscono al dibattito tra le teorie costruttiviste e innatiste sullo sviluppo cognitivo del ragionamento psicologico, nonchè sulla specificità di dominio della capacità metarappresentativa.

Studio 2. *On the origins of theory of mind: Conversational input and belief attribution in deaf and hearing infants.* L'obiettivo dello studio è approfondire il ruolo della precoce esperienza conversazionale nello sviluppo del ragionamento sugli stati mentali. Nel primo esperimento sono stati condotti due esperimenti e confrontate due popolazioni di infanti, udenti e sordi. I risultati hanno mostrato il ruolo della precoce comunicazione, verbale o dei segni, sullo sviluppo della Teoria della Mente.

Studio 3. '*Bilingualism Accentuates Children's Conversational Understanding'*. L'obiettivo dello studio è approfondire la funzione del linguaggio, nello sviluppo delle abilità pragmatiche, confrontando bambini bilingui e monolingui di età compresa tra i 3 e i 6 anni. E' stata esaminata l'abilità dei bambini di identificare le risposte ad alcune domande, come violazioni delle massime di conversazione (essere informative e pertinenti, non ridondanti, veritiere ed educate). I risultati hanno rivelato che il bilinguismo precoce rafforza lo sviluppo delle capacità pragmatiche e comunicative. Le implicazioni teoriche sono coerenti con le assunzioni che la precoce esposizione al linguaggio, o ancora meglio a più lingue, facilita le performance di comunicazione, nel riconoscere le intenzioni comunicative e risposte appropriate.

Studio 4. '*Theory of mind in patients with ventromedial or dorsolateral prefrontal lesions following traumatic brain injury'*. L'obiettivo è studiare la natura e la selettività del deficit di Teoria della Mente, nei pazienti con trauma cranico e prevalente lesione nel lobo prefrontale, nella regione ventromediale e dorsolaterale. Vengono analizzate due componenti della Teoria della Mente, il ragionamento inferenziale e la percezione sociale. I risultati hanno mostrato il coinvolgimento del lobo prefrontale ventromediale per il ragionamento inferenziale, sostenendo le teorie sul frazionamento del *mindreading system* e sul ruolo fondamentale della corteccia ventromediale nel ragionamento inferenziale, sostenendo la specificità di dominio del ragionamento sugli stati mentali rivelandone i correlati neurali.

Running head: ATTRIBUTION OF BELIEFS TO A GEOMETRIC SHAPE

Where will the triangle search? Attributing false beliefs to a geometric shape at 17 months

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Abstract

Prior research on infants' mindreading skills has focused on how they anticipate other persons' actions. This study investigated whether 11- and 17-month-olds spontaneously attribute false beliefs even to a simple animated geometric shape. Infants were shown a triangle chasing a disk through a tunnel. Using an eye-tracker, we found that 17-month-olds in the true belief task anticipated that the triangle would search for the disk in the correct place while in the false belief test they anticipated that it would search for it in the wrong, belief congruent place. These results suggest that 17-month-olds' psychological-reasoning system is applied to the actions of unfamiliar agents and triggered in the absence of any morphological features that are typical of natural agents.

More than 60 years ago, Heider and Simmel (1944) demonstrated that when people look at animated events involving interacting geometric shapes they readily go beyond the encoding of low level visual aspects of the stimuli and spontaneously attribute underlying psychological motives and other mental states to such shapes. In short, they apply their mindreading skills to make sense of the events. Current cognitive theorists agree that such skills require a metarepresentational competence, although they diverge on how such competence is acquired (e.g., Leslie, 1987; Meltzoff, 1999; Perner, 1991) and how we employ it to attribute mental states to ourselves and other people (e.g., Carruthers, 2009; Gallese & Goldman, 1998).

Developmental studies have been first focused on preschool children's mindreading skills as they are revealed in tasks that require the child to attend to the false beliefs of story characters, for short false belief tasks. Typically, successful performance on verbal test questions was not found before the age of 4 (for a meta-analysis see Wellman, Cross & Watson, 2001). Spontaneous gaze responses in verbally presented tasks (Clements & Perner, 1994; Garnham & Ruffman, 2001), or responses to pragmatically unambiguous test questions (Siegal & Beattie, 1991; Surian & Leslie, 1999; Yazdi, German, Defeyter, & Siegal, 2006) suggested the presence of beliefs understanding in three-years-olds, but not before.

Recently, however, researchers have turned to tasks more suitable to tap preverbal infants' cognitive and perceptual skills and five published studies have tried to assess infants' ability to attribute false beliefs by using violation-of-expectation tasks. Onishi and Baillargeon (2005) reported the first experimental evidence suggesting that 15-month-old infants can attribute false beliefs. Infants saw a person holding a true or a false belief about an object location searching either in a place that was congruent with her belief, or in the belief incongruent location. Infants looked longer at belief incongruent searches both in the informed person and in the misinformed person conditions.

Further infant studies have successfully replicated and extended Onishi and Baillargeon's findings using scenarios involving agents that were misinformed not only about objects' locations (Song, Onishi, Baillargeon & Fisher, 2008; Surian, Caldi & Sperber, 2007), but also about objects' identity (Scott & Baillargeon, 2009), or agents that were deceived by objects' misleading perceptual appearances (Song & Baillargeon, 2008). Song, Onishi, Baillargeon and Fisher, (2008) have also reported evidence suggesting that by 18 months infants are able to take into account the verbal and non verbal messages received by a person holding a false belief to predict whether she would correct her belief about an object location.

Converging evidence for an early false belief understanding comes also from the only previous eye-tracking study that reported infants' anticipatory looks (Southgate, Senju & Csibra, 2007). Southgate et al. (2007) tested 25-month-olds in two false beliefs scenarios involving a puppet hiding a toy in one of two boxes placed between the participant and the experimenter. Between the experimenter and the boxes there was an opaque panel with two windows, each window was placed above one of the boxes and the experimenter had to open a window to reach the toy placed into a box. In the familiarization phase infants learned that the experimenter correctly searched for the toy after that both windows were illuminated and a chime sounded. In the test phase, the experimenter saw the bear placing the toy into a box, then a phone rang, she turned away and therefore she did not see that the bear took away the toy from the box and removed it from the scene. Following the illumination of the windows, most infants' looked first at the window that was coherent with the experimenter's false beliefs about the toy's location. For example, if the experimenter's had watched the bear hiding the toy in the left box infants looked first at the window above that box. The present study employed a procedure that does not

require participants to learn arbitrary pairing of illumination and search action and it was aimed at assessing anticipatory looks in younger infants.

Relevant data are also reported in experimental work on early communicative skills. Liszkowski, Carpenter and Tomasello (2008), for example, showed that 12-month-olds differentiate between informed and uninformed partners when producing their communicative gestures. While this study was not about infants' ability to attribute false beliefs, it does suggest that infants can display a psychological reasoning ability that requires the attribution of some mental states such as knowledge states gained through perceptual access (see also Liszkowski, Carpenter, Striano & Tomasello, 2006; for further evidence on infants' reasoning about what others can see: Brooks & Meltzoff, 2002; Luo & Baillargeon, 2007; Luo & Johnson, 2009).

Why infants appear to succeed in these tasks and preschooler before 4 years of age typically fail verbal false belief tasks? The same question is asked in several areas of developmental research (e.g., Keen, 2003) and it is a hotly debated issue. One plausible explanation is that standard false belief tasks commonly used to assess preschoolers' skills, require a process of response selection that is not necessary in infant tasks because participants are explicitly required to provide an answer to a question, whereas infants measures are based on their spontaneous reactions (Scott & Baillargeon, 2009). Another possibility is that verbal tasks may require an explicit understanding that is not necessary to succeed on the implicit tasks used with infants (Onishi & Baillargeon, 2005). A third class of explanations point out the role of inhibitory processes (Leslie, Friedman, & German, 2004), particulary the processes involved in the inhibition of your own knowledge of reality while one is required to reason about other individuals' mental states of ignorance or false beliefs (Birch & Bloom, 2003), but this view needs to specify why the inhibitory skills required in standard tasks are greater than those required in implicit tasks.

An early false belief competence is clearly more coherent with nativist models (e.g., Leslie, 1987; 1994; Premack & Premack, 1997; Scott & Baillargeon, 2009) than with conceptual change theories (e.g., Perner, 1991; Wellman, 1990). Scott and Baillargeon (2009) pointed out that most current nativist accounts of the human psychological-reasoning system make four assumptions. These accounts assume, either explicitly or implicitly, that the psychological-reasoning system (1) is made up, to a large extent, of unconscious processes, (2) it is triggered by the actions of *any* entity that infants construe as an agent (Premack & Premack, 1997), (3) it includes an assumption about the rationality of agents' actions (Csibra, 2008; Gergely & Csibra, 2003) and (4) it can be fractionated into two main subsystems, one dedicated, in most proposals, to reasoning about goals and perception (actional or teleological understading) and the other to belief-desire reasoning (Leslie, 1994). The aim of the present study was to investigate the second assumption of these system-based accounts by presenting infants using an implicit false belief task involving a very unfamiliar agent.

It is well established that adults need no relevant morphological cues to engage spontaneously in mindreading processes (Heider & Simmel 1944; Kanizsa & Vicario, 1968; see also Tremoulet, & Feldman, 2000), possibly with the exception of individuals with autism spectrum disorders (Castelli, Frith, Happé & Frith, 2002; see also Senju, Southgate, White & Frith, 2009). By contrast, it is far from clear that this is also true of young infants. Several previous works showed that infants perceive causally contingent reactions at a distance of geometric shapes (Schlottmann & Surian, 1999; Schlottmann, Surian & Ray, 2009) and reason teleologically of the actions performed by boxes (Csibra, 2008; Luo & Baillargeon, 2005), geometric shapes (Gergely, Nádasdy, Csibra, & Bíró, 1995), and amorphous fuzzy objects

(Shimizu & Johnson, 2004). Teleological reasoning is based on the ability to attribute goals and interpret agents' motion accordingly. These results suggest that associative processes and previous experiences with natural agents play a modest role in triggering infants' teleological construals.

All previous studies on infants' attribution of false beliefs, however, have presented infants with events involving natural agents: 5 studies involved real people (Onishi & Baillargeon, 2005; Scott & Baillargeon, 2009; Song & Baillargeon, 2008; Song et al., 2008; Southgate, et al., 2007) and one presented animated events involving an animal (Surian et al., 2007). No previous study has examined whether infants reasoning about misrepresentations is also applied to entities that are morphologically very different from familiar or natural agents.

Investigating the scope of infants' attribution of beliefs is interesting because it allows us to reveal differences and similarities between infants and older individuals that help to clarify the role of experience on the development of the psychological-reasoning system. If learning prosesses that are based on experience with the familiar agents play a crucial role in the acquisition of mindreading skills, one should expect that, at the beginning, infants would restrict their mindreading activities to agents that are similar to familiar agents on several salient aspects, such as their shape and the non rigid motion that is typical of natural agents. By contrast, if one assumes that the infants' mindreading system is set up, from the start, to reason about agents' actions, regardless of the morphlogical cues, one should predict that it can be triggered even by very unfamiliar agents, as long as they display cues that are diagnostic of agency, such as autonomous motion (Caramazza & Shelton, 1995; Carey & Spelke, 1994; Luo & Baillargeon, 2005; Mandler, 2004; Shimizu & Johnson, 2004; Surian & Caldi, 2010), contigent reaction (Schlottmann et al, 2009) or equifinality of motions (Gergely & Csibra, 2003).

Experiment 1

Method

Subjects

Twenty-four infants participated in the experiment (10 females; mean age = 17 months 4 days, range = 14 months 6 days through 18 months 27 days). All infants were causasian. To be included in the study, infants had to show an anticipatory look in at least one of the two familiarization trials. Another 2 infants were tested but were excluded because they failed to meet this criterion.

Apparatus

The experiment was conducted in quiet rooms of 4 day-nurseries located in an urban area of Northern Italy (Rovereto, Trento). A Tobii 1750 Eye tracker was used to collect data on gaze direction and looking times. The eye tracker was integrated into a 17-in. monitor and the stimuli were presented on this monitor via a laptop computer running the Tobii's Clearview AVI presentation program. Each infant seated on an educator's lap, 50 cm from the monitor while the experimenter was behind a white curtain and controlled the stimuli presentation using the laptop computer. Two cameras were also used to record the testing sessions. One camera was placed behind the monitor to record infants' faces and the other was placed behind the infant to record the stimuli.

Stimuli and Procedure.

The testing session started with a five-point calibration procedure in which a picture of a rattle or a puppet appeared repeatedly on five different locations of the screen accompanied by attractive sounds. Infants automatically looked at the toys and their looks were used to calibrate the eye-tracker. The presentation was repeated until the calibration was considered successful, that is when measures from three or more calibration points were obtained (for further technical details

on the calibration procedure see von Hofsten, Dahlström & Fredriksson, 2005.) The light level during the calibration phase and the test phase was kept constant to reduce errors due to differences in pupil size.

Familiarization trials. Each infant was presented with two familiarization trials. The events shown in the familiarization trials involved a red triangle following a blue disk at a short distance in a motion that adults interpret as chasing. At the beginning of the events the disk was stationary in the central lower part of the monitor and the triangle was not visible. The attention of the infant was attracted on the screen with a sound and then triangle entered the scene from the left side of the monitor and approached the disk. The disk moved in the same direction and at the same speed of the triangle before being reached by it. Both shapes moved simultaneously along the path illustrated by the solid line in Figure 1. Then the disk entered in a Y-shaped tunnel from the lower entrance, it came out from one of two upper exits and went inside a nearby box. The red triangle followed the disk until the disk went into the tunnel, then it stopped in front of the tunnel's lower entrance and turned smoothly towards the disk when it came out from one of the tunnel's upper exits and went to hide into the nearby box. Finally the triangle entered the tunnel and, after a 3.5 s delay, it came out of the tunnel from the upper exit near the box chosen by the disk and went inside it. Familiarization trials ended when the infants looked away for more than 2 consecutive seconds or 60 s elapsed. The familiarization trials were identical except for the chosen hiding place.

Test Trials. On test events, the disk and the triangle moved in the lower part of the screen like they did in the familiarization trials, then the triangle went inside the tunnel while the triangle waited in front of the lower entrance. When the disk came out to hide in one the two boxes, the triangle oriented towards it, like in the familiarization trials. At this point the test events diverged from the familiarization events in that the disk came out from the first hiding place and finally moved into the other box (see Figure 1). The disk's final hiding place (right or left) was counterbalanced across participants.

On the FB task, the triangle was present when the disk went into the first box, then the triangle made a 180° rotation and moved briefly (1.4 s) out of the screen, disappearing below the lower border of the monitor, *before* the disk made its final motion to the second box. Therefore the triangle was absent when the disk changed its hiding place. By contrast, in the TB task the triangle was present when the disk changed its hiding place and oriented smoothly towards the disk during all its motions. The triangle left the screen immediately *after* the disk went into the second and final hiding place. This motion was included to maximize the similarity of the TB and the FB trials: in both trials the triangle left the screen, but given the different timing of this motion, only in the TB trial the triangle was informed about the disk's final location. All infants were tested on a False Belief (FB) and a True Belief (TB) task.

A pilot study on undergraduate students established that adults (17 out of 20) assume that the triangle in the FB animated event had not seen the disk's final motion. In the events, it is not clear why the triangle leaves the scene and this may be a source of unwanted inferences or interpretations. For example some infants may have thought that the triangle was not interested anymore in the disk. However, we assumed that the immediate return of the triangle was sufficient to counter possible irrelevant attributions that otherwise would have interfered with the generation of correct anticipatory looks. Also, the possible noise in the data due to such inferences should be equally distributed in the two conditions.

After returning on the scene, on both tasks, the triangle went inside the tunnel from the lower entrance and, after a 3.5 s delay, it came out from the upper exit next to the belief congruent box. That is, it went to the final hiding place in the TB task and to the first hiding place in the FB task. Half of the infant received the TB task first and the other half received the FB task first.

Results

To assess infants' expectations about the triangle's search actions, we first coded the first discernable saccade they made during the 3.5 s period after the triangle entered in the tunnel and before it came out of it, towards one of the two 9 cm X 12 cm areas, the Areas of Interest (AOI) in the Clearview program terms, that included the two boxes.

The effect of trail order on the number of successful anticipatory looks was not significant neither in the TB trails, nor in the FB trials (Fisher exact probability test, $p > .06$ and $p > .64$, respectively). No significant effect was found for final disk location (Fisher exact probability test, TB: $p = 1$, and FB: $p > .66$). Twenty-three infants showed anticipatory looks on both test trials and one infant showed an anticipatory look on the TB trial only. Of the 24 infants that showed anticipatory looks on TB trials, 18 gazed correctly towards the true belief congruent AOI (p = .022, p_{rep} = .923, two-choice binomial test, two-tailed). Of the 23 infants that showed anticipatory looks on FB trials, 17 gazed correctly towards the false belief congruent AOI (p = .034, p_{rep} = .902, two-choice binomial test, two-tailed, see Figure 1B). Six infants looked at the last hiding box (*tb-location*) and 6 infants looked at the first hiding box (*fb-location*) on both trials, 11 gazed correctly on both trials, namely they looked at the *tb-location* in the TB trial and at the *fb-location* in the FB trial, and none showed the reversed pattern (McNemar $(^2 = 9.09$, $p = .002$, $p_{rep} = .979$, two-tailed). The 11 infants that gazed correctly on both trials were evenly distributed in the two trial orders (4 vs. 7) and the two last disk location counterbalancing conditions (6 vs. 5). Their mean age did not differ significantly from the mean age of the rest of the sample (16.5 and 17.6 months, respectively, $t(1) = 1.8$, $p > .08$).

The gaze plots of all infants were replayed and analysed by two coders indipendently to assess whether infants had looked at: 1) the disk's initial and final hiding location and 2) the exit and return of the triangle. Both coders found that all infants had attended to all these crucial aspects of the event stimuli both in the TB and in the FB trails.

We also analysed the amount of time infants spent looking at each AOI from the moment the triangle went into the tunnel to the moment it came out of it. When the looking times of all infants were included in the ANOVA, the predicted test X location interaction, due to longer looks at the *tb-location* in the TB trial and at the *fb-location* in the FB trial, was not significant. However, the predicted interaction was significant when the looking times of the infants that showed correct anticipatory looks on both test trials (N = 11) were analyzed separately. On TB test trials these infants spent more time looking at the *tb-location* than at the *fb-location* (M = 677 ms, SD =557 ms and M = 497 ms, SD = 649 , respectively), whereas on FB trials they showed the reversed pattern (M = 191 ms, SD = 236 ms and M = 425 ms, SD = 581, respectively), $F(1, 10) = 5.41$, $p = .042$, $p_{rep} = .889$, $(_p^2 = .351$. This pattern is consistent with the hypothesis that they expected to see the triangle reappearing on the belief congruent location.

Experiment 2

The earliest evidence of false belief attribution comes from a study on 13-month-olds that employed the violation of expectation paradigm (Surian et al., 2007). The aim of Experiment 2 was to test whether false belief reasoning skills could be revealed in even younger infants using

their spontaneous anticipatory looks.

Subjects

Sixteen infants participated in the second experiment (6 females; mean age = 11 months 15 days, range = 10 months 0 days through 12 months 2 days). The criterion for subject inclusions was the same as in Experiment 1. Another 3 infants were tested but excluded, one because he failed to meet the inclusion criterion, and 2 due to fuzziness. All infants were causasian.

Apparatus, stimuli and procedure

The experiment was conducted in quiet rooms of 3 day-nurseries located in an urban area of Northern Italy (Rovereto, Trento). The apparatus, stimuli and procedure were the same as in previous experiment.

Results

Infants' expectations about the triangle's search actions were assessed by coding the first saccade they made after the triangle entered in the tunnel and before its exit from it. Fifteen infants showed anticipatory looks on both test trials and one infant showed the anticipatory look on the TB trial, but failed to complete the FB trial.

On TB trials, only 7 out of 16 infants gazed correctly towards the belief congruent location ($p > .80$, two-choice binomial test, two-tailed). On FB trials, only 7 out of 15 infants gazed correctly towards the belief congruent location ($p = 1$, two-choice binomial test, two-tailed). Two infants looked at the last hiding box (*tb-location*) and 3 infants looked at the first hiding box (*fb-location*) on both trials, 4 gazed correctly on both trials, namely they looked correctly at the *tb-location* in the TB trial and at the *fb-location* in the FB trial, and 6 failed both trials (McNemar ($\chi^2 = .100$, $p = .752$, $p_{rep} = .315$, two-tailed).

The gaze plots of all infants were replayed and analysed by two coders independently to assess whether infants had looked at the disk hiding locations, at the exit of the triangle and at its return. One coder judged that all infants had attended to all these events both in the TB and in the FB trails, the second coder agreed on all but one evaluations (99% interjudge agreement). Despite the fact that infants attended all crucial events in the animated stimuli, in Experiment 2 they did not show any sign of an ability to anticipate the agent' actions.

General Discussion

The results of Experiment 1 are coherent with the claim that 17-month-old infants are able to attribute a false belief to a simple animated shape and can anticipate its actions by relying on such attributions. By contrast, no evidence of correct anticipations was found in the 11-month-olds (Experiment 2). These findings corroborate the conclusions of previous studies on infants' false belief reasoning: between 11 and 17 months of age infants begin to apply their mind-reading system to interpret and and anticipate agents' actions. Moreover, these findings provide support for one of the assumptions made by system-based theoretical models by showing that infants' mindreading activities are not restricted to objects that are morphologically similar to familiar agents or agents that display non rigid motion, a typical features found in biological agents. This

suggests that morphological information concerning familiar agents does not play a crucial role in the acquisition or triggering of infants' mindreading competence. The present evidence, however, does not rule out that previous experiences with agents play a role in triggering the processes that allow infants use their metarepresentational resources.

These results suggest that once an entity is identified as an agent, presumably by relying on the equifinality of its actions or the presence of other agent-like dynamic cues (Mandler, 2004; Surian & Caldi, 2010), 17-month-olds can reason both about its goals and about its beliefs. Infants' ability to attribute beliefs to a self-moving, interacting object lacking agent-like morphological features suggests that infants' rely on dynamic cues to activate their psychological-reasoning system. These cues may include the ability to move autonomously (Luo & Baillargeon, 2005) and contingently at a distance (Gergely & Watson, 1999; Schlottmann & Surian, 1999; Schlottmann et al., 2008; Shimizu & Johnson, 2004; Surian & Caldi, 2010). This also suggests that the adults' tendency to mindread even the actions of geometric shapes (Heider & Simmel, 1944; Castelli et al., 2002) is not the product of a process based on analogical reasoning, but is more likely to be the output of a mindreading system that, from the start, is set up to interpret psychologically the actions of any entity identified as an agent because agents' actions are the input the system is specialized to handle (Carey, 2009; Carruthers, 2009; Leslie, 1994).

It has been argued that the violation-of-expectation tasks do not require any predictive inferences and therefore looking times results reported in studies that used such tasks may be the outcome of reasoning about the incongruence of the test outcomes *after* they have occurred and have been observed by the infants, not the outcome of predictive inferences (Keen, 2003; Southgate et al., 2007). In this view, infants react differently at the final test events in the violation-of-expectation method because they notice their incongruence with the previous parts of the test events, not because they anticipate a different final outcome. We doubt that this is the case, but from this perspective the evidence on anticipatory gazes is very valuable to strengthen the claim that infants are indeed able of predictive mentalistical reasoning. The only previous study on infants' anticipatory looks in a false belief scenario has reported positive results in 25-month-olds (Southgate et al., 2007). The present study is the first to report positive results on anticipatory looks in 17-month-olds and negative results in 11-month-olds.

There are three types of alternative accounts proposed in prior studies to explain infants' success on implicit false belief tasks without granting them a false belief competence: one account assumes familiarity effects, a second account is based on behavioural rules and the third one assumes that infants use an heuristic that links ignorance to errors. We now examine these alternative explanations in light of the available evidence. According to Perner & Ruffman (2005)'s 'event familiarity account', infants in previous violation-of-expectation studies have simply looked longer at the test outcomes that were more familiar given the agent-object-location associations previously established during the familiarization trials. Like in Southgate et al. (2007), the dependent measure in the present study was not looking time at test events, but anticipatory looks. Therefore, the relative familiarity of final outcome events could not have had any effect on our dependent measures. As it was originally proposed, the familiarity account cannot explain our results, but one may imagine a new version of such account in which previously established object-agent-place associations are involved in generating predictive looks. Given that the difference in our conditions was only in the timing in the triangle's absence, we believe this explanation is unlikely to be true, but it would be desirable to test it directly in future studies.

The 'behavioral rules accounts' claim that infants' inferences about agents' actions are

based on behavioral generalizations, rather than mentalistic concepts or principles (Perner & Ruffman, 2005). Such rules would link directly search actions to behaviors related to previous perceptual experiences, without the mediation of mental state attributions. For example, in the particular case of change-of-location tests (Onishi & Baillargeon, 2005; Southgate et al., 2007; Surian et al., 2007), infants may have relied on the rule 'agents search for a goal object where they last looked at it'. By exploiting such rule, infants (and older children too) could respond successfully in change-of-location tests without the need to form a metarepresentation. Empirical evidence currently available cannot yield a rejection, with absolute confidence, of all behavioral rules accounts. In fact, it has been proposed that generating the evidence necessary to this final rejection may be beyond the reach of methods we currently have to study cognitive processes in nonverbal organisms (Povinelli & Vonk, 2004).

However, leaning towards a cognitively 'rich' account rather than the 'economical' behavioral alternatives may be a rationally motivated choice after considering the results of all the previous studies. With little effort, one could concoct specific behavioral rules that would generate the looking times (e.g., Onishi & Baillargeon, 2005; Song et al., 2008; Surian et al., 2007), anticipatory looks (Southgate et al., 2007; the present study), spontaneous pointing behaviors (e.g., Liszkowski et al., 2006; 2008) or elicited showing (Tomasello & Haberl, 2003) reported in prior research. But the rules would be explanations proposed post hoc for each of these cases. More importantly, their viability would depend on the plausibility of a number of additional assumptions required to specify the relevant environmental input, learning mechanisms and experiences that allowed young infants to acquire all these rules.

Many researchers believe that the relative parsimony of each account can help us to choose between competing models of infants' performance (Haith, 1993). Since behavioral rules accounts posit no knowledge of mental states concepts, they are often seen as more parsimonious and, therefore, preferable (Perner & Ruffman, 2005; Povinelli & Vonk, 2004). But the relative parsimony of the behavioral rules models can be less trivial to establish if we consider the variety of contexts and tasks in which positive results have been reported so far. Also, we believe that arguments based on parsimony are not a safe ground to decide among alternative models of natural information processing systems since the core aspects of such systems are the result of a messy evolutionary process, not the outcome of a rational, parsimonious design.

The third alternative explanation that we would like to discuss is the proposal that assumes an incomplete metarepresentational competence. Could successful anticipatory gazes, in the present study, be due to sensitivity to informed vs. uninformed mental states? This would be an incomplete mentalistic competence, because it allows infants to consider the mental states of agents that lack information they themselves have, but it does not allow infants to consider others' reality incongruent mental representations. Southgate et al. (2007) proposed such a view for the results reported by Onishi and Baillargeon (2005) and Surian et al. (2007). They claimed that in the false belief conditions of those studies infants' longer looking times for the correct search actions as compared to looking times for incorrect actions were due to an 'ignorance-leads-to-error rule': infants assumed that 'ignorant agents will not search in the correct place'. This explanation would also hold for the results of the present study. However, Scott and Baillargeon (2009) have recently shown that infants behaved differently in conditions with misinformed agents holding false beliefs and conditions with ignorant agents lacking relevant knowledge. In the false belief conditions infants were surprised to observe that agents looked in the correct location, but in a condition involving an ignorant agent infants were *not* surprised when she searched in the correct location. This suggests that the ignorance-leads-to-error rule is not what

causes the patterns of anticipatory gazes in the present study and the looking times patterns reported in prior violation-of-expectation studies.

In sum, the available evidence from a variety of infant studies suggests that, in the first half of their second year of life, infants display a psychological-reasoning system that allows them to attend to agents' reality incongruent mental representation. It is a challenge for future research to reveal all the processing factors (e.g., Leslie et al., 2004; Sabbagh, Xu, Carlson, Moses & Lee, 2006) and the specific aspects of neural immaturity that limit the full expression of this system during childhood and to discover why some individuals with atypical development have a persistent difficulty in acquiring it.

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Figure Legend

Figure 1. (A) Selected frames from a false belief test trial in Experiments 1 and 2. The red triangle chased the blue disk in the lower part of the screen (first frame; white line, trajectory), the disk passed across the Y-shaped tunnel to hide inside one of the boxes while the triangle oriented towards it; then, while the triangle was out, the triangle came out from left box and went to hide in the other box (second frame); finally the triangle returned and looked in the first box visited by the disk (third frame). (B) Experiment 1: proportions of first gazes towards the false belief (*fb-location*) and the true belief (*tb-location*) congruent locations in the false belief (FB) and true belief (TB) test trials; * $p < .05$, two-choice binomial test; dotted line, chance level.

On the origins of theory of mind: Conversational input and belief attribution in deaf and hearing infants

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(in prep.)

Abstract

Recent research has shown that infants as young as 13 months display evidence of theory-of-mind ability in nonverbal violation-of-expectation tasks. These findings support the position that attribution of false beliefs is present early in development. However, the preconditions for false belief attribution in infants have not been documented. This study investigated the role of language experience in children's ability to track the false beliefs of a cartoon character on computerized ToM tasks. In Experiment 1, we compared 16 to 26-month-olds who were either hearing or deaf with hearing parents. The results show that hearing children, but not deaf children, accurately tracked the search behavior of a character with a false belief. Experiment 2 involved a comparison of the mental state language used in conversations with deaf infants by hearing and deaf mothers. Hearing mothers used far less cognitive mental state language than did their signing deaf counterparts. These findings support the position that access to at least a minimum of mental state talk either in a spoken or signed language contributes decisively to the expression of ToM reasoning – even in very early human development.

The possession of a theory of mind (ToM) permits us to reason about the mental states of others – their beliefs, desires, and intentions – and to understand and anticipate how these differ from our own and from reality. A lack of ToM would be a formidable obstacle to all sophisticated forms of human social interaction, including family cohesion and close relationships. Without the recognition that beliefs can be true or false, there would exist a constant state of misunderstanding, mistrust, and conflict. Moreover, without ToM reasoning, we would be unable to appreciate many of the hallmarks of human culture. Events portrayed in novels, theatre, and song would be meaningless as these often rely on the recognition that persons have been misled by their false beliefs. Indeed, given its importance, ToM has come to dominate the study of social cognition in typically and atypically developing children over the past 20 years.

Given its evolutionary significance, it has been hypothesized that ToM is present in human infancy as a prerequisite to language acquisition and cultural learning (Bloom, Leslie). Thus in recent years, there have been investigations designed to establish the extent to which preverbal infants demonstrate a pattern of visual attention indicative of possession of a ToM. These concern the understanding that a person with a false belief about the location of an object will search incorrectly for the object. Onishi and Baillargeon (2005) examined infants' performance on nonverbal looking tasks designed to examine differential attention to situations in which a false belief has been created in a person who has not been party to a deception. In these experiments, even preverbal 15-month-olds displayed patterns of attention that appear to reflect expectations about the search behaviour of a person with a false belief. These findings are in line with those from an increasing number of studies that have been stimulated by important alternative interpretations (Perner & Ruffman, 2005) that seek to explain this response pattern through associations between perception and behaviour without mind-mediated processes. These studies indicate that infants can indeed attribute true and false beliefs to others as indicated by infants' looking-preferences, communicative pointing gestures, and helping (Song, Onishi, Baillargeon & Fisher, 2008; Southgate, Senju & Csibra, 2007; Surian, Caldi & Sperber, 2007). Although this type of understanding may turn out to be of a different form than that shown on verbal ToM tasks by older children, experiments with infants have now shown that this pattern cannot be explained through associationist processes.

However, performance on ToM measures is not universal and there is evidence that deaf children aged 4 years and above who are from hearing families display a protracted delay on measures of ToM reasoning – a delay that does not extend to other areas of their cognitive development (Peterson & Siegal, 1998). By this account, ToM emerges and is maintained through enculturation in a language community that is lacking in deaf children who are without access to language (Perner & Ruffman, 2005), and indeed performance on verbal ToM tasks is significantly linked to the acquisition of verbal semantics and syntax.

According this account, a 'rich' interpretation for how children come to display ToM reasoning concerns the impact of language development on ToM. Nevertheless, should lack of access to language impair responses on ToM measures in infancy before language is established, ToM would reflect the importance of an early conversational input about mental states in human development even before language is acquired (Meins). (Meristo, Falkman, Hjelmquist, Tedoldi, Surian, & Siegal, 2007; Milligan, Astington, & Dack, 2007; Morgan & Kegl, 2006; Peterson & Siegal, 2000; Pyers & Senghas, 2009; Schick, de Villiers, de Villiers, & Hoffmeister, 2007; Siegal & Peterson, 2008; Siegal & Varley, 2002, 2006). In the investigation described here, we employed eyetracking technology to determine the extent to which deaf and hearing infants anticipate actions based on a knowledge that an actor has a true or false belief.

The participants in Experiment 1 were ten deaf/hearing impaired children (6 female) and 10 normal hearing children (4 female) were included in the study. Five other children were initially tested and excluded because they did not cooperate in the second session (1 deaf and 4 hearing children). The deaf children had a mean age at the time of testing of 23 months 15 days (range: 16 months 29 days to 26 months 9 days). They were healthy and without known additional disabilities such as cerebral palsy, autism, mental retardation, or visual impairment. Five children used cochlear implants (CI) and five hearing amplifications (HA). The CI children had pre-implant hearing levels in the range of 65 to 120 dB of hearing loss. The mean age of implantation was 14 months (range: 12 – 19 months), and the mean time since implantation was 7 months (range: 1 – 12 months). The HA children had hearing levels in the moderately to severely deaf range (between 50 and 80 dB of hearing loss). The mean age of amplification was 12 months (range: 3 – 26 months) and the mean time since first use of HA was 14 months (range: 0.5 – 21 months). The deaf infants had hearing parents who had gained some acquaintance with Swedish Sign Language and communicated with the infants in spoken Swedish supported with signs. However, none of the deaf children showed proficiency in SSL as measured by the MacArthur CDI that had been adapted for SSL from the comparable measure for British Sign Language that had been developed in England (see Table 1).

The ten hearing children were recruited as comparisons from preschools located in western Sweden. The mean age of the children was 23 months and 19 days (range: 19 months 11 days to 28 months 6 days). The deaf children had a mean number of siblings – older younger; the hearing children had – older younger siblings. No differences in their scores that were unrelated to sibling opportunities for conversation.

The Regional Swedish Government Ethical Review Board approved the study. Participating families were contacted through organizations for deaf/hearing impaired children and main hospitals in Sweden. The parents were informed about the purpose and procedure of the study and asked to sign a consent letter. All children were participating at home and given a small gift after the testing sessions (approximately 10 U.S. dollars). The tasks were administered in two sessions in two days in an interval of one to seven days. During the experimental session the children were seated on a parent's lap and viewed a 17-inch-monitor placed 50 cm from the infant. Gaze was measured with a Tobii T120 (Tobii Technology, Sweden) near infrared eye tracker. Each child was first given a standard 5-point infant calibration procedure represented by animated bouncing objects.

The calibration was followed by presentation of two familiarization trials and one test trial, interleaved with brief animations designed to orient the infants' attention to the screen. In the familiarization trials, the children viewed a cat (Tom) that followed a mouse (Jerry) through a Y-shaped tube with two exit points on the right and left sides. Tom was witnessing Jerry running through the tube, then exiting and hiding in one of two boxes located outside the exit points. Tom followed Jerry to look for him in the appropriate box. The purpose of the familiarizations was to teach children that Tom was chasing Jerry through the tube and looking for him in one of the boxes. In one familiarization trial, Jerry hid in the left box and in the other he hid in the right box. The order was counterbalanced across children in each group. Two children in each group did not anticipate the correct side of the Tom's appearance on the second familiarization trial. The statistical analyses are done both with and without these children.

Then half the infants in each group received the true-belief (TB) test trial. Here Jerry was shown moving through the tube again and hiding in one location but then moving to the opposite location in full view of Tom. Once Jerry disappeared in the second box, Tom entered the tube.

The other half of the infants in each group received the false-belief (FB) task. The procedure was the same except that Tom was illustrated moving out of the screen and not witnessing Jerry's second hiding. Each infant participated in both conditions (TB and FB) on separate days. The order of the two conditions and the hiding place (right vs left box) were counterbalanced across participants in each group.

For our dependent measure we coded total fixation lengths at the two areas of interest (AOIs), which were created to cover each of the two exit points of the tunnel as depicted in Figure 2. A fixation was defined as a stable gaze (within 0.8 visual degrees) for at least 100 ms. For each infant we then calculated the proportion of the time fixating at correct vs. incorrect AOI by dividing the total fixation time inside each of the AOIs by the total time Tom was travelling trough the tunnel invisible for the child, 2700 milliseconds.

Scores were analyzed using a 3-way ANOVA with condition (TB vs. FB) and location (correct vs. incorrect) as within-subject factors and group (deaf vs. hearing) as between-subject factor. There was a significant three-way interaction between group, condition and location, $F(1, 18) = 5.66$, $p < .05$, $?_p^2 = .24$. Planned contrasts showed that deaf and hearing children fixated equally at the correct location in the true-belief condition, $t(18) = 1.26$, ns., while hearing children had longer fixation times at the correct location than deaf children in the false-belief condition, $t(18) = 7.95$, $p < .001$, $?_p^2 = .78$. The interaction effect remained significant when excluding the two children in each group who didn't pass the second familiarization trial $F(1, 14) = 4.77$, $p < .05$, $?_p^2 = .25$; and planned contrasts confirmed that the hearing fixated longer than deaf children at the correct location in the FB-condition ($p < .001$, $?_p^2 = .73$), but not in the TB-condition ($p > .19$).

We carried out a second experiment to determine the mental state talk input received by the deaf and hearing children who participated in Experiment 1 together with a group of deaf children of hearing parents and typically developing hearing children in England. These consisted of 27 deaf/hearing impaired children (13 female) and 12 normal hearing children (6 female) were initially included. Four of these children were excluded: two children did not cooperate during the first testing visit, one child had cerebral palsy, and the data of another child was lost. Of remaining children, the deaf children had a mean age at the time of first testing visit of 26 months (range: 15 months to 35 months). They were healthy and without known additional disabilities such as autism, mental retardation, or visual impairment. 15 children had CIs (5 unilateral, 8 bilateral) and five hearing amplifications (HA) at the time of the first visit (there were originally 14 children with HA but 9 of these children had their implant before the time of the first visit), with no information on two children. The CI children had pre-implant hearing levels in the range of 80 to >140 dB of hearing loss. The mean age of implantation was 17 months (range: 12 – 27 months) (data available of 15 children), and the mean time since implantation was 10 months (range: 5 – 20 months) (data available of 14 children). There was no information on the hearing levels in the HA children. The mean age of amplification was a) 5 months (range: 3-9 months)(data available of 5 children) b) 4 months (range: 1 – 14 months)(data available of 13 children, including those that later switched to CI) and the mean time since first use of HA was 18 months (range: 13 – 25 months)(data available from 5 children). All deaf children had hearing parents who had no more than basic understanding of British Sign Language (BSL) (average self-ranking for mothers at '3' and '2' for fathers on a scale from 0-10 with 0=none and 10=native-like fluency). About one third of the parents (data available of 7 children) reported having taken (or were in the process of taking) at least one BSL course, and about half of the mothers reported using some kind of signing when communicating with their child (e.g., Sign Supported English).

The twelve hearing children were recruited as comparisons from preschools located in the London area. The mean age of the children was 28 months (range: 20 months to 35 months).

The parents of the children were given 10 pictures portraying emotionally charged or mentalistic situations (e.g. a girl showing signs of shyness, a father scolding his son, a boy clapping his hands after building a tower of blocks) taken from Ruffman, Slade, and Crowe (2002). Each parent was asked to look at the pictures together with their child while video recoding. Additionally, parents of deaf children were asked to fill in the MacArthur CDI measuring children's proficiency in SSL. The picture task was used to measure parents' mental state talk with the children. Parents' language use was video recorded and analyzed according to Ensor and Hughes (2008) in respect to mental state categories. These included all references to *emotions* (e.g. "happy", "pleased", "sad", "worried" or "bored"), *desires* (e.g. "want", "like", "don't like" or "hope") and *cognitive* terms (e.g. "think" or "know"). To control for parents verbosity we calculated proportions of each type of reference in relation to total amount of words used by the parents.

We then coded each conversational turn, defined as the utterances of one speaker bounded by another speaker's utterances (Ensor & Hughes, 2008). Each turn in the parent-child conversation was classified as *connected, initiated, failed* or *unclear*. *Connected* turns were defined as all utterances which were semantically related to the other interlocutor's previous turn. A turn was categorized as *initiated* when the speaker initiated a new topic that was unrelated to the previous turn and successful in eliciting a semantically related response from the other. *Failed* turns were coded as turns which were directed to the other interlocutor but failed to elicit a semantically related response. Utterances that were not understandable were classified as *unclear*. An additional category from Hughes and Ensor, conflict turns, was excluded since these were infrequent and could be included as one of the other four categories. Proportions of each type of turns were calculated in relation to total amount of turns.

Ten per cent of the conversations in each group were independently transcribed by another coder for the reliability. For the Swedish sample, Cohen's kappa was ? = .73 for the mental state categories, and ? = .54 for the quality of conversational turns. For the English sample, we then coded each conversational turn, defined as the utterances of one speaker bounded by another speaker's utterances. Each turn in the parent-child conversation was classified as *connected, initiated* or *failed*. *Connected* turns were defined as all utterances which were semantically related to the other interlocutor's previous turn. A turn was categorized as *initiated* when the speaker initiated a new topic that was unrelated to the previous turn and successful in eliciting a semantically related response from the other. *Failed* turns were coded as turns that were directed to the other interlocutor but failed to elicit a semantically related response. Proportions of each type of turns were calculated in relation to total amount of turns. All measures of talk were log transformed before conducting statistical analyses, in order to reduce any effects of the positive skew.

The number of minutes devoted conversations about the pictures by the deaf and hearing groups respectively were 8.26 (SD= 4.37) and 9.27 (SD = 5.50) in Gothenburg and X and Y in London. These times were not significantly different for children tested at either location, t = .543. For each sample, a 2 (group: deaf children vs. hearing children) X 3 (content: cognitive vs. desire vs. emotion references) ANOVA was conducted to look at the differences in mental state language among the groups. There was a significant group X contact interaction effect, $F(2, 36) = 3.85$, $p < .05$, $?_p^2 = .18$. H/H-dyads had more connected ($t(18) = 3.18$, $p < .01$, $?_p^2 = .36$) and initiated ($t(18) = 3.01$, $p < .01$, $?_p^2 = .34$) turns than D/H-dyads, while there were more failed turns

among D/H-dyads than among H/H-dyads ($t(18) = -3.21$, $p < .01$, $?_p^2 = .36$). Among H/H-dyads, the turns were significantly more likely to be connected than initiated, $t(9) = 6.39$, $p < .001$, $?_p^2 = .82$; but equally likely to be failed or connected, $t(9) = .44$, *ns*; and failed or initiated, $t(9) = 1.83$, *ns*. In the D/H-dyads, turns were more likely to be failed than connected, $t(9) = 5.02$, $p < .001$, $?_p^2 = .74$; or initiated, $t(9) = 9.09$, $p < .001$, $?_p^2 = .91$. In addition, turns in the D/H-group were more likely to be connected than initiated, $t(9) = 3.75$, $p < .05$, $?_p^2 = .61$. In the D/H-group children's age was significantly related to the proportion of connected turns, $r = .72$, $p < .05$; initiated turns, $r = .72$, $p < .05$; and failed turns, $r = -72$, $p < .05$. There were no correlations among H/H-group between the children's age and any of the conversational quality measures.

Correlations between content and quality measures showed that there was a positive relation among hearing children between parents' references to cognitive terms and the dyads connected turns, $r = .65$, $p < .05$. This indicates that dyads with more connected turns used more talk about cognitive references, and possibly that connected talk makes it easier to discuss topics with cognitive content. As there were no such correlations among deaf/hearing dyads ($r = -.09$, ns), hearing parents when using mental state talk with their deaf children do not tend to do it in connected context.

Our results demonstrate that typically developing hearing infants clearly differentiated between the search behaviour of an animated character with a true or false belief while deaf infants of hearing parents showed no differentiation. Moreover, parents directed far greater conversations about mental states to their hearing infants than to deaf infants.

Although possession of a ToM is so evolutionarily adaptive that it must be present in very early development as a core knowledge that continues in childhood, and adulthood, this knowledge needs to be "triggered" by a very early conversational input about beliefs coupled with joint attention between speakers and listeners that conveys to infants the notion that others have beliefs that may differ from one's own or that are false representations of reality. Second, the increase with age in performance on verbal ToM tasks reflects a pragmatic development that enables children to select accurately between two competing attention demands based on the canonical situation where beliefs are a true representation of reality and the situation that the test question on a ToM task refers to how a person with a false belief will be initially misled as to the location of an object.

Whatever the preferred account, there seems little doubt that performance on story-based ToM tasks does depend on early experience in conversational exchanges that provides children with the insight that others have beliefs that can differ from reality. Evidence comes from research on ToM reasoning in deaf children with different language backgrounds. Deaf children with deaf parents acquire a sign language as their native language in the same way as hearing children acquire the spoken language of their parents (Petitto & Marentette, 1991). Deaf children in sign language environment have early opportunities for exposure to conversations about the beliefs of others and to formulate an understanding of how these can be false. Such children can be regarded as 'native signers' and often display ToM both on standard verbally-based story tasks and on 'thought-picture' tasks designed to minimize the need for verbal story comprehension at the same time as hearing children (Courtin & Melot, 2005; Peterson & Siegal, 1999; Peterson, Wellman, & Liu, 2005; Remmel, Bettger, & Weinberg, 2001; Siegal & Peterson, 2008; Woolfe, Want, & Siegal, 2002). By contrast, since deaf children of hearing parents are commonly not exposed to a language until they go to school, they do not have early opportunities for exposure to conversations about beliefs. These children have difficulties on ToM tasks that persist throughout childhood and even later in development. For example, Morgan and Kegl (2006) report that

Nicaraguan deaf adults without early access to language show persistent difficulties on ToM thought picture tasks though, as in previous studies (Marschark, Green, Hindmarsh, & Walker, 2000), they do display a good degree of proficiency on other measures of mentalizing such as in characterizing the mental states of characters in cartoon stories. Other studies have been carried out in Sweden where there is legislation to provide deaf children with access to Swedish Sign Language from the age of two years. Even when provided with this early access, Swedish deaf children with hearing parents still show protracted difficulties on a range of ToM false belief tasks (Falkman, Roos, & Hjelmquist, 2007). These difficulties appear to be specific to the representation of false beliefs and do not generalize to other areas of cognitive development. Therefore, research with deaf children is consistent with the view that some minimal exposure to conversation in very early communicative exchanges is necessary to trigger a core ToM understanding in young children (Siegal, 2008; Siegal & Peterson, 2008; Siegal & Varley, 2002).

***Table 1*. Means and Range for Chronological Age and MacArthur Communicative Development Inventory (MCDI) for Swedish Sign Language (SSL) in Experiment 2.**

	Deaf children (n=10)		Hearing children (n=10)	
	Mean	Range	Mean	Range
Chronological age	23m 15d	16m 29d – 26m 9d	23m 19d	19m 11d – 28m 6d
MCDI for SSL Comprehension scale	90.8	0 – 285		
MCDI for SSL Production scale	41.7	0 – 180		

Mean and Range for Chronological Age and MacArthur Communicative Development Inventory (MCDI) for **British Sign Language (BSL) in Experiment 2.**

	Deaf children (n=14)		Hearing children (n=12)	
	Mean	**Range**	**Mean**	**Range**
Chronological age	26	15-35	28	20-35

MCDI for BSL		
Comprehension scale	195.43	20-481
MCDI for BSL		
Production scale	112.50	8-371

Mean and Range for Chronological Age and MacArthur Communicative Development Inventory (MCDI) for **English in Experiment 2**

	Deaf children (n=19)		**Hearing children (n=12)**	
	Mean	**Range**	**Mean**	**Range**
Chronological age	26	15-35	28	20-35
MCDI for English				
Comprehension scale	236.42	4-393		
MCDI for English				
Production scale	144.89	3-316		

Table 2. Descriptive Statistics for Measures of Mental State Talk and Connectedness (Percentages Shown in Parentheses)

	Deaf children		Hearing children	
Measure	M	SD	M	SD
Total utterances	728.3	509.38	578.6	365.3
Mental total	13.6 (2.21)	9.24	19.1 (3.35)	11.85
Cognitive references	5.6 (0.83)	5.27 (0.72)	12.1 (2.03)	8.97 (1.37)
Desire references	2.5 (0.33)	2.46 (0.36)	2.7 (0.48)	3.20 (0.39)
Emotion references	5.5 (2.57)	4.01 (1.05)	4.4 (0.85)	3.50 (0.74)
Number of turns	149.9	135.6	183.7	93.5
Mean length of turns	10.1	3.5	7.9	3.9
Connected turns	37.9 (19.1)	56.25	79.4 (43.7)	41.4 (19.6)
		(14.0)		
Initiated turns	16.4 (9.1)	21.62(4.7)	33.1 (18.0)	16.9 (8.0)
Failed turns	95.1 (71.3)	73.90	70.8(38.2)	68.55
		(18.7)		(26.7)
Unclear	0.5 (1.4)	1.27 (0.4)	0.4 (1.6)	0.97 (0.2)

Descriptive Statistics for Measures of Mental State Talk and Connectedness (**all recordings)**

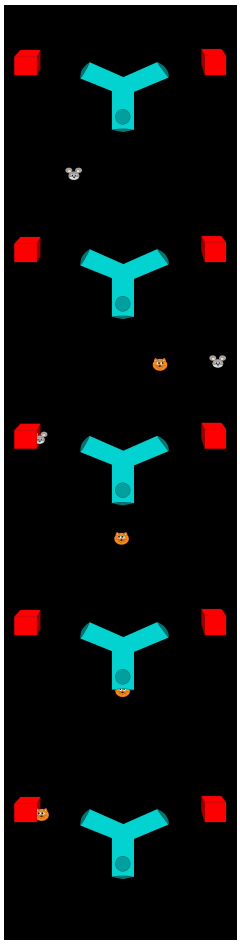
	Deaf Children		Hearing Children	
	M	SD	M	SD
Total utterances	**538.65**	**319.35**	**738.83**	**276.60**
Mental utterances	**16.57**	**16.04**	**40.42**	**25.91**
Cognitive references	**9.91**	**12.30**	**31.00**	**23.45**
Desire references	**4.00**	**4.67**	**4.42**	**3.53**
Emotion references	**2.65**	**3.77**	**5.00**	**3.02**
Number of turns	**64.09**	**53.99**	**80.00**	**55.03**
	Mean length of turns			
Connected turns	**33.04**	**34.59**	**60.67**	**51.95**
Initiated turns	**18.43**	**11.02**	**13.25**	**3.49**
Failed turns	**1.48**	**3.33**	**0.42**	**0.79**
Unclear	**11.48**	**9.67**	**5.67**	**5.23**

	Deaf/Hearing			Hearing/Hearing		
	Connected turns	Initiated turns	Failed turns	Connected turns	Initiated turns	Failed turns
Cognitive references	-.09	-.15	.09	.65*	.54	-.58
Desire references	.26	.32	-.23	-.05	-.11	.15
Emotion references	-.21	-.16	.20	-.61	-.53	.52

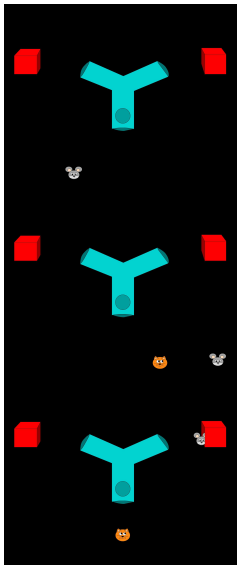
Table 3. Correlations Between Content and Quality of Talk.

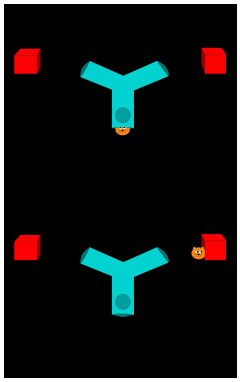
***Figure 1*. Sequence of frames shown to deaf and hearing infants in the familiarization and true- and false-belief conditions in Experiment 1.**

Familiarization 1

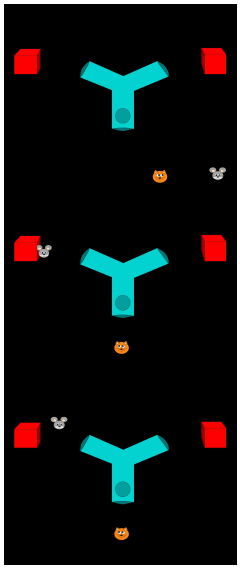


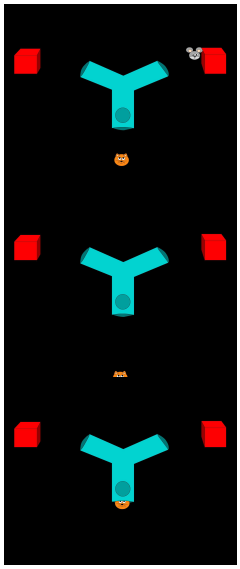
Familiarization 2



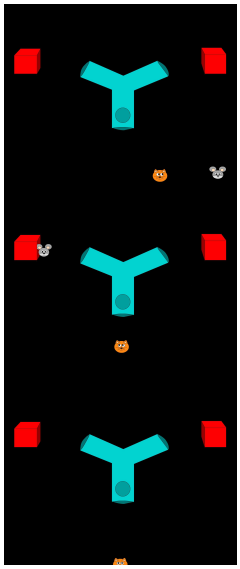


True-Belief Condition





False-Belief Condition



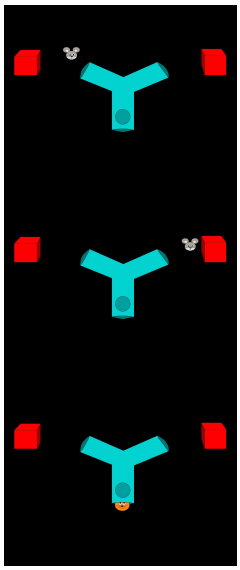


***Figure 2*. Areas of interest (AOIs) indicated in red used to score eye movements as based on knowledge of Jerry possessing a true or false belief about Tom's location**

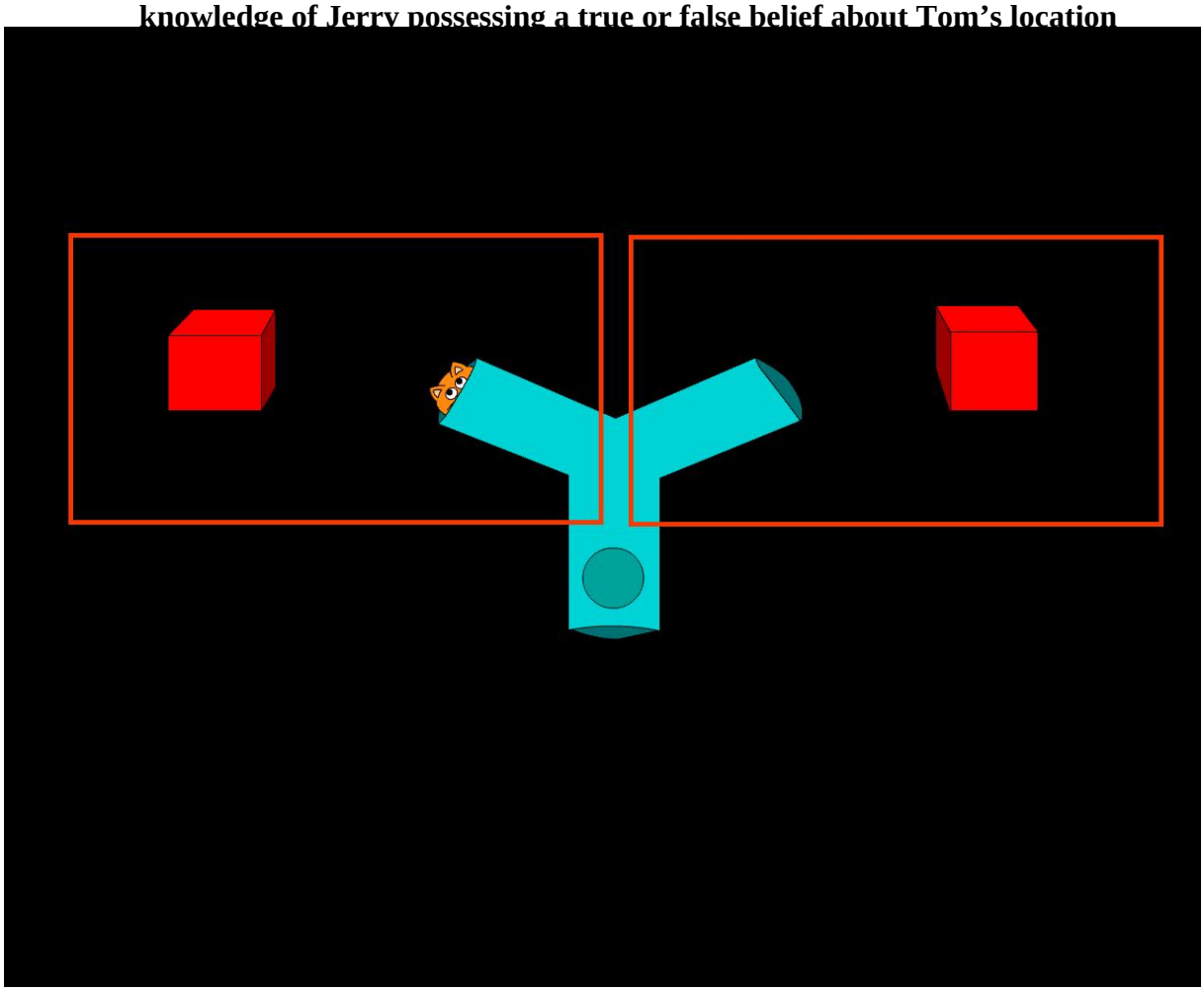


Figure 3. **Mean proportions (+SE) of total fixation lengths within the correct and incorrect areas of interest for each group and condition.**

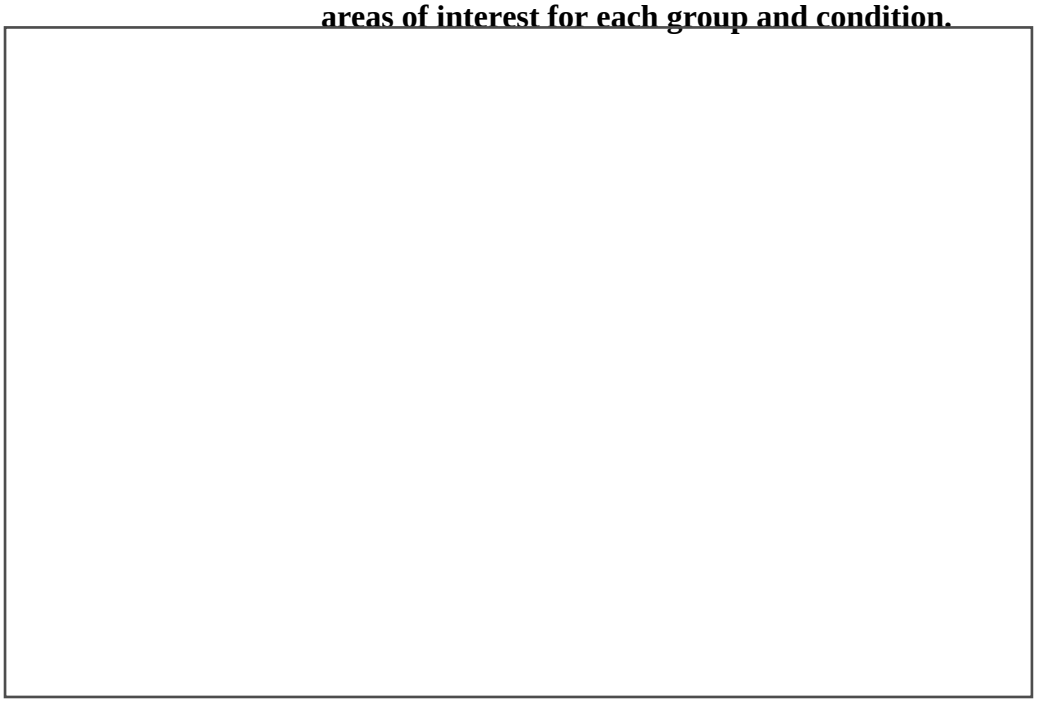


Figure 4. **Mean (±SE) proportions of parents' references to cognitions, desires and emotions in the picture describing task for each group of parents**

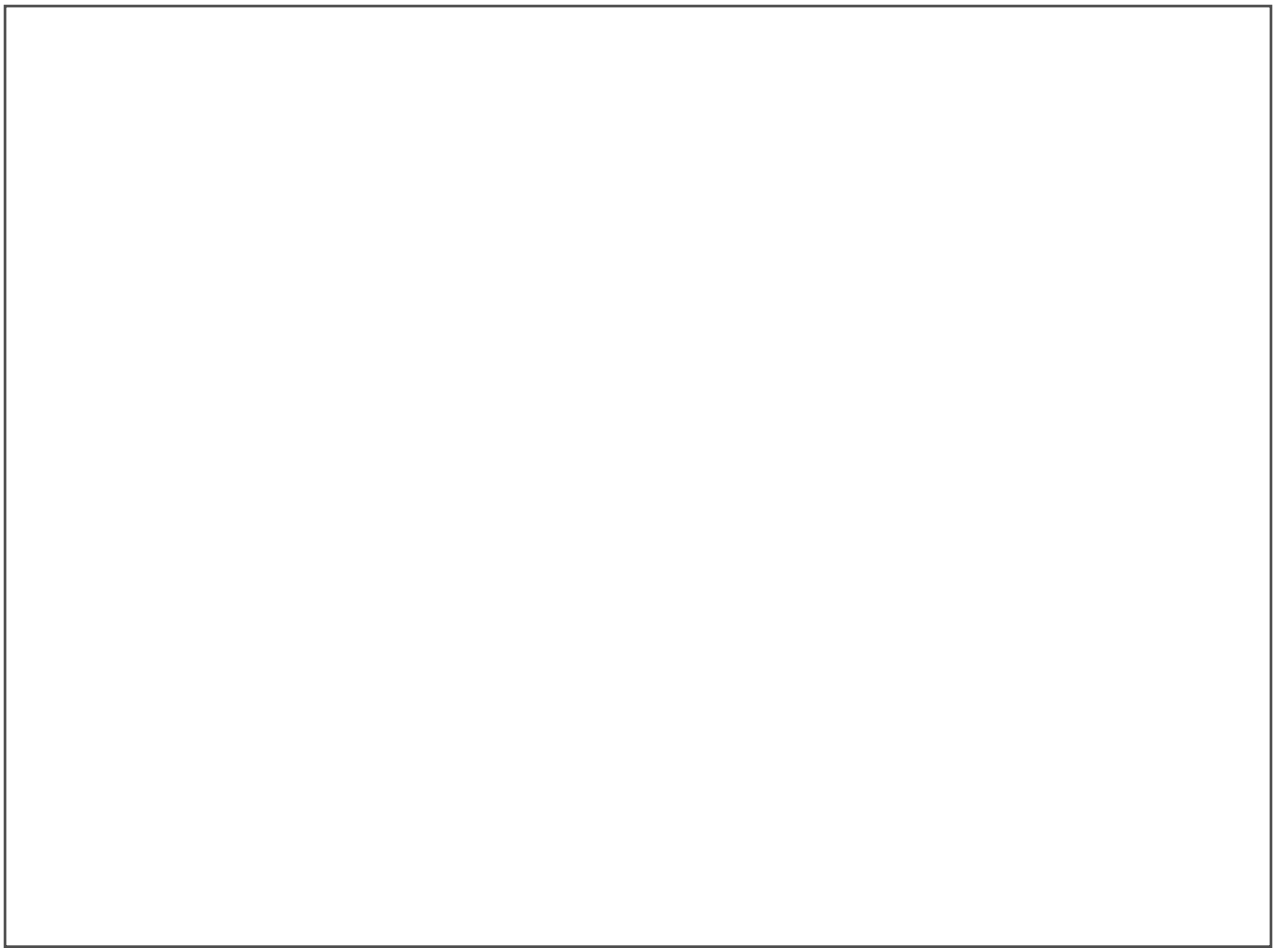
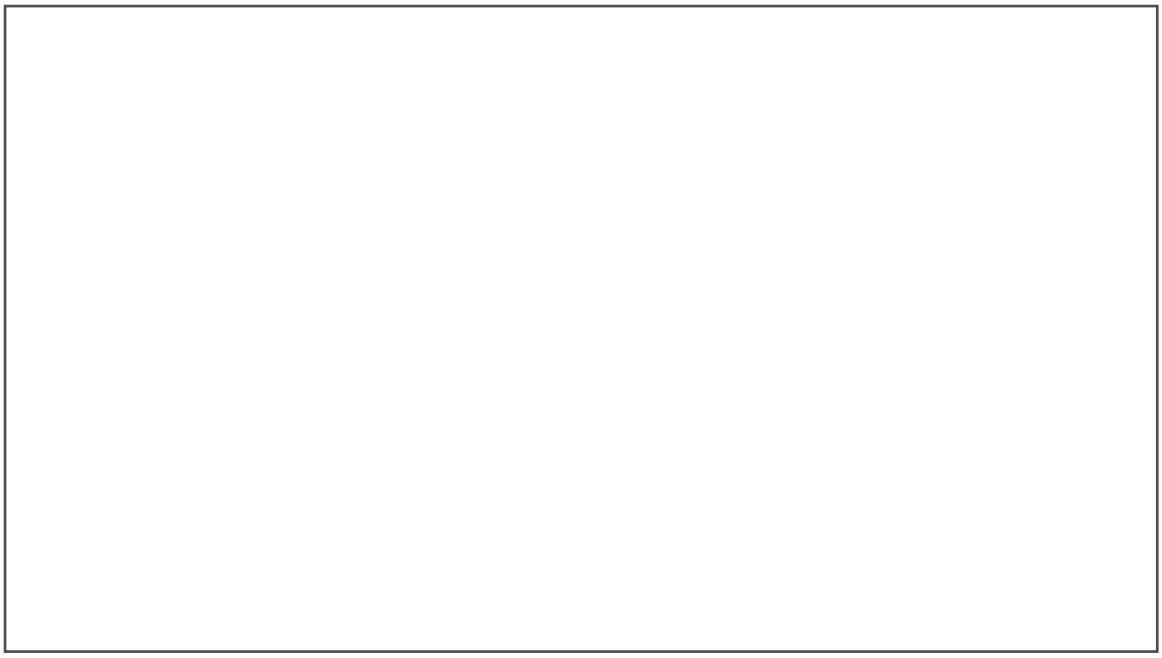


Figure 5. **Mean (±SE) Proportions of Connected, Initiated and Failed Conversational Turns for Each Group of Parent-Child Dyads in the Picture Describing Task**



Bilingualism advantages children's conversational understanding

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Abstract

Despite its prevalence throughout the world, little is known about the extent to which bilingualism influences early conversational understanding. In our investigation, children aged 4–6 years were given a Conversational Violations Test (CVT) to determine their ability to identify responses to questions as violations of Gricean conversational maxims (to be informative and avoid redundancy, speak the truth, and be relevant and polite). Children bilingual in German and Italian (with German as the dominant language L1) significantly outperformed Italian monolinguals and, after statistically controlling for verbal scores, English-Japanese bilinguals (with English as L1) significantly outperformed Japanese monolinguals. These results demonstrate that bilingualism confers an advantage on children's conversational understanding in accelerating their ability to appreciate effective communicative responses.

Bilingualism is present to some extent in every society and at least half of the world's population uses more than one language in everyday life. From this perspective, it is monolingualism rather than bilingualism that is uncommon *(1,2)*. Yet the consequences of early childhood bilingualism remain controversial *(3,4)*, and misgivings about its importance have resulted in decreasing numbers of children from English-speaking homes studying a second

language *(5)*. Here we report evidence that early access to a second language promotes young children's awareness of effective responses in conversation with others.

The seminal work of Bialystok *(6)* has shown that bilingualism has a positive effect on children's ability to judge grammar and to substitute symbols. This capacity for flexibility in the representation of language, together with an enhanced ability to attend to conflicting attentional demands *(7)*, suggests that early bilingualism should be accompanied by advanced meta-pragmatic skills. However, little is known about the extent to which bilingualism influences performance on measures of conversational understanding – a process that is often central to cognitive development and learning *(8)*.

In his widely influential analysis, the philosopher Paul Grice *(9)* depicted communication as a cooperative exchange. He proposed that appreciation of certain conversational rules or maxims provide the foundation for pragmatic competence. These maxims enjoin speakers to 'say no more or no less than is required for the purpose of the (talk) exchange' (maxims of *quantity*), 'tell the truth and avoid statements for which there is insufficient evidence (maxims of *quality*)', 'be relevant (maxim of *relation*)', and 'avoid ambiguity, confusion and obscurity (maxims of *manner*).' To characterize the nature of effective communication more fully, Grice also discussed the need to invoke other maxims such as 'be polite' (maxim of *politeness*).

Even in the earliest years, children demonstrate sensitivity to conversational maxims *(10,11)*. The purpose of a recent investigation was to determine whether bilingual children aged 3 to 6 years excel more generally in their recognition of conversational maxims compared to their monolingual counterparts *(12)*. A Conversational Violations Test (CVT, Fig 1 and supplementary material) was given to two groups of children from the Trieste, Italy, and the Slovenian border area: one that was monolingual in Italian and the other bilingual in Slovenian (L1) and Italian (L2). Using a laptop, children were shown a DVD in which short conversational exchanges in Italian were staged by three doll speakers, one male and two female. For each episode, one of the two female speakers asked a question to the other two speakers who each gave a short answer. One answer violated a conversational maxim and the other did not. The children were asked to ''point to the doll that said something silly or rude." Though comparatively delayed in their L2 as shown by performance on picture vocabulary tests, children who were bilingual in Italian and Slovenian (with Slovenian as the dominant language L1 spoken at home) generally outperformed those who were either monolingual in Italian or Slovenian on utterances violated the maxims of Quantity, Quality, Relation and Politeness with five episode items for each of these components.

These initial results were restricted to children with proficiency in either Italian or Slovenian or both languages. There was no comparison of bilinguals' CVT performance in both their languages and no direct measure of socioeconomic status despite evidence that differences between bilingual and monolingual children on measures of cognitive development may reflect non-linguistic factors based on pre-existing differences such as in socioeconomic status *(13,14)*.

The research that we report here involved children exposed to one or more of four major languages: English, German, Italian, and Japanese. In Experiment 1, we compared performance on an Italian version of the CVT by 36 children bilingual in German and Italian (with German as L1 and Italian as L2) with 41 Italian monolingual children. The children attended Italian preschools in Bolzano in the Trento-Alto Adige region of Italy on the Austrian border. The mean ages of the bilingual and monolingual children were 54 months (s.d.= 10.4) and 57 months (s.d.= 11.4) respectively. Both parents of the monolinguals used Italian at home whereas in the bilingual group at least one parent used German and the children had a predominantly German home language environment. The bilingual children outperformed their monolingual counterparts on the

CVT (Fig 1). A 2 (language groups) X 4 (maxims) analysis of variance showed significant main effects for language group: $F(1,75) = 35.61$; $p < 0.0001$, $?^2 = 0.322$ and maxims, $F(3,225) = 38.59$, $p < 0.0001$, $?^2 = 0.340$. Post-hoc t-tests at the p <. 01 level indicated that children scored significantly higher on the Relevance and Politeness than on Quantity and Quality. Years of parental education, seen to be an optimal measure of SES in Italy *(15)*, were quite similar for both groups (for mothers and fathers of bilingual children, M = 12.10, s.d. = 2.84, M = 11.64, s.d. = 3.04, for mothers and fathers of monolingual children, M = 12.63 s.d. = 3.28, M = 13.00, s.d. = 3.00) and a 2 (parent) x 2 (language group) analysis of variance yielded no significant effects. Therefore the highly significant CVT difference between the language groups cannot be interpreted to be a function of SES.

In Experiment 2, we compared performance on the CVT by 33 children bilingual in English and Japanese (with English as L1 and Japanese as L2) with 59 Japanese monolingual children. The bilingual children were from Derby, Leeds and Manchester in England and attended English language schools and playgroups where Japanese was used. The monolingual children were from Kyoto, Japan, and attended Japanese language schools. The mean ages of the bilingual and monolingual children were 69 months (s.d.= 7.8) and 67 months (s.d.= 8.6) respectively. Both parents of the monolinguals used Japanese at home whereas in the bilingual group in which at least one parent was Japanese and a mixture of Japanese and English was used. The bilingual children were given the CVT both in English and in Japanese in two testing sessions with half receiving the English version first. The monolingual children received the CVT in Japanese only. As measures of vocabulary mental age (VMA), both groups were given the Japanese Picture Vocabulary Test *(16)*. The bilingual children also received the British Picture Vocabulary Scale *(17)*. The VMA of the bilinguals was significantly higher in English (M = 69 mos, s.d.= 13.8) than in Japanese (M = 57 mos, s.d.= 11.1), $F(1,64) = 17.39$; $p < 0.0001$, $?^2 = .214$, and their Japanese VMA was significantly lower than that of the monolingual children (M = 76 mos, s.d.= 14.8), $F(1,90) = 38.30$; $p < 0.0001$, $?^2 = .299$. Their VMA in English also tended to be lower than of the monolinguals, $F(1,90) = 3.07$; $p < 0.09$, $?^2 = .033$.

A 2 (language group) X 4 (maxims) analysis of variance was carried out on CVT scores in English for the bilingual group and Japanese for the monolingual group. This analysis yielded a significant language group X maxims interaction. Despite their lower VMA scores, children bilingual in English and Japanese (with English as L1) significantly outperformed the Japanese monolinguals on the quality and politeness (stats to come) with no differences for the other two maxim components of the test. A similar analysis for both groups' scores on the Japanese CVT version yielded no significant effects. A 2 (language group) X 4 (maxims) analysis of covariance was then carried out on CVT scores in English for the bilingual group and Japanese for the monolingual group using English VMA for the bilinguals and Japanese VMA for the monolinguals as a covariate. This analysis revealed only a significant main effect for language group (Fig 2), with bilinguals outperforming monolinguals, $F(1, 89) = 9.15$, $p = 0.003$, $?^2 = 0.093$. Similarly, a 2 (language group) X 4 (maxims) analysis of covariance on CVT scores in Japanese using Japanese VMA as a covariate for both groups again revealed only a significant language group main effect, $F(1,89) = 6.87$, $p < 0.01$; $?^2 = 0.072$. There were no significant differences in the bilinguals' scores on the Japanese and English versions of the CVT and no significant order of presentation effects. The correlation between responses on the English and Japanese CVT versions was 0.59, $P < .001$.

Thus in both experiments, bilingual children significantly outperformed their monolingual counterparts in their awareness of effective conversational responses. Whether proficient in

German and Italian or English and Japanese, their performance was remarkably similar to that reported previously of children bilingual in Slovenian and Italian.

It has been observed that early-developing preferences for native-language speakers may serve as a foundation for later-developing preferences and conflicts among social groups as young children prefer to accept toys from native language speakers and to favor native language speakers as friends *(18)*. In this connection, our results underscore an invaluable outcome of early exposure to more than one language. Although the use of more than one language in a culture has often been seen as socially divisive, our findings indicate that early bilingualism contributes to children's awareness of what it means to communication effectively.

That early bilingualism confers an advantage on conversational understanding is consistent with the position that exposure to more than one language can facilitate children's performance on key measures of cognitive development such as in their expression of "theory of mind" reasoning *(19, 20)*. Further research involving both behavioral and neuroimaging techniques *(21)* is needed to determine the extent to which bilingual children are advantaged in managing specific attentional demands and in their grasp of other features of language proficiency that require meta-pragmatic abilities such as metaphors, idioms, and irony.

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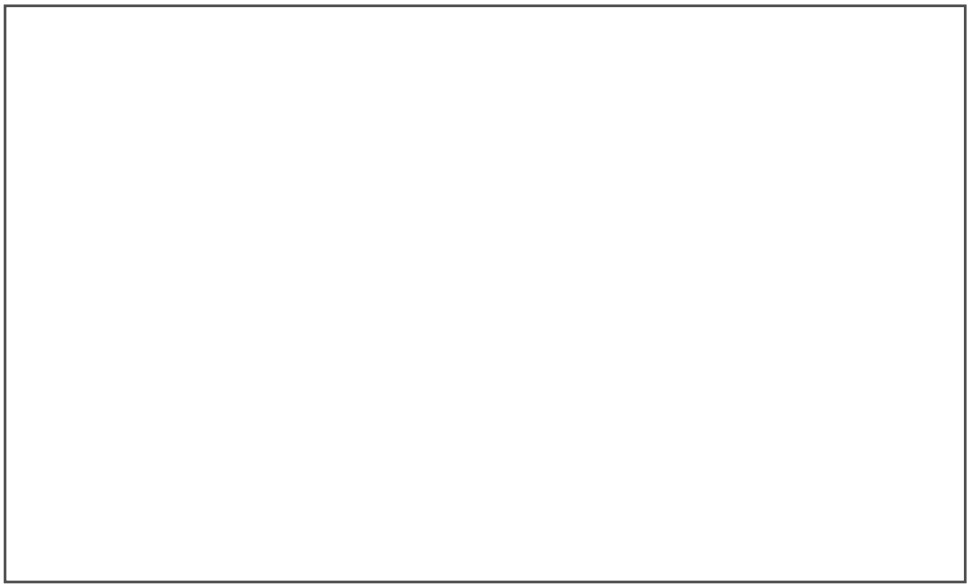

Figure 2. Mean scores (out of 5) for the Italian monolinguals (IM) and German-Italian bilinguals GIB) on the CVT component maxim items

Figure 3. Mean CVT scores adjusted for verbal mental age for the Japanese monolinguals (IM) and the English-Japanese bilinguals tested in English (EJB-CVT-E) and Japanese (EJB-CVT-J) – needs to be reformatted to be out of 20 and with the abbreviations changed to be consistent with the text.

Supplemental Material

Table S1 Conversational Violations Test items

Italian CVT used in Experiment 1

1- SECONDA MASSIMA DELLA QUANTITA’

1.1 M.: Cosa vuoi per colazione?

I.: Il latte con i biscotti.

G.: Il latte scaldato nel pentolino sul fuoco con biscotti dolci rotondi

1.2 M.: Chi è il tuo migliore amico?

I.: Il mio migliore amico è Pietro. Porta i pantaloni.

G.: Il mio migliore amico e Sergio. Viene a scuola con me.

1.3 M.: Che cuccioli ti piacciono?

I.: Mi piacciono i cagnolini.

G.: Mi piacciono i cagnolini che sono animali con quattro zampe e coda.

1.4 M.: Dove sei andato questa mattina?

I.: Sono andato nell’ aula di pittura e mi sono divertito

G.: Sono andato a scuola e non sono restato a casa

1.5 M.: Qual è il tuo colore preferito?

I.: Giallo che è il colore di un colore

G.: Blu che è il colore del mare

2 - PRIMA MASSIMA DELLA QUALITA’

2.1 M.: Dove abiti?

I.: Abito sulla luna

G.: Abito in paese (città)

2.2 M.: Hai dei fratelli?

I.: Si, ho 500 fratelli

G.: Si, ho 2 fratelli

2.3 M.: Hai visto il mio cane?

I.: Si, è in giardino (cucina)

G.: Si, è sulle nuvole.

2.4 M.: Perchè non giochi con me?

I.: Perchè devo andare a casa a far merenda

G.: Perchè sto giocando con un marziano.

2.5 M.: C’è ancora del cioccolato?

I.: Si, è tutto nella mia pancia

G.: Si, te ne ho lasciato un pezzo del mio

3 - MASSIME DI RELAZIONE

3.1 M.: Cosa hai fatto in vacanza?

I.: Sono andato in bicicletta tutti i giorni

G.: I miei pantaloni erano blu

3.2 M.: Cosa avete fatto a scuola?

I.: Abbiamo fatto il bagno

G.: Abbiamo disegnato

3.3 M.: Cosa ti piace mangiare?

I.: Mi piace il mare

G.: Mi piace il gelato

3.4 M.: Cosa ti piace guardare alla t.v.?

I.: Mi piacciono i cartoni

G.: Mi piacciono i panini

3.5 M.: A cosa sai giocare?

I.: So giocare a pallone

G.: So il tuo nome

4 - MASSIMA DELLA CORTESIA

4.1 M.: Ti piace il mio vestito?

I.: E’ bello (carino)

G.: Fa schifo

4.2 M.: Vuoi un pezzo della mia torta?

I.: Si grazie

G.: No, mi fa vomitare

4.3 M.: Posso disegnare con la tua matita?

I.: No, non sei capace di disegnare.

G.: No, l’ ho dimenticata a casa

4.4 M.: Vuoi giocare con me?

I.: No, sei troppo stupido

G.: No, sono troppo stanco

4.5 M.: Mi aiuti a pulire la mia stanza?

I.: No, arrangiati

G.: Si, tra un attimo.

English CVT items used in Experiment 2

1- Maxim of Quantity

1.1 M.: What did you have for breakfast?
L.: I had cornflakes, and then a boiled egg and toast.
J.: A hard boiled egg cooked in hot water in a sauce pan.
1.2. M.: Who is your best friend?
L.: My best friend is Peter. He wears clothes.
J.: My best friend is John. He goes to my school.
1.3. M.: What pet do you like?
L.: I like puppies.
J.: I like puppies which are animals with four dog-legs and tail.
1.4. M.: Where did you go this morning?
L.: I went to painting class and I had a great time.
J.: I went to school and I didn't stay at home.
1.5. M.: Which is your favourite colour?
L.: Yellow which is a colour like a colour
J.: Blue like the sea.

2 – First Maxim of Quality

2.1. M.: Where do you live?
L.: I live on the moon.
J.: I live in London.
2.2. M.: Do you have any brothers?
L.: yes, I have 500 brothers.
J.: Yes, I have two brothers.
2.3. M.: Have you seen my dog?
L.: Yes, he is in the garden
J.: Yes, he is in the clouds.

2.4 M.: Why don't you play with me?
L.: Because I have to go home for tea.
J.: Because I am playing with a Martian.
2.5. M.: Is there any more chocolate?
L.: Yes, It's all in my tummy.
J.: Yes, I saved you a piece of mine

3 - Maxim of Relation

3.1. M.: What did you do on holiday?
L.: I cycled every day.
J.: My trousers were blue.
3.2. M.: What did you do at school?
L.: We had a bath.
J.: We did some drawings.
3.3. M.: What do you like to eat?
L.: I like sea.
J.: I like ice-cream.
3.4. M.: What is your favourite programme on television?
L.: My favourite is cartoons.
J.: My favourite is sandwiches.
3.5. M.: What game do you know?
L.: I know how to play football.
J.: I know your name.

4 - Maxim of politeness

4.1 M.: Do you like my dress?

L.: It's nice

J.: It' s disgusting

4.2 M.: Would you like a piece of my cake?

L.: Yes thanks

J.: No, it sickens me

4.3 M.: May I draw with your pencil?

L.: No, you aren't able to draw.

J.: No, I forgot it at home

4.4 M.: Would you like to play with me?

L.: No, you are too stupid

J.: No, I’m too tired

4.5 M.: Could you help me to clean up my room?

L.: No, make it by yourself

J.: Yes, in a while

Japanese CVT items used in Experiment 2

To come in the supp material, background of the CVT (Surian et al, 1996), and details on test administration in both experiments

traumatic brain injury

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Abstract

Primary objective: Previous studies on patients with traumatic brain injuries (TBI) and diffuse brain damages have reported selective deficits in mental states reasoning, or 'Theory of Mind'(ToM). The goal of the current study is to investigate the fundamental role of the prefrontal cortex in two ToM components: inferential reasoning and social perception.

Research design: Selective cognitive impairments following a TBI provide crucial evidence for assessing competing models of specific aspects of the cognitive system.

Method and procedure: We compared the performance of patients with a pre-dominantly focal lesions in the ventromedial (n = 11) or dorsolateral prefrontal cortex (n = 7) with matched controls (n = 20). All subjects performed two ToM tasks: the Eyes Test, the Faux-pas Test.

Results: We found that both groups of patients performed equally poorly on the Eyes Test, but only patients with pre-dominantly lesions in the ventromedial cortex performed poorly on the Faux-pas test. The group effects on ToM tasks could not be reduced to differences in the global severity of brain injuries.

Conclusions: These results provide evidence supporting some current models of the fractionation of the mindreading system and support the claim that the ventromedial cortex plays a fundamental role in inferential reasoning.

Keywords: Theory of Mind, traumatic brain injury, prefrontal cortex, social cognition

Introduction

The effects of traumatic brain injury (TBI) on communication skills and social cognition have been investigated in a number of previous studies. Patients with TBI have been reported to show social isolation [1], poor social skills [2], poor understanding of non literal language [3-5] and difficulties in evaluating the communicative adequacy of utterances [6]. They have been described also as having reduced expression of affection [7] and empathy [8], egocentric biases and inappropriate levels of social interaction [4].

One possible explanation for at least some of these difficulties in social interaction and communication is that TBI may result in an acquired impairment in representing and reasoning about mental states, for short Theory of Mind (ToM). The investigations of ToM deficits in patients with TBI have often focused on three related and different problems: the validity of ToM tasks, the fractionation of ToM competence and the localization of mental processes in the brain. The order in which we listed these problems roughly corresponds to the amount of empirical data currently available that address them.

Bibby and McDonald [9] assessed a group of patients with TBI on both first- and second-order ToM tasks. The former are meant to tap the ability to use first-order meta-representations, whereas the later require the attribution of more complex, second-order metarapresentations. The clinical group performed worse than healthy controls on both ToM tasks and related and control tasks. A generalized weakness in inferential skills, combined with linguistic and working memory limitations, may thus explain the failures on ToM tasks, particularly failures on those requiring second order metarapresentations. This conclusion was also supported by Henry, Phillips Crawford, Ietswaart and Summers [10], who found poor executive functioning in patients with TBI and a correlation between these deficits and scores in an advanced mindreading task (the 'Eyes Test') [11].

However, lesions following TBI may differ substantially in size and site and thus different causal pathways may underlie poor ToM skills in patients with TBI. According to Samson, Apperly, Kathirgamanathan and Humphreys [12], belief reasoning errors of patients with prefrontal lesions may arise mainly from an executive functioning deficit. By contrast, the errors of patients with lesions in the temporo-parietal junction (TPJ) may be domain specific and concern the conceptual knowledge involve in ToM.

Havet-Thomassin, Allain, Etcharry-Bouyx, and Le Gall [13] employed four executive functions tests (Tower of London, Stroop Colour Word Test, Modified Card Sorting Tests and Trail Making Test) and two ToM tasks (the Eyes Test and the Character Intentions Task). They found no relationship between the patients' performance on executive functioning tests and their scores on ToM tasks. These results dovetail with those on patients that had undergone frontal lobe excisions [14] and brain-damage from different aetiologies [15-19] and suggest that failures of ToM tasks in patients are not merely an effect of weak executive functioning. Stone, Baron-Cohen and Knight [20] studied ToM skills in five patients with bilateral damages in the orbito-frontal cortex and five patients with unilateral left lesions in the dorsolateral frontal cortex. ToM was assessed with three kinds of tasks: first-order false belief tasks, second-order false belief tasks

and the Faux-pas test. Patients with orbito-frontal damages showed good performance on first- and second- order false belief tasks, but performed poorly on the Faux-pas test, a test that taps more subtle social reasoning required in story comprehension, and failed to detect that something awkward had been said in the stories. In contrast patients with left dorsolateral lesions performed like healthy controls in the Faux-pas test and failed only in the versions of the tasks that made high working memory demands. This data suggests that while bilateral lesions in the orbitofrontal areas may result in domain specific ToM deficits, lesions in the left dorsolateral areas are associated with domain general processing limitations.

All previous studies of ToM in patients with TBI, with the exception of Stone *et al*. [20], included patients with lesions extending in several cortical areas. Neurological and neurosurgical investigations distinguish between diffuse and focal lesions resulting from TBI in the frontal, orbito-frontal and temporal poles [21, 23, 26].

Numerous studies have shown the involvement of prefrontal areas in mental states reasoning [19, 27-30]. In a review of the relevant neuroimmaging literature, Gallagher & Frith [31] claim that the network sub serving ToM includes a distinctive key region located in the medial prefrontal cortex, while the superior temporal sulcus and the temporal poles bilaterally are not uniquely associated with ToM. By contrast, Saxe and Kanwisher [32] claimed that the temporo-parietal junction is a key region in reasoning about the true or false contents of others' beliefs. Studies on brain injuries with heterogeneous aetiologies have also pointed out the role of the prefrontal cortex in ToM [14, 17, 19, 18, 33, 14].

While a consensus is emerging about the claim that different ToM components may have different neural correlates, no agreement has been reached yet on how ToM skills should be functionally fractionated and which neural structures subserve the different ToM components. According to a some recent proposals, ToM can be analyzed into two main components: a perceptual component that deals mainly with decoding social information from facial expressions and other social signals, and an inferential, or conceptual, component, that is responsible for mental state attribution in social scenarios [34, 35-38]. Another series of proposals tried to analyze the mindreading system in affective vs. cognitive components. In an fMRI study, Hynes, Baird and Grafton [39] demonstrated that the medial orbitofrontal cortex was more involved in emotional as compared to cognitive perspective-taking. McDonald and Flanagan [40] showed that in patients with TBI emotion recognition and first order theory of mind judgments were not related to inferential reasoning skills, whereas second-order theory of mind judgments were related to social perception. Shamay-Tsoory and Aharon-Peretz [41] studied patients with heterogeneous aetiologies and with different prefrontal lesions (ventromedial, dorsolateral, and mixed) or with posterior lesions. This study was aimed at examining whether 'affective' ToM processing is, to some extent, distinct from 'cognitive' aspects of ToM and depends in part on separate neuroanatomical substrates. Patients with lesions in ventromedial cortex had scores significantly lower than patients with lesions in dorsolateral cortex in the affective trials of the stories task, but not in the cognitive trials. Poor performance in 'cognitive trials' was found associated with extensive prefrontal damage. A recent study showed the existence of two distinct neural systems for empathy in humans [42]. The findings showed that inferior frontal gyrus (IFG) was critical for affective empathy on emotion recognition task, and ventromedial prefrontal cortex for cognitive empathy on theory of mind task.

The main aim of the study reported here was to investigate whether affective-perceptual and cognitive aspects of ToM competence may be disproportionally damaged by lesions in different prefrontal areas by assessing ToM in patients with TBI and predominantly focal prefrontal

lesions. While previous studies have investigated the performance of patients with TBI on a number of ToM tasks, this is the first study on patients with TBI aimed at evaluating whether different patterns of ToM difficulties follow from lesions in different prefrontal cortical sites.

Method

Participants

Eighteen patients with pre-dominantly focal injury in the prefrontal cortex following a Traumatic Brain Injury (TBI) were recruited in two public health services for rehabilitation in Ferrara and Padova (Italy). The aetiology for all cases was head injury caused by a domestic or road accident. None of the patients reported a history of psychiatric disease or a premorbid history of alcohol or drug addiction. Patients with a more diffuse axonal injuries were excluded on the basis of MRI/CT and neurological examination. Patients with comorbid neurological conditions (e.g. stroke or premorbid seizure disorders) or marked difficulties in executive functioning were also excluded reported by a screening test, the Frontal Assessment Battery (FAB) [43].

All patients lived in their home. Testing was conducted at the chronic phase of recovery. All patients had at least 11 months post trauma or surgery, except one that had 5 months post trauma. The time after onset ranged from 5 to 288 months (M = 34.72, SD = 64.93) and the days of unconsciousness were ranged from 1 to 60 (M = 14.72, SD = 13). The inclusion conditions for patients were: a) a Level of Cognitive Functioning (LCF) of 7 (Automatic, Appropriate Response) or 8 (Purposeful, Appropriate Response) [44]; b) an equivalent global score on the WCST equal or greater than 2. Equivalent global scores below 2 reveal weak executive functioning, whereas equivalent score equal or greater than 2 reveal executive functioning within the normal range (see Procedure section for more details). The GCS (Glasgow Coma Scale) scores, measured at arrival to hospital, available for 15 patients, ranged from 3 to 14 (for GCS < 7 the TBI is severe: 9 patients; for GCS 8-13 the TBI is moderate: 6 cases; for GCS 14-15 the TBI is mild: 1 case; Not Notified in 2 cases). PTA (Post-Traumatic Amnesia) scores, available for all patients, ranged 1 – 30 weeks (M = 13.17, SD = 10.43).

Patients with TBI were divided into two groups according to their lesion locations (see Table 1), a group of 11 patients with pre-dominantly focal injury in the ventromedial prefrontal cortex (VM group) and a group of 7 with predominantly focal injury in the dorsolateral prefrontal cortex (DL group). The mean non-verbal IQ of the VM and DL groups did not differ significantly from the mean IQ of the HC group, $t(29) = .52$, and $t(25) = 1.4$, *both p's* > .10, respectively.

Twenty healthy participants served as controls (HC group). The HC group included 6 women and 14 men, aged 21-50 (M = 36.0, SD = 9.27), with 8-13 years of education (M = 11.45, SD = 2.23). Healthy controls matched the patients on demographic variables, as shown by an analysis of variance (ANOVA) which found no significant difference between the groups with regard to age ($F(2,35) = 1.61$, $p = .21$) and years of education ($F(2, 35) = .33$, $p = .72$). All subjects completed the Raven Progressive Matrices to obtain a measure of general intellectual functioning.

Insert Table 1 about here

Anatomical classification

A neurologist and two neuropsychologists carried out the anatomic examination and classification of patients' lesions based on the neurological examination and on the most recent CT or MRI scans. For inclusion, lesions had to be pre-dominantly localized in the ventromedial or dorsolateral regions of the prefrontal cortex. Lesion sites were transcribed from CT or MRI images to the appropriate slices of the MRIcro program (Rorden, www.sph.sc.edu/comd/rorden/mricro.html, and see Figure 1) and evaluated using standard atlases [45].

The 18 patients were divided in two groups according to their lesion site: 7 patients formed the group with pre-dominantly focal injury in the dorsolateral prefrontal cortex (DL group) and 11 the group with pre-dominantly focal injury in the ventromedial prefrontal cortex (VM group, see Table 1 for information on patients). In the DL group, 5 patients showed focal lesions in the dorsolateral prefrontal cortex (Broadmann dorsolateral areas 8, 9, 43, 44, 45); the remaining 2 patients (BOL and AND) also had a small parietal lesion. Five patients of DL group had a left lesion, 2 patients had a right lesion. In the VM group, 9 patients showed focal lesions in the ventromedial prefrontal cortex (Brodmann mesial areas 8, 9, 10, 24, 32 and orbital areas 10, 11, 12 and 14), one patient (SOL) also showed a small right parietal lesion and another patient (DEP) showed two small and circumscribed bilateral occipital lesions. In the VM group, 5 patients had a left lesion, 1 a right lesion and 6 a bilateral lesion.

Considering both groups of patients, the estimated volume of the prefrontal lesions ranged from 56 to 940 cm ^{3} (M = 265.06 cm^3, SD = 206.53 cm^3). In the DL group the volume of the prefrontal lesions ranged from 186 to 289 (M = 234.14 cm^3, SD = 33. 51 cm^3); in VM group ranged from 56 to 940 (M = 284.73 cm^3, SD = 265.99 cm^3). The size of the prefrontal lesions did not differ significantly in the two groups, t (16) = 0. 49, p = .62.

The DL group included 7 men, aged 20-56 years (M = 41.29, SD = 11.94), with 8-15 years of education (M = 10.57, SD = 2.99), an average IQ (M = 92.14, SD = 2.67), Glasgow Coma Score (GCS) scores from 5-14 (M = 9.67, SD = 3.50; GCS scores were available for 6 patients of DL group) and Post-traumatic amnesia (PTA) scores from 1 to 5 weeks (M = 3.14, SD = 1.77). The VM group included 2 women and 9 men, aged 20-46 (M = 32.82, SD = 9,16) with 8-13 years of education (M= 11.18, SD = 2.52), a good IQ (M = 94.36, SD = 4.71) , GCS scores from 3-11 (M= 5.22, SD = 2.99; available for 9 patients) and PTA score from 4-30 weeks (M = 19.55, SD = 8.26). The VM and DL groups did not differ significantly on chronological age, t(16) = 1.7, education years, t(16) = .46, and IQ t(16) = 1.12, all p's > .10). The mean GCS of patients of VM group was significantly lower than those of patients of DL group, t(13) = 2.63, p < .05, whereas the PTA duration is longer in patients of VM group, t(16) = 6.35, p < .001. Patients' performance of both groups on the WCST did not differ significantly, t (16) = .45, p = .65.

Insert Figures 1 and 2 about here

Materials and procedures

Theory of mind – perception: Eyes Test. To test 'perceptual' aspects of ToM competence we used an Italian adaptation of the Eyes Test [46] which is based on the original English version

devised by Baron-Cohen *et al.* [11]. In order to perform well on this test participants need to know a number of mental state terms, match them to the ocular region of a face, and decide whether the terms describe adequately the face by choosing one adjective among four possible alternatives. The correct interpretation of visual cues is thus a crucial component of this task, but another important aspect is lexical knowledge. Participants were presented 37 black and white photographs showing the ocular regions of male and female adults. On each trial, first a photograph was presented and the participants were asked a control questions about the gender of the person in the photo. Then, four adjectives describing complex emotions or other mental states (e.g. dispirited, bored, embarrassed, flirting) were shown below the picture and participants were asked to choose the word that best described the photograph. Participants were asked to read all four words before making their choice and, if they felt that more than one word was applicable, to 'choose just one word, the word which you consider to be most suitable'. The Experimenter asked: 'Which word best describes what this person is feeling or thinking?'. In the Italian version, the four terms presented in each trial were written below the photo, rather than at the corners of the photo as in Baron-Cohen *et al*. [11]. Following the procedure used by Baron-Cohen *et al*. [11], participants were encouraged to consult a glossary of all words used in the task whenever they felt they were not sure about their meaning. The norms for the Italian adult population and all the verbal materials are reported in Serafin and Surian [46]. To minimize the negative effects of impulsive tendencies, patients were asked to look at the stimuli for 30 s before responding. The maximum score on test and control questions was 36.

Theory of mind – reasoning: the Faux-pas Test. Participants were presented with 10 stories that told about the occurrence of a 'social boathook' or faux pas. The stories used in the present study were selected from the 20 faux pas items of the original test. In each story, someone saids something awkward [47]. Each story involved two o three characters and at least two separate statements. The language used was simple. After hearing each story, subjects were asked a series of questions. The first question assessed whether a faux pas was present: 'Did someone say something they shouldn't have said?'. Understanding a faux pas required understanding a mental states of belief or knowledge and having an empathic understanding of how the person in the story would feel. If subject answered 'yes' to the first question then he/she was asked the other four questions. Subjects who answer 'no' to the first question don't get asked this question and score a 0 for that item. In the second question the participants were asked to identify who said the inappropriate utterance. The third questions asked why he/she should not have said the silly thing. The fourth question asked why the speaker said the silly thing. The fifth question required an attribution of knowledge to the speaker, and the sixth question was about the feelings of the listener. Following the test questions there were two control questions assessing whether the participant was confused or forgot the details of the story. Each story was posted in front of the subject and the experimenter read it aloud. After a story had been read, participants answered the test and control questions while keeping the printed story in front of them. In this study we used ten of original twenty faux pas stories reported in Baron-Cohen *et al.* [47]. The maximum score was 60 on test questions and 20 on control questions.

Executive functioning: the Wisconsin Card Sorting Test (*WCST)*. The WCST was administered using standard materials (128 cards) and instructions [48]. Performance was scored according the rules set out by Laiacona, Inzaghi, De Tanti and Capitani [49]. This task is widely used for clinical and research purposes to assess reasoning abilities. It requires a number of cognitive skills including attention shifting, working memory, and cognitive flexibility in problem solving. During the test a patient is required to match a series of cards according for their

similarity with four stimulus cards. At the beginning of the test, four stimulus cards were placed in front of the participant displaying one red triangle, two green stars, three yellow crosses and four blue circles (form left to right). Three possible sorting categories were assumed: form, colour and number. The participant was notified only whether the responses were right or wrong, without mentioning the underlying sorting criterion. When subject had made 10 consecutive correct matches, the criterion was changed, without warning. Performance was assessed using the 'equivalent global score' [49]. The global score is computed by subtracting from the total number of administered trials the number of categories completed multiplied by ten. This scoring system proved effective in identifying dysexecutive patients in a coincided and informative way [49].

Results

The performance of the three groups on the two ToM tasks and the executive functioning test is summarized on Table 2. A significant group effect was found on the test questions of the Eyes Test, F (2, 35) = 12.82, $P < .001$, $?_p^2 = .42$. Both clinical groups performed worse than healthy controls (Sheffé post-hoc comparisons, $p < .01$) and the mean scores of the two clinical groups did not differ significantly. All three groups performed at ceiling on the control questions, F (2,35) = .23, $p = .79$, $?_p^2 = .013$.

Insert table 2 about here

A significant group effect for was also found on the Faux-pas test questions, F (2,35) = 19.21, $p < .001$, $?_p^2 = .52$. VM group performed significantly worse than controls (Sheffé, $p < .001$) and DL group ($p < .02$). By contrast, in DL group scores did not differ significantly from controls ($p = .18$). All three groups performed well on the control questions of the Faux-pas test and did not differ significantly from each other, F (2,35) = 1.23, $p = .30$, $?_p^2 = .06$.

WCST scores correlated with the Eyes Test scores in both clinical groups (VM group: $r = .64$; DL group: $r = .80$, both p's $< .05$), but did not correlate with the Faux-pas Test scores (VM group: $r = .06$; DL group: $r = -.09$, both p's $>. 05$). Also, the performance on the Faux-pas test questions did not correlate with the performance on the Eyes Test (DL group: $r = -.15$, $p = .73$; VM group: $r = .54$, $p = .08$; HC group: $r = .28$, $p = .23$).

GCS scores did not correlate with Eyes Test (VM group: $r = -.19$; DL groups: $r = -.37$, both p's $> .05$) and Faux-pas Test scores (VM group: $r = -.19$; DL group: $r = -.32$, both p's $>. 05$). Similarly, PTA duration did not correlate with Eyes Test scores (VM group: $r = .26$; DL group: $r = .42$, both p's $> .05$) and Faux-pas Test scores (VM group: $r = .56$; DL group: $r = -.44$, both p's $>. 05$).

Altogether, these results show that the difference between the two groups of patients on the Faux-pas Test cannot be explained away with reference to a possible confounding with GCS scores and PTA duration, despite the fact that the patients with pre-dominantly ventromedial lesions did have a mean GCS significantly lower than patients with pre-dominantly dorsolateral lesions. In accord to this, we compared VM and DL groups on Faux-pas test results with an ANOVA, that did not reveal a significant effect of group F (1,16) = 4.62, $p = .05$, $?_p^2 = .224$, also

after controlling for the effect of GCS F (1,12) = 3.15, p = .10, $?_p^2$ = .208 and PTA duration F (1,15) = .09, p = .76, $?_p^2$ = .006.

We also we compared VM and DL groups on Eyes Test results with an ANOVA, that did not reveal a significant effect of group F (1,16) = 2.84, p = .11, $?_p^2$ = .151, also after controlling for the effect of GCS F (1,12) = 1.64, p = .22, $?_p^2$ = .120 and PTA duration F (1,15) = .05, p = .81, $?_p^2$ = .004. From our results, the global severity of injury did not seem the determining factor of patients' performances on both ToM tasks.

Discussion

Two tasks were used to assess social cognition in patients with TBI, the Eyes Test and the Faux-pas Test. While the former requires the interpretation of visual social information, the success on the latter depends on mental states reasoning skills. Patients were divided into a dorsolateral and a ventromedial group, according to the site of their pre-dominantly focal injury. We found that both groups performed equally poorly on the Eyes Test, but only patients with ventromedial lesions performed poorly on the Faux-pas Test. These findings have a number of important theoretical implications that suggest that both dorsolateral and ventromedial prefrontal areas play an important role in interpreting social information encoded in the ocular region of the face. By contrast, as previously found by Stone *et al*.[20] , patients with dorsolateral lesions performed similarly to healthy controls on the Faux-pas Test, suggesting that dorsolateral areas are not a core component of the neural circuits involved in mental states reasoning. Moreover, in the Faux-pas Test patients with ventromedial lesions performed poorly compared to both the healthy controls and patients with dorsolateral lesions[50]. This supports the claim, put forward in a number previous studies [18, 27] that the ventromedial prefrontal cortex plays a key role in the inferential components of ToM competence.

The present findings are also relevant for the current debate on the role of executive deficits on patient's difficulties in ToM tasks. We found no significant relation between the performance on the Faux-pas Test and performance on the executive functioning test. In the present study patients with severe executive deficits were not included, hence our conclusions may not be generalized to patients with frontal damage that show substantial limitations of executive functioning. Nevertheless, this finding is important because it provides support for the claim that not all ToM difficulties in patients with TBI can be ascribed to weak executive functioning [13, 20]. This provides further evidence that executive functioning and ToM may be dissociated [15, 16, 38, 51]. Our results suggest that some patients with TBI present a selective deficit in inferential reasoning that is independent of executive abilities. These acquired ToM deficit may share many features with the deficits found in other clinical groups like persons with autism [52], Asperger Syndrome [20], or schizophrenia [53].

The patients' difficulties in the Eyes Test are more difficult to interpret with regard to the domain-specific vs. domain-general nature of their underlying deficit. The performance of both groups on this test was poor and, given the patients' overall good scores of WCST, one could propose that lower scores on the Eyes Test do not depend on domain-general processing limitations. However, patients' scores were positively correlated with the WCST scores and this suggests that lower scores on the Eyes Test can, at least in part, be the result of limitations in executive functioning. This would support the conclusions proposed by Henry *et al*. [10], that found that verbal fluency, a sensitive measure of executive functioning, was significantly associated with Eyes Test scores and proposed that patients' lower scores on that test depended on weak executive functions. The results of the present study cannot be taken as showing clearly the

involvement of both ventromedial and dorsolateral prefrontal areas in the perceptual components of ToM competence, because the impairment of either group of patients, or both, could be due to domain general executive dysfunctions or performance factors. While the association of Eyes Test and WCST scores point to a meaningful role of domain general resources in the success on some ToM tasks in patients with TBI, as suggested by a number of previous studies [6, 10, 51], patients with good scores on WCST and poor performances on the Eyes Test suggest that these difficulties should not be construed solely as a result of a domain general deficit related to the executive demands of the Eyes test.

Theoretically interesting implications may be derived by the dissociation between the Eyes Test and the Faux-pas Test in the patients with damages in dorsolateral prefrontal cortex. This dissociation shows that perceptual and inferential aspects are two different components involved in ToM reasoning tasks, as in previous studies [34, 35, 37, 41]. Tager-Flusberg [34] has suggested that theory of mind reasoning can be fractionated into two components: 1) detecting mental states from perceptual and observable information; 2) reasoning about those mental states predicting others actions. Our study extents Sabbagh's research [35] and Tager-Flusbergh's [34] hypotheses and reveals that in prefrontal cortex while dorsolateral areas are less involved than ventromedial areas in the inferential components of theory of mind, and also that both areas are involved in the attribution of mental states by processing of information from the ocular region of the face. The reported differences between patients with ventromedial or dorsolateral lesions cannot be ascribed to their demographic variables or global severity of injury since the two groups of patients did not differ significantly on these variables. These results are also coherent with Frith and Frith's [54, 55] model of the neural bases of ToM. According to such a model, the mindreading system can be analyzed into three main components: the medial prefrontal cortex, the temporal poles and the posterior superior sulcus [56, 57]. The medial prefrontal cortex is the basis of the decoupling mechanism that creates mental states representations as distinct from representations of physical states.

A major limitation of the present study is that, given the small sample size and the heterogeneity of their severity, we do not exclude the possibility that their findings are only coincidental. Laterality proved to be critical in several previous studies [20] and thus the conclusions we have reached need to be investigated further in future studies that will be able to compare patients with left and right lesions in the dorsolateral and ventromedial prefrontal cortex. Also, the control questions used for the ToM tasks yielded undesirable ceiling effects that could be avoided in future studies by using more sensitive measures and improved control tasks [58].

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Table 1. Clinical features of the TBI participants

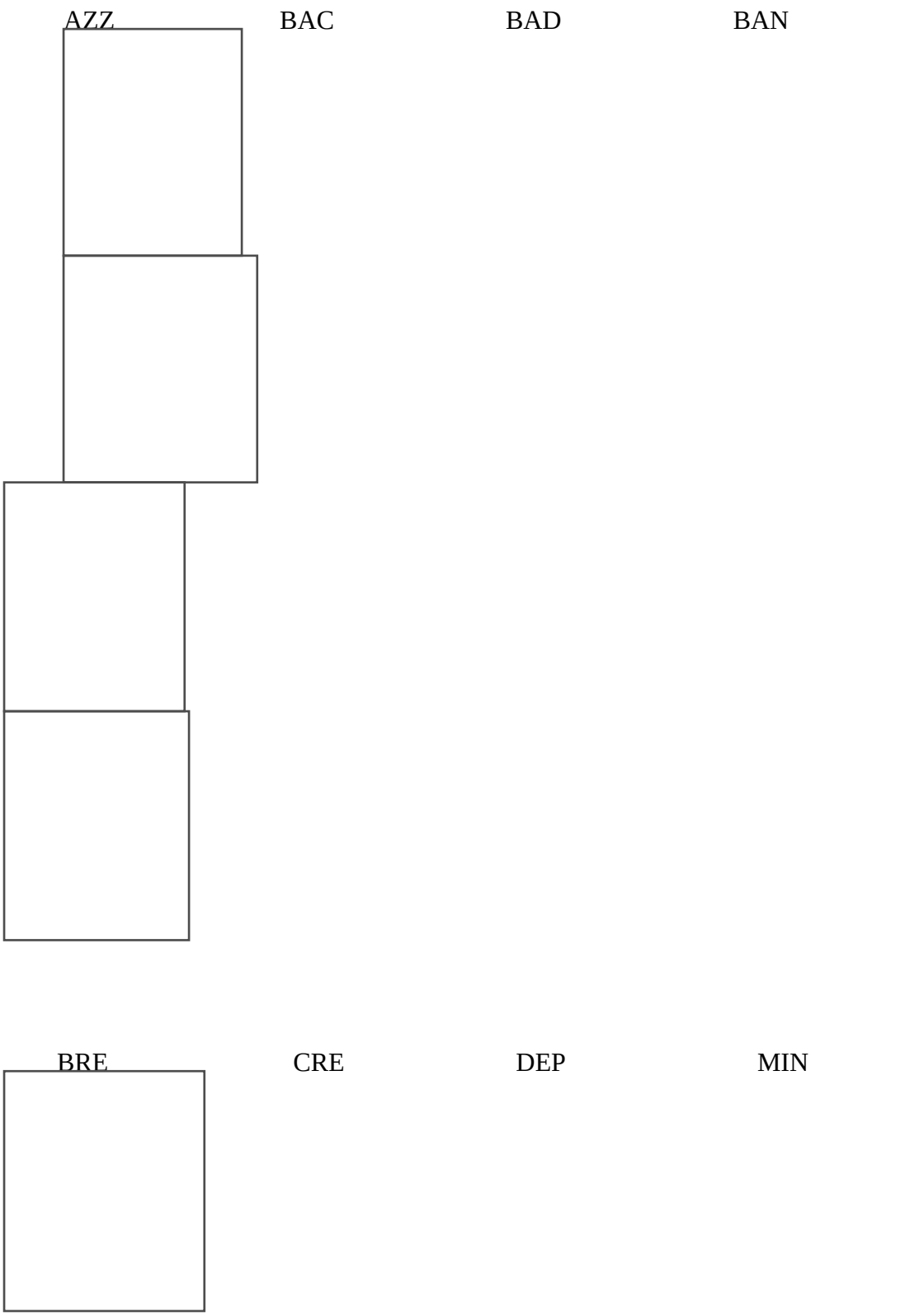
Subjects	Age		Education (years)		Lesion site	
	M	SD	M	SD	M	SD
Eyes Test	22.6	4.3	19.8	3.8	27.7	4.1
Eyes Test	35.2	.9	35.2	1.0	35.4	.8
control						
Faux Pas	25.8	20.1	45.6	15.0	56.2	4.2
Faux Pas control	19.6	.7	19.8	.4	19.9	0.3
WCST	3.0	.8	3.2	.4		

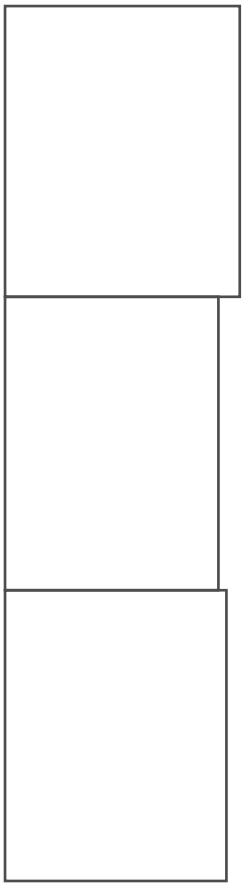
Figure Captions

Figure 1. Maps of lesions in the ventromedial patients.

Figure 2. Maps of lesions in the dorsolateral patients.

Figure 1





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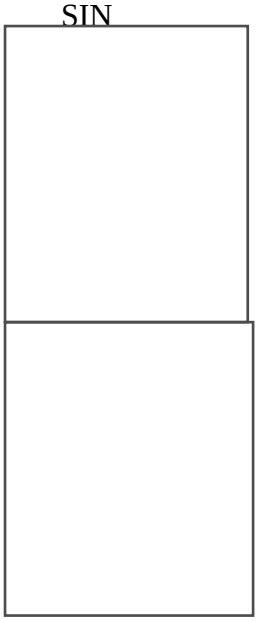


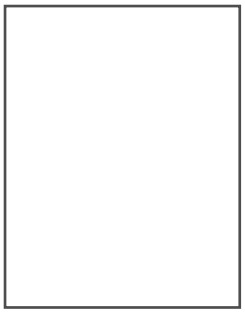
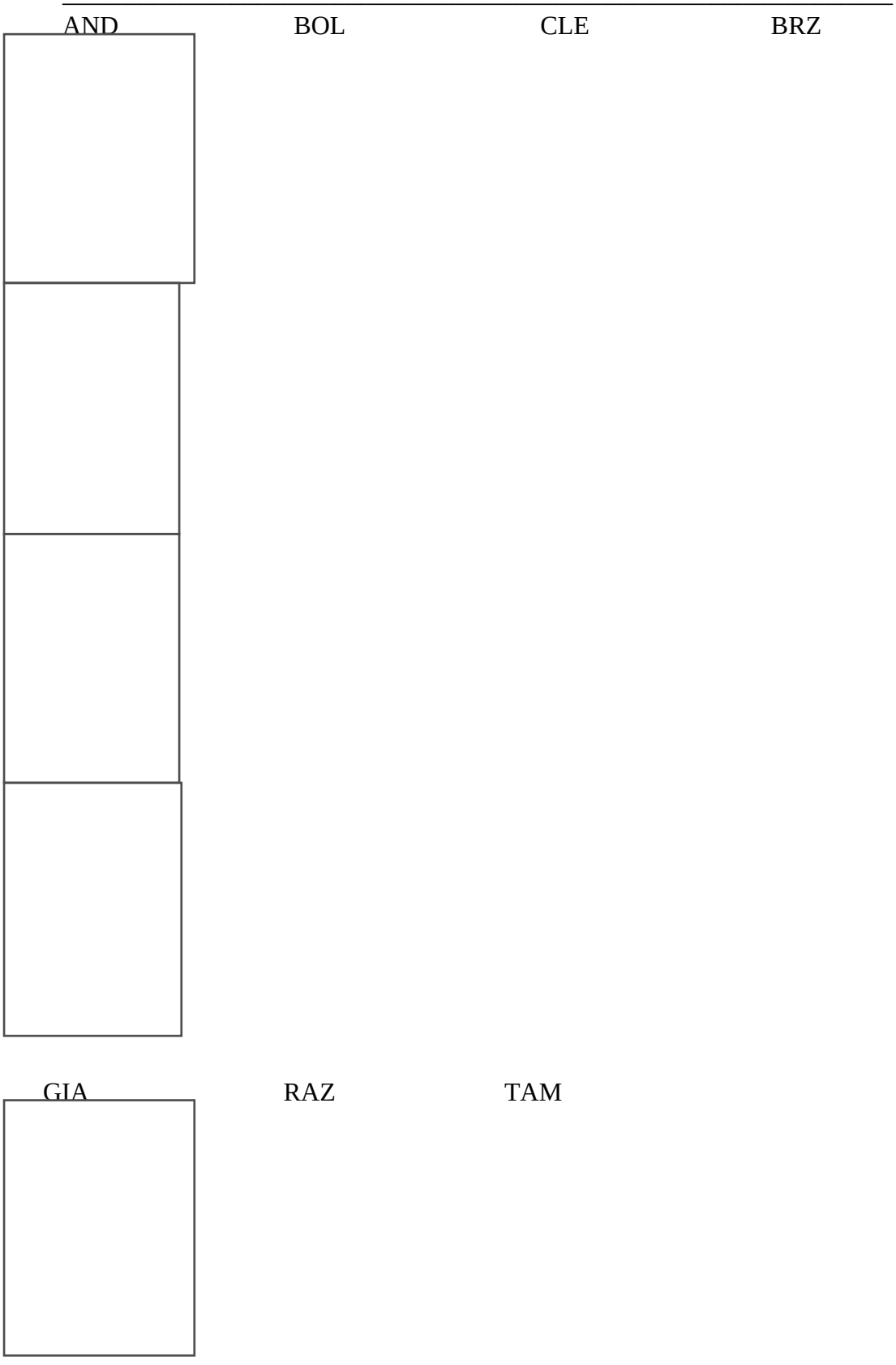
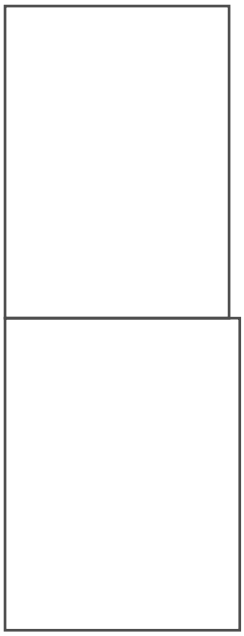


Figure 2





3.2 Studi sulla Valutazione Sociale

Studio 5. ‘*The developmental roots of fairness: Infants’ reactions to equal and unequal distributions of resources.’*. Lo scopo del seguente lavoro è indagare se i bambini tra il primo e il secondo anno di vita valutano le azioni distributive sulla base di un precoce senso di giustizia distributiva. Dopo aver presentato degli eventi di familiarizzazioni che ritraevano delle azioni distributive commesse da due diversi distributori, uno equo e l’altro iniquo, sono stati presentati ai

bambini due test: uno visivo, per l'inferenza delle diposizioni altrui, l'altro di scelta manuale, per la preferenza personale per uno dei due distributori. Sono state confrontate le performance di bambini appartenenti a due diverse fasce d'età, 11 mesi e 16 mesi. I risultati hanno rivelato nel bambini di 16 mesi una preferenza per l'agente che distribuisce le risorse in maniera equa, a quello che opera una distribuzione iniqua. Le conclusioni hanno implicazioni teoriche che sostengono le nuove proposte sull'origine evolutiva del senso morale.

Studio 6. *'Distributive Justice and social evaluations in 27-month-olds'*

L'obiettivo è indagare se i bambini a due anni d'età valutano positivamente le azioni distributive compiute da due agenti, di cui uno distribuisce le risorse in maniera equa e l'altro in maniera iniqua. Dopo aver mostrato le distribuzioni, ai bambini è stato chiesto qual è dei due fosse il distributore buono. I risultati hanno rivelato un giudizio positivo per l'agente che distribuisce le risorse coerentemente con il principio di uguaglianza. I risultati si sono ripetuti in altri due esprimenti, dove sono stati controllate le spiegazioni alternative relative alla preferenza di bambini per le distribuzioni simmetriche e alla comprensione delle esigenze degli agenti, aggiungendo dei riceventi di maggiori dimensioni. Al contrario, i bambini non hanno mostrato un giudizio positivo per il distributore equo in un esperimento di controllo, dove i riceventi sono stati sostituiti con due oggetti inerti, controllando la corrispondenza uno ad uno. Le conclusioni sostengono i recenti modelli teorici relativi allo sviluppo del senso morale.

Running head: Infants' reactions to resources distributions

The developmental roots of fairness: Infants' reactions to equal and unequal distributions of resources

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Abstract

The problem of how to distribute available resources among members of a group is a central aspect of social life. Adults react negatively to inequitable distributions and several works have reported negative reactions to inequity also in non-human primates and dogs. We report two experiments on infants' reactions to equal and unequal distributions. The results provides for the first time evidence suggesting that 16-month-old infants attend to the outcomes of distributive actions and generate social evaluations of agents by relying on this information. These results support recent theoretical proposals on the developmental roots of social cognition and are at odds with classic theories that emphasize the effect of peer interactions in the acquisition of a sense of equity and fairness.

The problems concerning fairness of resources distributions are ubiquitous in everyday reasoning and are central topics for social sciences and theories of ethics (e.g. Mill, 1861/1998; Rawls, 1971; Sen, 2008). How do individuals acquire the ability to reason about these problems? Classic developmental theories (Piaget, 1932; Kohlberg, 1981) emphasized the effect of peer interaction, verbal and mathematical skills on how children and adolescents perform and evaluate distributive actions (e.g., Damon, 1975; Gunzburger, Wegner & Anooshian, 1977; Hook, 1978; Lane & Coon, 1972; Larsen & Kellogg, 1974; Lerner, 1974). Studies have repeatedly found that children before 5 years of age are mainly guided by self-interest, whereas older children tend to prefer egalitarian distributions (Arsenio & Gold, 2006; Fehr, Berhardt & Rockenbach, 2008; Carson & Banuazizi, 2008; Lane & Coon, 1972; McGillicuddy-De Lisi, Daly & Neal, 2006; Sigelman & Waitzman, 1991). It is only in late childhood that a systematic preference for proportional distributions based on merit or need is reported (but see McCrinck, Bloom & Santos, 2008 for evidence that even 5-year-olds can reason proportionally to evaluate donations).

There are several problems for these theories and the empirical research stimulated by them. Explicit verbal reasoning is likely to confound moral competence and language skills and express post-hoc constructions generated after an implicit and automatic evaluative process has been completed (Haidt, 2001). Also, while proportional reasoning is surely required when distributions must take into account relative effort, merit or need, its development does not explain the origins of the evaluative component of the process. School-aged children's verbal responses are useful to chart the development of explicit judgments, but they are useless in investigating the origin of the sense of fairness and testing whether humans possess spontaneous evaluation skills that are applied to agents' distributive actions.

An alternative theoretical view, defended by the British empiricists, emphasized the role of spontaneous sentiments in the generation and development of moral judgments (Smith, 1759/1948; Hume, 1740/1978). To apply this view to distributive justice scenarios one needs to imagine that spontaneous emotional reactions caused by the distress of an actual or potential victim may stimulate an aversion for unjust distributions. Hypotheses derived by moral sentimentalism have recently received considerable empirical support from behavioral, (Haidt, 2001; Rozin, Lowery, Imada & Haidt, 1999), physiological (Blair, Mitchell & Blair, 2005) and neuroimaging studies (e.g., Greene, Sommerville, Nystrom, Darley & Cohen, 2001; Hsu, Anen & Quartz, 2008). Given that some empathic reactions emerge very early in development (Hoffman, 1991), this view would predict an early emergence of aversion to inequity in children.

A third theoretical view can be traced back to Kant's and Rawls' theories of moral competence (Kant, 1785/1964; Rawls, 1971). Works inspired by this view have suggested that adults (Hauser, 2006; Cushman, Young & Hauser, 2006) and preschool children (Pellizzoni, Siegal & Surian, 2010), evaluate actions' morality by relying on a set of tacit principles including the 'contact principle' (i.e., "harm involving physical contact with a victim is worse than harm involving no physical contact") or the 'intention principle' (i.e., "harm intended as a means to a goal is morally worse than equivalent harm foreseen as the side effect of a goal"). Preverbal infants display an ability to attribute positive values to helping actions and negative values to hindering actions (Hamlin, Wynn & Bloom, 2007; Kuhlmeier, Wynn & Bloom, 2003). No previous work, however, has investigated directly the hypotheses that a tacit principle may guide human intuitions about distributive actions and infants' detection of inequitable distributions.

Olson and Spelke (2008) have recently found that, when helping another agent to distribute some resources, 3.5-years old children, like adults, take into account (1) the degree of relation existing between the donor and the recipients ('principle of close relations'), (2) whether the

potential recipients had given resources to the donor in the past ('principle of direct reciprocity'; see also Dunfield & Kuhlmeier, 2010), and (3) whether the recipients had previously shown a generous behavior toward third parties ('principle of indirect reciprocity'). The sensitivity to these principles was shown clearly in contexts where the donor did not have enough resources to allocate an equal amount to each potential recipient. By contrast, when the number of resources was equal to the number of recipients, children consistently showed a tendency to divide the resources equally among all the recipients, with little regard for the principles of close relations or reciprocity. This bias could have been due to a spontaneous tendency or to a rule that was explicitly taught by parents and that mandates to perform a one-to-one mapping between available resources and potential recipients.

Negative reactions to inequity in human adults are universal (e.g., Fehr & Rockenbach, 2003; Kahneman, Knetsch & Thaler, 1986) and several studies have also found them in some non-human species such as brown capuchin monkeys (Brosnan & de Wall, 2003; see also Lakshminarayanan & Santos, 2008) chimpanzees (Brosnan, Schiff & de Waal, 2005) and dogs (Range, Horn, Viranyi & Huber, 2008). Capuchin monkeys and chimpanzees react negatively to inequity in reward allocations, for example they are likely to through a reward back to the experimenter when two equally performing animals are given unequal rewards. Moreover, male chimpanzees show such negative reactions not only when they are the victims of an unequal allocation of rewards (e.g., they received a piece of carrot while their partners received grape), but also when their partner is the victim of the experimenter's inequity in that their reward was *more* attractive then the one given to their partner (Brosnan, Talbot, Ahlgren, Lambeth & Shapiro, in press). This evidence supports the claim that some species may have evolved an ability to detect inequity that does not depend on explicit teaching, peer interaction or verbal reasoning (Darwin,1871/2004).

The present experiments were aimed at assessing whether infants can take into account the outcome of distributive actions in encoding and reasoning about agents' actions. In Experiment 1, infants first saw four animation events in which one agent (e.g., a schematic bear) performed equal distributions towards two recipients and another agent (e.g., a lion) performed unequal distributions while a bystander (a chicken) observed all the distributive actions. In the test phase, infants saw the bystander approaching either the egalitarian distributor or the other agent while we recorded infants' anticipatory looks and looking times at the final outcomes. Finally, infants were given the chance to choose manually one of the two distributors. Manual choices should reveal a preference or dispositions towards the two distributing agents, whereas anticipatory looks and looking times were used to assess whether infants could attribute their dispositions to other agents and use such attributions to anticipate or interpret their behaviours.

EXPERIMENT 1

Method

Subjects

Participants (N = 37) were divided in two age groups: 17 10-month-olds (9 females; mean age = 10 months 6 days, range = 7 months 15 days through 12 months 18 days) and 20 16-month-olds (13 females; mean age = 16 months 0 days, range =12 months 24 days through 18 months 27 days). No infant had participated in previous experiments.

Apparatus

The experiment was conducted in a quiet room of the day nurseries of Rovereto (Italy). A Tobii 1750 Eye tracker was used to collect data on gaze direction and looking times. The eye tracker was integrated into a 17-in. monitor and the stimuli were presented on this monitor via a

computer running the Tobii's Clearview AVI presentation program. Each infant seated on an educator's lap, 50 cm from the monitor while the experimenter was behind a white curtain and controlled the stimuli presentation using a laptop computer. Two cameras were also used to record the testing sessions; one was placed behind the monitor to record infants' faces and the other was placed behind the infant to record the animations.

Stimuli and Procedure

The testing session started with a five-point calibration procedure in which a picture of an infant toy (either a rattle or a puppet) appeared on the screen accompanied by attractive sounds. To pass the calibration phase infants had to fixate successfully at least three points.

Familiarization trials. Each infant was presented with six familiarization trials (four in the first familiarization phase and two in the second), one test trial involving animation stimuli and one test trial on a manual choice task. An attractive sound was also used at the beginning of each trial. On each of the first four familiarization trials, infants were shown four animals and two multicoloured disks on a green lawn. One of the animals (a chicken) played always the role of the 'observer'. Another animal (a lion or a bear) played the role of 'distributor' of the two disks, while the other two (a donkey and a cow) played the role of 'receivers'. All familiarization trials started showing the distributor in the centre of the screen close to the two multicoloured disks. Next, the chicken entered, brought the two disks closer to the distributor and rested at the bottom of the screen, looking at the distributor. Then the receivers entered in the scene, one by one, moved towards the centre and then moved back, resting one on each side of the screen. From this point, familiarization trials differed depending on the type of distributive action displayed. In familiarization trials with *equal distributions* (E), the distributor gave one disk to each receiver (see Figure 1). In familiarization trials with *unequal distributions* (U) the distributor gave both disks to one of the two receivers (Figure 1). Half of the infants saw two equal distributions performed by the same agent followed by two unequal distributions performed by the other agent (Order 1: EEUU). The other half of the participants saw the event type in reversed order (Order 2: UUEE). The identity of the distributors performing equal and unequal distributions and the identity of the receivers in the unequal distribution trials were counterbalanced across subjects. These trials were aimed at providing infants with information about the fairness or unfairness of the two distributors.

Insert Figure 1 about here

In the second familiarization phase, infants were shown twice the following event: the chicken entered into a Y shaped tunnel from a bottom entrance and come out from one of the two upper exits, in a counterbalanced order. These two trials were aimed at familiarize the infants with the tunnel and the possibility of passing through it. Familiarization trials ended when the infants looked away from more than 2 consecutive seconds or 60 s elapsed. The duration of the events shown in each familiarization trial was 65 s.

In the test phase, infants were presented with two test trials, one using a final animation event (Figure 1) and the other one using a manual choice task. The animation test event started with the observer at the bottom of the monitor, one of the two distributors near one of the two upper exits of the tunnel and the other distributor near the other exit. For half of the infants the fair distributor was on the right side and for the other half it was on the left side of the monitor. The chicken entered into the tunnel and, after 3.5 sec, it came out to approach either the fair or the unfair distributor. The presence of the tunnel allowed us to record anticipatory gazes towards one

of the two upper exits. Half of the infants saw the observer approaching the fair distributor and the other half saw the observer approaching the unfair distributor. Test trials ended when the infants looked away from more than 2 consecutive seconds or 60 s elapsed.

After seeing the animation test event, all infants were given a manual choice task. Infants were shown two 10 cm X 13 cm pictures of the two distributors mounted on foam board. The pictures were placed in front of the infants using a 32 cm X 28 cm yellow tray. Infants were encouraged to choose one by saying "Which one do you want? Pick it up". This task aimed at assessing infant's preference for fair or unfair distributors. The position of the fair and unfair distributor on the right or left side was counterbalanced.

Results and discussion

Looking times at the end of familiarization and test trials, first looks on test trials and responses on the manual choice task were coded independently by one experimenter and by an independent judge who was blind to the fairness of the distributors. The interjudge reliability for looking times on all trials was very high (mean Pearson's r = .99) and the analyses reported below were carried out on the looking times coded the experimenter. In the responses on the manual choice task the agreement between the two judges was perfect.

Familiarization trials

Infants in each age group looked equally long at the outcome of equal and unequal distributions (10-month-olds: M_S = 12.7 s and 13. 9 s, respectively; 16-month-olds: M_S = 18 s and 19.8 s). A 2 (age group) X 2 (distribution type) analysis of variance showed only a main effect for age group, revealing that the older infants looked significantly longer than the younger infants, $F(1, 34) = 4.63$, p = .04, $(_p^2 = .120$, $p_{rep} = .892$.

Test Trials

To assess infants' expectations about the observer's search actions we used gazes replay files exported using the Tobii Clearview program showing infants' eye motions and fixation points. We coded the first discernable look infants made, after the 'observer' entered into the tunnel, towards one of the two 9 cm X 12 cm Areas of Interest (AoIs) surrounding the two distributors and the two upper exits of the tunnel.

Eleven out of 17 10-month-olds and 8 out of 20 16-month-olds looked first at the AoI that included the fair distributor, p = .33, p_{rep} = .622 and p = .50, p_{rep} = .500, two-choice binomial test, two tailed, respectively. Neither age group showed a significant bias for one of the two AoIs, suggesting that they did not anticipated that the agent would go towards the fair or the unfair distributor.

We also coded the *total looking time* at the outcomes of the test trials, starting from the moment the bystander came out from the tunnel. Infants' total looking time on the test trial were analyzed in an analysis of variance (ANOVA) with distributor identity (lion or bear) and distributor location (left or right) as between-subjects variables. This analyses found no significant main effect or interaction.

Ten-month-olds looked equally long at test trials showing the observer approaching the fair or the unfair distributor (M_S = 16.77 s and 20.87 s, respectively), t (14) = .69, p = .501, p_{rep} = .499. By contrast, 16-month-olds looked significantly longer at test trials showing the agent approaching the fair distributor than at test trials showing the agent approaching the unfair distributor (M_S = 25.36 s and 11.53 s, respectively), $t(18) = 2.37$, p = .029, p_{rep} = .910 (see Figure 2). This is the opposite outcome one should predict if infants expected the agent to go towards the fair distributor. A similar pattern of results have been reported by Kuhlmeier et al. (2003) in a previous study on infants' attribution of behavioural dispositions towards helping and hindering

agents. Like present study, infants looked longer at test events showing a natural continuation of the familiarization phase events.

Insert Figure 2 about here

This interpretation is supported by the results on the manual choice task. In this task, the distributor's identity and the side of distributor did not have any significant effect on infants' responses. Three 16-month-olds were excluded because they did not choose any distributor. Ten of the 17 10-month-olds and 14 of the 17 16-month-olds chose the fair distributor, $p = .629$, $p_{rep} = .408$, and $p = .012$, $p_{rep} = .945$, two-choice binomial test, two-tailed, respectively. In sum, the older group, but not the younger group, showed a significant preference for the fair distributor.

Both the manual choices and the looking times of the 16-month-olds suggest that they were sensitivite to the outcomes of the distributive actions. The results of Experiment 1 suggest that by 16 months infants (1) evaluated the agents on the basis of their distributive actions, (2) preferred the distributor that performed a fair distribution of resources and (3) reasoned about the approach performed by to an agent a preference for fair rather than unfair distributing agents. The null results in anticipatory gazes suggests that infants' did not generate an expectation about the observer future actions. Therefore, looking times at the final test outcomes, showing a preference for events in which the observer approached the fair distributor appear to be the result of a judgement that such events were the most coherent continuation of the animation scenarios. However, another possibility is that infants may have simply responded to perceptual aspects that differed in the two distributive actions, such as the symmetry of fair distributions or the asymmetry of unfair ones. To assess the hypothesis that the preferences found in Experiment 1 were due to perceptual factors unrelated to the equality of the distributions, such as a preference for distributions ending in one-to-one mapping between resources and salient locations, we carried out a second experiment.

EXPERIMENT 2

Method

Subjects

Participants were 15 infants (7 females; mean age = 15 months and 18 days; range = 12 months 24 days through18 months 15 days). Given the lack of significant results in the younger infants of Experiment 1, in the present experiment we did not test younger infants. No infant had participated in previous experiments.

Procedure

The procedure was the same as in Experiment 1 except that, on the first four familiarization trials, the recipients were replaced with two inanimate objects (a bottle and a coffee pot) that were present on the stage from the beginning of each familiarization trial and never moved (see Figure 2). Like in Experiment 1, each infant was presented with six familiarization trials, test trial with an animation event followed by the manual choice task.

Results

Looking times at the end of each trial, first looks on test trials and responses on the manual choice task were coded independently by two judges, one of them blind to the fairness of the distributors. For looking times, the inter-judge reliability was very high (mean Pearson's r = .99) and the two judges always agreed in the coding of the first saccades.

Familiarization trials. Looking times at the outcomes of balanced and unbalanced distributions (*Ms* = 18.9 s and 15.6 s, respectively) did not revealed a significant preference for one of the two events, t (14) = 1.47, p = .162, p_{rep} = .757.

Test trials. We coded the first discernable look infants made after the 'observer' entered into the tunnel, towards one of the two 9 cm X 12 cm AoIs surrounding the two distributors. Five out of 15 infants looked first at the AoI that included the fair distributor, p = .301, p_{rep} = .644, two-choice binomial test, two-tailed. We also coded the *looking time* at the outcomes of the test trials, like in experiment 1. Infants did not look significantly longer at one of the two types of outcomes (observer approaching the balanced or unbalanced distributor: *Ms* = 31.67 s and 23.75 s, respectively), t (13) = .81, p = .432, p_{rep} = .548. On the manual choice task, the distributor identity and the side of distributor location did not have any significant effect on infants' responses. Five of the 15 infants chose the balanced distributor, p = .301, p_{rep} = .644, two-choice binomial test, two-tailed. The patterns of choices in experiment 1 and 2 were significantly different, $?^2$ (1, N = 32) = 6.04, p = .010, p_{rep} = .940).

Overall, these results rule out the hypothesis that the response patterns found in Experiment 1 were due to low-level features such as the symmetry of equal distributions, or to a preference for distributions ending in one-to-one mapping between resources and salient locations.

General discussion

Infants at 16 months, but not younger ones, showed a sensitivity to the equality of distributive actions both when they observed the final outcome of test events and when they choose manually between distributors that performed equal and unequal distributions. Their preference for the former suggests that they assigned a positive value to equal distributions and a negative, or inferior, value to unequal distributions. Their longer looking times at events showing an agent approaching the fair distributor, as opposed to events showing the agent approaching the unfair distributor suggest that they preferred to look at events that completed more coherently the scenarios (Kuhlmeier et al., 2003). Previous studies showed that these early social evaluation take into account whether an agent helped or hindered another agent's attempts to realize a goal (se also Hamlin et al., 2007). The present results suggest that infants can also evaluate agents' distributive actions.

In the present study, no information was available on recipients' relative merit or need. Future works is therefore needed to assess whether infants can use such information in evaluating the distributions of resources. This investigation will also help to decide whether infants simply apply a default egalitarian rule ("all should receive the same amount"), or they can also apply equity rules that link the distribution to relevant differences among possible recipients. Previous works on chimpanzees found negative reactions to inequitable outcomes when rewards were given by the experimenter in response to a similar task performance, but were not found when rewards were given for free (Brosnan et al., in press). These results could be due to the fact that chimps were used to unequal allocation of 'free' rewards, or they would suggest that chimps are sensitive to the relative effort. The fact that infants responded the inequitable allocations of free rewards is likely to result from the numerous procedural differences, but is also suggestive of cross-specific differences.

An alternative explanation for the present results is that infants' used information on distributive actions to assess agents' popularity rather than their fairness. That is, by seeing an agent that distribute resources to two recipients rather than one, infants may have inferred that the former is more popular than the latter and this inference affected their manual preferences and

looking times. This is a possibility that can and needs to be tested in further studies. Confirming an inference based on the agent popularity would provide further support for the claim that young infants generate social evaluations by attending to the outcome of distributive actions. However, this conclusion would militate against the claim that sensitivity to distributive outcomes reveal an emerging sense of fairness.

A spontaneous emergence of a sense of fairness in infants is compatible and could be predicted both by theories based on empathic reactions (Haidt, 2001; Smith, 1812) and by theories based on tacit principles (Cushman et al., 2006; Hauser, 1996; Rawls, 1971), provided that the set of principles proposed so far is enriched by an 'equality principle' that deals with agents' distributive actions. While numerous works have demonstrated that empathic reactions play an important role in moral intuitions, we believe that these works do not provide a solution to some long lasting problems for moral sentimentalism and its view on how humans acquire and use their sense of fairness. For example, empathy, by itself, falls short of distinguishing between a person that is suffering because of an unjust violation of her rights and a person that is suffering because of causes unrelated to ethical violations, such as an unlucky course of events. Leslie, Mallon & DiCorcia (2006) ha recently shown, by contrast, that preschoolers do make such distinction. Moreover, they found that children with autism, a disorder that is associated with severe and persistent deficits in empathy and mindreading skills (e.g., Surian & Leslie, 1999), do not fail on basic moral reasoning tasks (see also Blair, 1996). This suggests that the acquisition of moral intuitions in young children does not depend on intact empathic and mindreading skills. Coherently, negative evaluations of unequal distributions may also be independent of empathy for the victim of such distributions.

Authors' note

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Figure captions

Figure 1. Illustration of the familiarization and test events used in Experiment 1.

Figure 2. Mean looking times (with standard error bars) to the test movies showing an approach to agents that had previously performed equal distributions of resources (‘fair distributors’) or unequal distributions (‘unfair distributors’).

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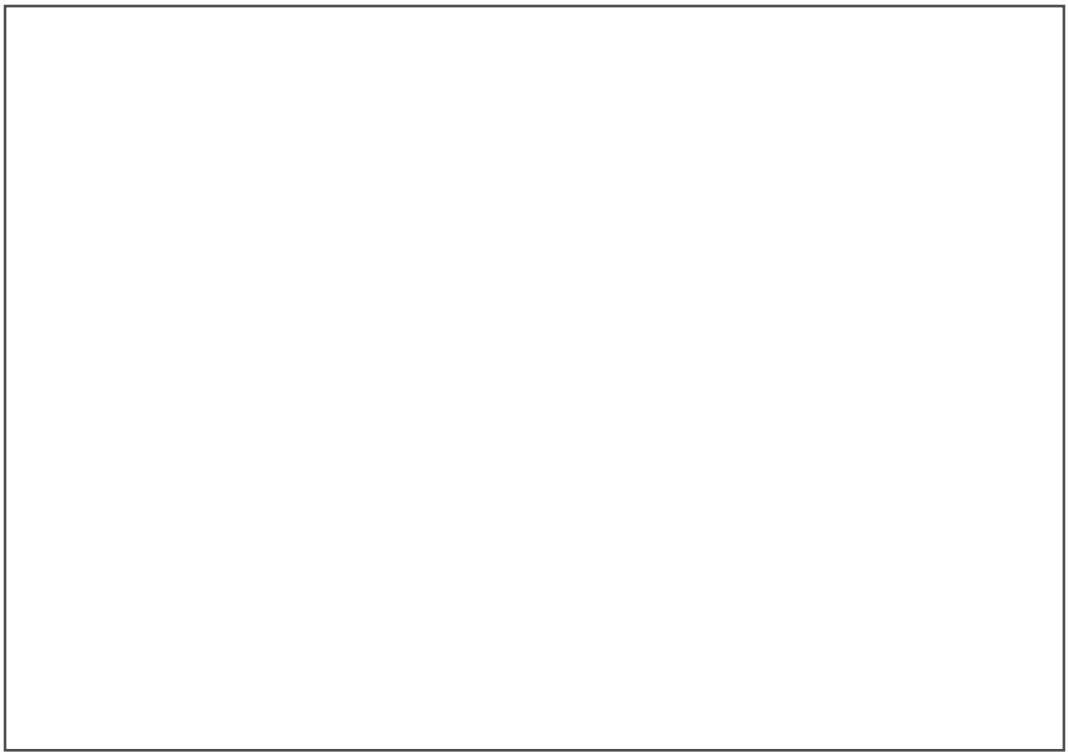

Distributive Justice and social evaluations in 27-month-olds

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Introduction

On development the evaluations of others' distributive behaviors very early studies have supported the idea that distributive justice might change with age in a stage like fashion (Kohlberg, 1971; Piaget, 1932). Previous studies, using allocation task or preference task on equal and unequal distributions of resources, supported the classical developmental theories and suggested that before 5 year of life children are guided by a self-interest, but older children tend to prefer egalitarian distributions (Arsenio & Gold, 2006; Fehr, Bernhard, & Rockenbach, 2008; Carson & Banuazizi, 2008; Lane & Coon, 1972; McGillicuddy-De Lisi, Daly & Neal, 2006; Olson & Spelke, 2008; Sigelman & Waitzman, 1991). Accord to this theory, investigating the criteria and using a verbal task to evaluate the distributive behaviours and niceness of agents, McCrink, Bloom and Santos (2009) compared adults and children. Children were presented with a Giving Game with a 'rich' puppet with 12 chips and 'poor' puppet with 4 chips. They measured what puppet the child though was 'nicer', showing that 4-years-old children use absolute amount as cue, while adults focus exclusively on proportion. Olson & Spelke (2008) revealed that 3.5-year-olds, when they have to help another agent to distribute resources to other, with a number of resources unequal to the number of recipients, take into account these principles: close relation, reciprocity and indirect reciprocity. When the number of the resources was equal to the number of recipients, children preferred to distribute equally the resources. These results could be due to a tendency to perform a one-to-one mapping between resources and recipients.

New models on moral competence emphasize the evolutionary roots of moral judgement, supporting the claim that adults (Cushman, Young & Hauser, 2006; Hauser, 2006) and children (Pellizzoni, Siegal & Surian, 2010) and infants (Hamlin, Wynn & Bloom, 2007; Kuhlmeier, Wynn & Bloom, 2003), may have yielded a tacit principle that sets a positive value on some pro-social actions. The presence of such a principle very early in development has far-reaching implications for current models on the origins and nature of moral intuitions (Darwin, 1871/2004; Haidt, 2001; Hauser, 2006; Kant, 1785/1964; Rawls, 1971).

Hauser (2006) supported that the moral sense derive by a “universal moral grammar”, that is based on innate knowledge characterized by some universal principles that guide moral judgments unconsciously and automatically. This biological equipment does not determine a moral competence in an endogenous way, because the cultural context establish parameters. Parameters and principles mechanisms explain the biological and cultural components of moral system, like in the language competence described by Chomsky.

Dupoux and Jacob (2007) claimed that the moral beliefs derive by a moral faculty, that is dependent from a biological equipment. According to this theory, the moral faculty has an innate origin, it does not present a grammatical structure underlying and principles and parameters mechanisms can not explain the moral diversity. Moral judgments can derive from a emotional and automatic answer. Some studies on infancy or early childhood are needed to investigate the development of moral sense.

No previous work has investigate the hypothesis that younger children, before 3 year of life, could show a preference for: a) an egalitarian distribution, showing an early moral intuition in according to the evolutionary theory on continuity; b) a one-to one distribution between resources or recipients or symmetric distributions, in according also to the classical models on developmental changes.

In all three experiments toddlers were presented with a simple verbal question and we tested for the first time whether even two-year-olds judge an agent that performed an egalitarian distribution more positively than an agent that performed an unfair distribution.

EXPERIMENT 1

Method

Subjects

Sixteen 2-year-olds participated (11 females; mean age = 27 months 1 days, range = 20 months 18 days through 32 months 21 days).

Procedure

Children were tested in a quiet room of their nurseries, after a week long familiarization with the experimenter in their classroom. Infants were tested on a distributive justice task (DJT 1) with a verbal ask. Children were given three similar trials. On each trial, 2 different triplets of animals were shown on two 29.7 cm X 42 cm yellow trays together with two cookies (see Figure 1 a). One of the animals on each tray (i.e., the distributor) was described as possessing the two cookies, while the other two played the role of receivers. One of the distributors (the ‘*fair’* one), gave one cookie to each receiver, while the other one (the ‘*unfair’* distributor) gave both cookies to just one of the two receivers.

On each trial, following the two distributive actions, the experimenter put the two distributors in front of the child and asked her: “Which one is the good one? Please, show me the good one.” The identity of distributor, the identity of two receivers and the order of presentation of distributions (fair or unfair) were counterbalanced.

Results

Toddlers pointed to the equal distributor 37 out of 48 times (77%), $t(15) = 4.61$, $p < .001$.

No child did not point the equal distributor in any trial. Only 2 out of 16 children pointed to the equal distributor just in one of the three trails, while all 14 out 16 children pointed the equal distributor more times (7 in two trials and 7 in all three trials), ($p < .001$, binomial test, two-tailed). This data confirm the positive social evaluation of the distributor that performed a equal distributions of resources.

EXPERIMENT 2

The choices made on Experiment 1 were simply the result of a preference for distributions terminating with a one-to-one correspondence between portions of resources and salient locations or a preference for symmetrical motion events. We tested another group of toddlers on two tasks. Children were presented with two tasks: a) Distributive Justice Task 2 (DJT 2) ; b) Displacement Control Task (DCT).

Method

Subjects

Sixteen toddlers participated, with a mean of 26 months and 21 days (9 females; range = 20 months 18 days through 32 months 21 days). They did not participate to Experiment 1.

Procedure

As in the previous study, this experiment was conducted in day nurseries. After a week of familiarization children were tested with a modified distributive justice task (DJT 2) and a displacement control task (DCT). In both tasks toddlers were given three similar trials.

In the DJT 2, there was a distributor, three receivers and three cookies on each tray. The fair distributor gave one cookie to each receiver, while the unfair distributor gave all cookies to the receiver placed in the middle (Figure 1b).

In the DCT, distributors had two cookies and receivers were replaced by two different cups. One of the distributors placed both cookies in front of one cup while the other, the balanced distributor, placed one cookie in front of each cup (Figure 1c). On each trial, following the two distributive actions, the experimenter put the two distributors in front of the child and asked her: "Which one is the good one? Please, show me the good one." In both tasks, on each of three trials the identity of distributor, the identity of receiver or cup and the order presentation of distributions were counterbalanced.

Results

In the modified DJT 2, with symmetrical distributions, toddlers pointed the fair distributor 36 out of 48 times (75%), $t\ (15) = 5.19$, $p < .001$. In the displacement control task children chose the balanced distributor only 19 out of 48 times (40%), $t(15) = 1.90$, $p = .076$, $p_{rep} = .844$.

Moreover analyzing the frequencies of choices on the DJT 2, 5 out of 16 children pointed equal distributor as the 'good distributor' in all three trials, 10 children pointed it in two trials, and 1 pointed it just in one trial. All children pointed in the test trials. These frequencies in DJT 2 differed significantly, $? ^{2}(2, N = 16) = 7.62$, $p = .022$, $p_{rep} = .923$). They reveal in toddlers a tendency to judge positively the distributor that perform a equal distribution more times that one.

On the DCT, 5 out of 16 children pointed the equal distributor as the 'good distributor' in two trials, 9 children pointed it just in one trial and 2 children did not point it in any trial. These

frequencies in DCT did not differ significantly, ? $_2$ (2, N = 16) = 4.62, p = .099, p_{rep} = .819).

Insert Figures 1 and 2 here

EXPERIMENT 3

Positive evaluations of distributor that perform a equal distribution of resources reveal a sensitivity for equality principle and a tendency to share resources with the others. Controlling this sensitivity for egalitarian principle in the second year of life, we introduced a new distributive task, where the two receivers are different in size, one is bigger than other. This variable is used to investigate the understanding of others' needs, and a sensitivity also for equity principle, in which the bigger animal has to eat more food than that small receiver. We hypothesis a replication of previous results, a strong preference for egalitarian distribution with a positive evaluation of equal distributor, whether only equality principle guide toddlers' social relations.

Method

Subjects

Sixteen toddlers participated, with a mean of 28 months and 8 days (7 females; range = 22 months 4 days through 34 months 5 days). They did not participate to the previous experiments.

Procedure

As in the previous two experiments, this was conducted in day nurseries. After a week of familiarization children were tested with a new distributive justice task (DJT 3). Children were given three similar trials. On each task there was a distributor, two different receivers in size (one small and one big) and two cookies. The fair distributor gave one cookie to each receiver, while the unfair distributor gave both cookies to the big receiver. As in previous experiments, on each trial, following the two distributive actions, the experimenter put the two distributors in front of the child and asked: "Which one is the good one? Please, show me the good one." On each of three trials the identity of distributor, the identity of receiver and the order presentation of distributions were counterbalanced.

Results

Toddlers chose the equal distributor 29 out of 48 times (60%), $t(15) = 7.962$, $p < .001$. One child chose no distributor. 5 children pointed the equal distributor just in one trial, while 10 out 15 children pointed the equal distributor more times (6 in two trials and 4 in all three trials), ($p > .05$, binomial test, two-tailed). These results confirm a preference for the equal distribution of resources.

General Discussion

These results show for the first time that children's positive evaluation of fair distributors is not simply the result of a preference for distributions terminating with a one-to-one correspondence between portions of resources and contextually salient locations or a preference for symmetrical motion events. In evaluating distributors, children were sensitive to the

beneficiaries of the distributor's actions and assigned a different value to distributors only when real sharing rather than a mere displacement of goods was performed. Such an early tendency to evaluate egalitarian distributors as better than unfair ones may help overcome selfish biases and consolidate inequality aversion when, later in development, children will choose among alternative distributions that involve themselves as receivers.

Our results suggested that toddlers are not sensitive to others' needs according to the equity concept, but they showed only a early moral intuition for equality. In the second year of life the children' relations seem to be guided by egalitarian tendency and cooperative instinct.

On the psychological theoretical models on moral development, the results suggest a development of moral sense, because 26 month-olds showed a early intuition based on equality principle but any understanding of equity principle. Our results revealing a early moral intuition in the second year of life, extend recent findings on distributive justice in 3-year-olds (Fehr et al., 2008; Olson & Spelke, 2008).

The presence of an idea of distributive justice has far-reaching implications for recent hypothesis on the continuity of the origin and nature of moral intuitions (Hamlin et al. 2007; Hauser, 2006). Our results, revealing an early idea of justice in the second year of life, are coherent with the new theoretical models that supported the role of the biological equipment and the innate origin of moral sense (Hauser, 2006; Dupoux & Jacob, 2007).

Our findings support the new theoretical model interpreted by Dupoux and Jacob (2007) on moral faculty, that is based on moral instincts and emotional reactions. Our results are coherent with this theory, because the early egalitarian tendency could derive from an innate tendency to cooperate in a group. According to this theoretical model, some findings on non-human species revealed a negative reaction to inequity, as in capuchin monkeys (Brosnan & de Wall, 2003; see also Lakshminarayanan & Santos, 2008) chimpanzees (Brosnan, Schiff & de Waal, 2005) and dogs (Range, Horn, Viranyi & Huber, 2008). This universal sense of 'justice' found early in humans and also non-human species can not explained by Hauser's theory (2006) about a moral sense that involve a grammatical structure with parameters and principles mechanisms. Other studies can address to explain better this point with new investigation on early moral sense.

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Figure captions

Figure 1. Distribution Justice Tasks in Experiment 1 and 2.

Figure 2. Percentage of times that agents that performed a balanced (blue) or an unbalanced (green) distribution were chosen in tasks on three experiments.

Figure 1

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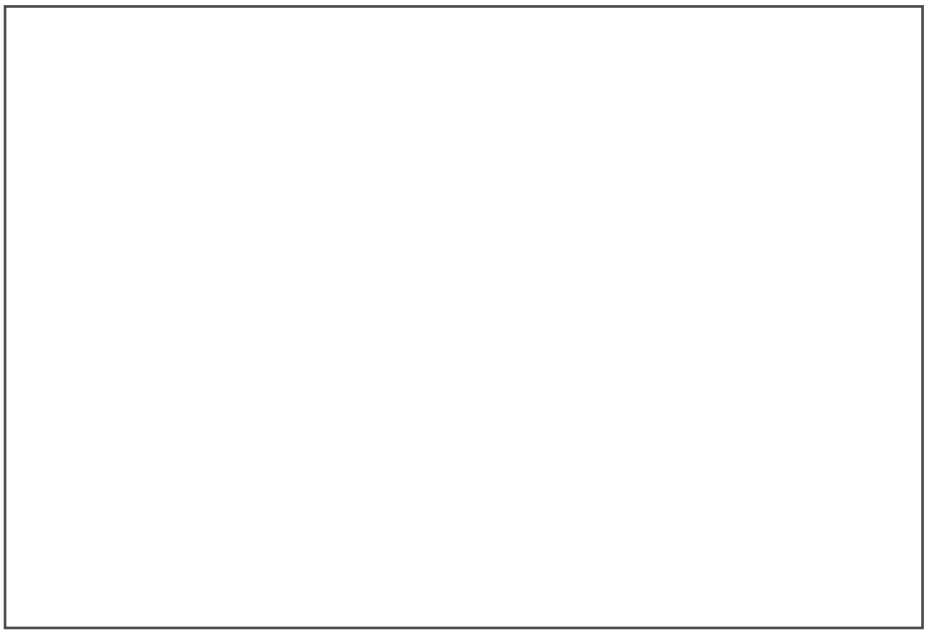
a)

b)

c)

Figure 2



Capitolo IV: Discussione Generale

4.1 Lo sviluppo della Teoria della Mente

Uno degli obiettivi principali della mia tesi è stato quello di affrontare il seguente problema: quali sono le basi innate e quali sono gli effetti dell'esperienza nello sviluppo della Teoria della Mente?

Il primo studio (Surian e Geraci, submitted; v. pag. 35) ha indagato l'ipotesi relativa alla comparsa precoce della capacità di attribuire stati mentali, avanzata da recenti studi. Secondo questa ipotesi gli infanti nel secondo anno di vita sono in grado di riconoscere gli agenti e di attribuire loro credenze vere e false (Onishi e Baillargeon, 2005; Surian, Caldi e Sperber, 2007; Southgate, Senju e Csibra, 2007). Il possesso di queste complesse abilità sociali viene anche suggerito da alcuni dati sulla comprensione degli intenti comunicativi (Aureli, Perucchini, Genco,

2009; Behne, Carpenter e Tomasello, 2005). In questo lavoro, attraverso l'uso di un eye-tracker, sono stati rilevati gli sguardo anticipatori degli infanti di 17 mesi, I risultati mostrano, per la prima volta, negli infanti di 16 mesi la capacità di attribuire false credenze ad agenti non familiari, come figure geometriche che si muovono in modo autonomo. Questi dati rappresentano un' ulteriore evidenza a sostegno dei recenti modelli teorici secondo cui gli infanti precocemente dimostrano di possedere un sistema di ragionamento psicologico dedicato all'interpretazione delle azioni altrui (Leslie, 1994; Gergely e Csibra, 2003; Premack e Premack, 1997; Scott e Baillargeon, 2009).

I risultati sostengono che a 17 mesi di vita sarebbe attivo quel meccanismo di *decoupling*, che permette ai bambini di formare una rappresentazione mentale che include le false credenze e le finzioni degli altri e rendendo possibile l'interpretazione delle azioni altrui (Leslie, 1994).

I risultati dello studio 1 sono coerenti con le scoperte di alcuni studi recenti (Onishi e Baillargeon, 2005; Southgate, Senju e Csibra, 2007; Surian, Caldi e Sperber, 2007). Secondo la proposta modularista di Alan Leslie (1994), l'acquisizione della Teoria della Mente sembra esser garantita da un bagaglio di conoscenze innate e da meccanismi specializzati nell' acquisizione e elaborazione di informazioni che riguardano le azioni degli agenti e la loro mente. I risultati del primo studio contraddicono alcune spiegazioni alternative sulla capacità degli infanti di attribuire false credenze.

In primo luogo, i dati del primo studio, utilizzando le misure implicite, quali la rilevazione dello sguardo anticipatorio, nella condizione di credenza vera o falsa, non possono sostenere l'interpretazione *associazionista*, proposta da Perner e Ruffman (2005). Secondo questa differente interpretazione, nei compiti di falsa credenza, i bambini formerebbero delle associazioni tra l'agente, l'oggetto e la posizione dell'oggetto nascosto, che permetterebbero ai bambini di guardare più a lungo l'evento che non è coerente con questa associazione, ovvero quando l'agente cerca l'oggetto in un altro posto. Il nostro studio estende i risultati di Southgate e al. (2007), rilevando lo sguardo di anticipazione ed aggiungendo le condizioni di vera e di falsa credenza. I risultati rivelano la capacità dei bambini di 17 mesi di attribuire agli agenti non familiari false o vere credenze, anticipandone l'azione attraverso lo sguardo di anticipazione. Questi dati non possono esser interpretati con la spiegazione avanzata da Perner e Ruffman (2005), secondo cui i bambini comprendono le regole comportamentali del compito, aspettandosi, per esempio, che l'agente cerchi l'oggetto coerentemente con la prima o ultima posizione.

I nostri dati sostengono un modello teorico innatista e non di apprendimento.

In merito agli ***effetti dell'esperienza*** il secondo studio (Meristo e al., in prep.; v. pag. 61) e il terzo studio (Siegal e al., 2010. v. pag. 87) hanno indagato, rispettivamente il ruolo dell'esposizione precoce a più lingue e della deprivazione di esperienze linguistiche nello sviluppo delle abilità pragmatiche.

Nello secondo studio sono state utilizzate le misure implicite, quali la rilevazione dello sguardo anticipatorio, nella condizione di credenza vera o falsa, confrontando le performance dei bambini con sviluppo tipico e sordi. I risultati hanno rivelato un deficit nell'attribuzione delle false credenze con lo sguardo anticipatorio nei bambini sordi. Il secondo esperimento ha confrontato il linguaggio sugli stati mentali usato nelle conversazioni con i bambini sordi e udenti figli di genitori udenti. I risultati hanno mostrato che una precoce conversazione sugli stati mentali contribuisce allo sviluppo della teoria della mente.

Questi risultati sono coerenti anche con i dati del terzo studio (Siegal et al., 2010; v. pag. 87). Nello studio 3, confrontando le performance dei bambini prescolari bilingui e monolingui, i risultati sostengono l'assunzione che l'esposizione al linguaggio, ed a più linguaggi, contribuisce all'acquisizione della Teoria della Mente, agevolando la comprensione degli stati mentali altrui

(Kovacs, 2009) e dei messaggi comunicativi (Siegal, Iozzi e Surian, 2009), indipendentemente dai fattori socio-culturali. Queste conclusioni sostengono l'idea di un precoce sviluppo cognitivo della teoria della mente, determinato da processi specializzati e predisposizioni biologiche (Leslie, 1994), su cui l'esperienza conversazionale precoce può esercitare un ruolo importante per sviluppare la comprensione e l'uso delle nozioni psicologiche, automatizzando i meccanismi specializzati. I risultati sono coerenti con alcune evidenze empiriche che enfatizzano l'associazione causale tra la teoria della mente e l'esperienza conversazionale nei bambini bilingui (Kovacs, 2009) e nei bambini sordi (Woolfe, Want e Siegal, 2002). Lohamann e Tomasello (2003) hanno dimostrato attraverso l'uso di training cognitivi, che i bambini di tre anni mostravano miglioramenti nei compiti di metarappresentazioni se erano stati sottoposti ad un training basato su discorsi *perspective-taking,* che includevano l'inferenza degli stati mentali. Nell'insieme questi risultati suggeriscono che una ricca esperienza di comunicazione determina uno sviluppo adeguato della comprensione sociale.

Il quarto studio (Geraci e al., 2010. v. pag. 106) ha indagato la specificità di dominio della Teoria della Mente, nei pazienti con lesioni cerebrali localizzate in due aree diverse della corteccia prefrontale, ventromediale e dorsolaterale, causate da trauma cranio-encefalico. Gli studi neuropsicologici condotti su pazienti con lesioni cerebrali hanno raggiunto un accordo quasi unanime sul ruolo della corteccia prefrontale mediale nella Teoria della Mente (Frith e Frith, 2006; Gallagher e Frith, 2003), mentre gli studi di neuroimmagine hanno individuato più estese regioni neurali che si attiverebbero negli adulti durante compiti di attribuzione delle false credenze: poli temporali, solco temporale superiore inferiore, giunzione temporo-parietale e corteccia prefrontale mediale (Saxe e Powell, 2006). Gli studi su neuroni specchio (*mirror neuron system)* non hanno fornito dati più decisivi sull'area specifica implicata per la Teoria della Mente e l'attribuzione delle false credenze. Nello studio, sono state confrontate le prestazioni nei due compiti di teoria della mente (uno di inferenza degli stati mentali e l'altro di percezione sociale delle emozioni), correlandole con le misure delle funzioni esecutive e dell'intelligenza generale. I risultati hanno confermato il ruolo della corteccia prefrontale ventromediale nella capacità d'inferire gli stati mentali, indipendentemente dalle funzioni esecutive e dall'intelligenza generale. Questo sarebbe un' ulteriore conferma dell'ipotesi sull'esistenza del meccanismo neurocognitivo specializzato per la Teoria della Mente, che opera indipendente da altri processi cognitivi.

4.2 Valutazione Sociale delle azioni distributive

L'obiettivo degli studi della seconda parte del lavoro è indagare nei bambini tra il primo ed il secondo anno di vita l'origine della valutazione sociale delle azioni distributive altrui, se determinata da un ragionamento psicologico, generato da meccanismi specifici o generali.

Nell'insieme i risultati del seguente lavoro hanno sostenuto l'ipotesi di una precoce valutazione sociale dei comportamenti altrui, come le azioni distributive coerentemente con le ultime rivelazioni scientifiche (Hamlin e al., 2007; Kuhlmeier e al., 2003). I risultati del quinto studio (Geraci e Surian, in prep.; v. pag. 136), suggeriscono nei bambini di 15 mesi l'esistenza di un precursore del giudizio morale che si manifesta con la preferenza propria ed attribuita agli altri, per l'agente che ha operato una distribuzione equa delle risorse, coerentemente con il principio di uguaglianza. I risultati non sono coerenti con i modelli basati sul costruttivismo epigenetico (Kohlberg, 1981), che sostengono che il soggetto formula i giudizi a partire da un ragionamento razionale ed esplicito, dopo una fase di apprendimento delle norme convenzionali.

Nel nostro lavoro, a causa dell'assenza delle reazioni emotive in tutti gli agenti,

distributori e riceventi, i risultati non possono essere usati per valutare i modello teorici di orientamento *humiano* che riconducono le capacità morali ad un meccanismo emozionale che codifica una risposta positiva o negativa a situazioni sociali e produce un giudizio morale (Haidt, 2001; Damasio, 2005). Nonostante nei nostri esperimenti manchino le espressioni emotive in tutti gli agenti, non si esclude la possibilità che i bambini abbiano valutato i comportamenti altrui dopo averne inferito le reazioni emotive.

La scoperta nei bambini di 15 mesi di una precoce capacità di valutazione delle azioni distributive potrebbero sostenere alcune proposizioni dei modelli *rawlsiani* (Rawls, 1971; Hauser, 2006), secondo cui l'uomo fin dalla nascita sarebbe dotato di principi e parametri per costruire un sistema morale. Questo è coerente anche con i risultati delle ricerche recenti sulla valutazione sociale dei bambini nel primo anno di vita, che hanno rivelato i precursori del senso morale (Premack e Premack, 1997; Hamlin e al., 2007; Kuhlmeier et al., 2003).

Le scoperte di questi studi sostengono il modello teorico di Hauser (per una valutazione critica si veda Dupoux e Jacob, 2007) sullo sviluppo della facoltà morale, secondo cui l'origine del senso morale sarebbe basata sugli istinti morali e le tendenze innate a cooperare in un gruppo. Questa spiegazione è coerente con le scoperte sulle specie animali che hanno rivelato una reazione negative all'inequità, come nelle scimmie (Brosnan & de Wall, 2003; Lakshminarayanan & Santos, 2008), negli scimpanzé (Brosnan, Schiff & de Waal, 2005) e nei cani (Range, Horn, Viranyi & Huber, 2008).

In merito alla valutazione sociale espressa esplicitamente i risultati del sesto studio (Geraci e Surian, submitted; v. pag. 159) suggeriscono la coerenza tra la preferenza e il giudizio positivo, sostenendo il recente modello teorico della continuità (Hauser, 2006; Dupoux e Jacob, 2007). Il giudizio positivo attribuito esplicitamente al distributore equo, rivelato in questo studio conferma i risultati di una ricerca condotta sui bambini più piccoli e che ha confermato che i bambini, già a 12 mesi, associano le azioni positive alle facce piacevoli e le azioni negative alla facce non piacevoli (Taylor-Pertridge, Griffin, Rosen, Langlois e Principe, 2006).

Riguardo al giudizio sociale basato sul senso morale, i dati di questo lavoro, condotto sui bambini di 15 mesi (quinto studio) e di 26 mesi (sesto studio), sostengono i risultati di alcune ricerche sulla competenza morale, i cui risultati hanno enfatizzato l'origine evolutiva del giudizio morale, suggerendo che gli adulti (Cushman, Young & Hauser, 2006; Hauser, 2006), i bambini (Pellizzoni, Siegal & Surian, 2010) e gli infanti (Hamlin, Wynn & Bloom, 2007; Kuhlmeier, Wynn & Bloom, 2003) possono aver sviluppato un principio tacito che attribuisce un valore positivo alla condivisione delle risorse e alla cooperazione.

Relativamente al dominio specifico della facoltà morale, i risultati di questo lavoro sembrano coerenti con quanto ipotizzato da Jacob e Dupoux (2008), i quali, commentando i risultati di Hamlin e al. (2007), hanno sostenuto che questi dati suggeriscono una cognizione morale e sociale basata su '*core systems of knowledge'*, cioè su sistemi specializzati che elaborano le informazioni sociali ed emozionali in maniera inconscia e automatica. Jacob e Dupoux (2008) hanno suggerito la necessità d'indagare l'ipotesi di un solo fondamento cognitivo per la cognizione morale, ipotizzando l'esistenza di una specifica "facoltà morale". I nostri risultati convergono con la recente teoria dell'organo morale umano (Darwin, 1871; Hauser, 2006; Rawls, 1971), rivelando un precoce senso morale già tra il primo e il secondo anno di vita.

4. 3 L'inferenza nella valutazione sociale: un'interazione fra due processi?

Complessivamente i risultati del seguente lavoro sostengono la tendenza teorica che sembra dominare recentemente le ricerche sullo sviluppo cognitivo della cognizione sociale:

interpretazione “ricca”. Secondo questa teoria, l’infante percepisce lo scopo di un’azione quando inizia a comprendere il principio causale e psicologico. I bambini precocemente sono abili a capire gli scopi degli altri agenti, perché sanno che gli altri possiedono stati mentali che li inducono ad agire per la realizzazione di uno scopo (Onishi e Baillargeon, 2005; Surian e al., 2007; Southgate e al., 2007).

Nella prima parte, gli studi sulla teoria della Mente hanno confermato l’ipotesi del dominio specifico rivelando: a) meccanismi specializzati per attribuire stati mentali altrui, false credenze anche ad agenti non familiari (primo studio); b) ruolo della precoce esperienza conversazionale nello sviluppo della cognizione sociale (secondo e terzo studio); c) coinvolgimento della corteccia prefrontale ventromediale nel ragionamento inferenziale (quarto studio), evidenziando l’indipendenza da altri processi cognitivi, come le funzioni esecutive e l’intelligenza generale.

Nella seconda parte, lo scopo è stato dimostrare l’applicazione di tale ragionamento in un contesto sociale complesso, che implica un ragionamento inferenziale ed una valutazione sociale delle azioni distributive altrui. I risultati hanno rivelato: a) una precoce valutazione sociale dei comportamenti altrui e una tendenza a condividere le risorse in maniera equa, manifestata dai bambini di 15 mesi con una preferenza per il distributore equo, nonchè con l’attribuzione di tale valutazione agli altri (quinto studio); b) connotazione positiva dell’azione del distributore equo, manifestata esplicitamente dai bambini di 26 mesi (sesto studio).

Il quinto studio ha rivelato nel bambino di 15 mesi il possesso di queste complesse abilità, suggerendo l’ipotesi di un *social- moral infant*, dotato di principi impliciti. Le due abilità indagate dal seguente lavoro, quale la Teoria della Mente (ragionamento psicologico) e la Valutazione Sociale (senso morale), sembrano esser determinate da propri meccanismi specializzati, ma risultano interagire in contesti sociali complessi. I dati hanno rivelato nei bambini di 15 mesi una complessa cognizione sociale, che con l’azione di abilità specifiche, come il ragionamento psicologico e il senso morale permettono la comprensione della azioni altrui, in termini di scopi e intenzioni, e il giudizio di tali comportamenti per gli effetti sociali derivanti.

I risultati sono coerenti con la proposta teorica dell’interpretazione “ricca” dell’infante, secondo cui i bambini svilupperebbero precocemente una complessa cognizione sociale, supportata da abilità cognitive dominio specifiche che nei contesti sociali interagiscono in modo complesso (Pellizzoni, Siegal e Surian. 2009).

Le nostre conclusioni sono coerenti con quanto ipotizzato da Jacob e Dupoux (2008), secondo cui la cognizione sociale e morale, sarebbero basate su *core systems*, cioè su sistemi specializzati che elaborano le informazioni sociali ed emozionali in maniera inconscia e automatica. Nei contesti complessi, cognizione sociale e morale interagiscono dinamicamente, come dimostrato dal seguente lavoro, in cui gli infanti hanno inferito le disposizioni altrui, in seguito alla valutazione sociale delle azioni altrui.

Il lavoro non può non concludersi con le seguente affermazione: in un contesto sociale complesso, il bambino a 15 mesi applica un ragionamento psicologico che può essere guidato da un precoce senso morale.

4.4 Limiti e direzioni future

Il seguente lavoro presenta alcuni limiti, di cui i più importanti meritano di esser notati per delineare le proposte future.

Nel primo studio sull’attribuzione delle false credenze a forme geometriche, i risultati non escludono la spiegazione dell’attribuzione dell’ignoranza. In entrambe le condizioni di vera e falsa

credenza, il disco si sposta da una scatola all'altra, per cui durante l'assenza del triangolo (condizione di falsa credenza) gli infanti potrebbero aver attribuito al triangolo uno stato di ignoranza sulla posizione finale del disco (ultima posizione). Per ovviare a questa spiegazione Southgate e al. (2007) hanno presentato degli eventi in cui in due condizioni di falsa credenza un agente portava via dalla scena l'oggetto, facendo in modo che i bambini attribuissero al secondo agente una falsa credenza sulla posizione iniziale dell'oggetto. Sarebbe interessante introdurre nel nostro lavoro una condizione in cui il disco si sposta ed esce di scena in entrambe le condizioni di vera e di falsa credenza .

Nel quinto studio sulla valutazione sociale nei bambini di 11 e 16 mesi sono presenti alcuni limiti. In primo luogo, manca un esperimento per controllare la preferenza percettiva per la distribuzione simmetrica. I risultati non escludono la spiegazione che i bambini possano aver preferito la distribuzione simmetrica, senza ricorrere alla giustizia distributiva. In secondo luogo, tutti gli agenti delle animazioni erano privi di emozioni. I risultati non danno informazioni se i bambini possano aver valutato i comportamenti altrui, inferendo le reazioni emotive. Sarebbe interessante aggiungere un esperimento di controllo, dove siano evidenti le reazioni emotive degli agenti, per verificare se le emozioni possano modificare i risultati, rivelando l'inferenza delle emozioni e il ruolo dell'emozione nella valutazioni delle azioni pro-sociali altrui. Negli stimoli dello studio di Hamlin e al. (2007), l'agente 'climber' con l'aiuto del secondo agente, 'helper', raggiunge la cima del pendio e poi ruote su stesso, comunicando una positiva reazione emotiva. Hamlin e al. (2007) non hanno mai descritto o discusso questo particolare in nessuna parte dell'articolo. Nel nostro studio rimane sconosciuta la possibilità che i bambini possano aver valutato le azioni distributive sulla base delle reazioni emotive dei riceventi.

Il sesto studio ha indagato la valutazione sociale nelle azioni distributive e l'esplicita connotazione positiva per il distributore equo nei bambini di 26 mesi. Sarebbe interessante ampliare il campione e confrontare i risultati dei bambini prescolari confrontando i risultati delle diverse fasce d'età, dai 2 ai 5 anni.

Le prospettive future permetteranno di continuare i propositi di questo lavoro, al fine di indagare l'origine e lo sviluppo cognitivo della Teoria della Mente e del senso morale.

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[1] Kuhlmeier e al. (2003) scrivono: "*If infants make a nonmentalistic analysis of the ball's behavior, an assumption or psychological principle regarding goal behavior would be necessary to mediate the interpretation of the new goal action in the new context. We proposed earlier that such an assumption would be in the form of "agents are more likely to approach objects that are positively associated with previous goal completion than to approach objects that are not positively associated with previous goal completion." However, this assumption would require that 12-month-old infants possess an abstract, nonmentalistic concept of "goal," in which agents are seen to have the overall goal (nonmentalistic) of achieving all future goals. Moreover, this abstract notion would have to be attributed to the agents themselves*." (Kuhlmeier et al., 2003; p. 407).

(A)

(B)

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t

Equal distribution

Unequal distribution

Test event