Origins of Mind (Umeå)

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1. Introduction

1.1. The Question

How do humans first come to know about—and to knowingly manipulate—objects, causes, words, numbers, colours, actions and minds?

'… 'tis past doubt, that Men have in their Minds several Ideas, such as are those expressed by the words, Whiteness, Hardness, … and others: It is in the first place to be enquired, How he comes by them?' (Locke 1689, p. 104)

'How does it come about that the development of organic behavior into controlled inquiry brings about the differentiation and cooperation of observational and conceptual operations?' (Dewey 1938, p. 12)

'the fundamental explicandum, is the organism and its propositional attitudes … Cognitive psychologists accept … the … necessity of explaining how organisms come to have the attitudes to propositions that they do.' (Fodor 1975, p. 198)

1.2. From Myths to Mechanisms

'the soul inherently contains the sources of various notions and doctrines which external objects merely rouse up on suitable occasions' (Leibniz 1996, p. 48)

'Men, barely by the Use of their natural Faculties, may attain to all the Knowledge they have, without the help of any innate Impressions' (Locke 1689, p. 48)

'Developmental science […] has shown that both these views are false' (Spelke & Kinzler 2007, p. 89).

1.3. Two Breakthroughs

1. *Joint Action* Preverbal infants enjoy surprisingly rich social abilities. These may well facilitate the subsequent acquisition of linguistic abilities and enable the emergence of knowledge (e.g. Csibra & Gergely 2009; Meltzoff 2007; Tomasello et al. 2005).

2. *Core Knowledge* Infants in the first year of life enjoy sophisticated abilities to track causal interactions, numerosity, actions, mental states and more besides in infants in the very first months of life (e.g. Spelke 1990; Baillargeon et al. 2010).

1.4. What Is Knowledge?

Knowledge is constitutively linked to practical reasoning and to inference. It is the kind of thing that can typically influence how you act when you act purposively, and it is the kind of thing that can influence purposive actions in any domain at all. Knowledge is also the kind of thing that you can sometimes arrive at by inference, and which can enable you to make new inferences in any domain at all.

Knowledge states are *inferentially integrated* with other attitudes like beliefs, desires and intentions (see the glossary).

1.5. Davidson's Challenge

'if you want to describe what is going on in the head of the child when it has a few words which it utters in appropriate situations, you will fail' (Davidson 2001b, pp. 127–8).

'The difficulty in describing the emergence of mental phenomena is a conceptual problem […] In […] the evolution of thought in an individual, there is a stage at which there is no thought followed by a subsequent stage at which there is thought. To describe the emergence of thought would be to describe the process which leads from the first to the second of these stages. What we lack is a satisfactory vocabulary for describing the intermediate steps' (Davidson 2001b, p. 127).

'We have many vocabularies for describing nature when we regard it as mindless, and we have a mentalistic vocabulary for describing thought and intentional action; what we lack is a way of describing what is in between' (Davidson 1999, p. 11)

1.5.1. Uncomplicated Account of Minds and Actions

For any given proposition [There's a spider behind the book] and any given human [Wy] …

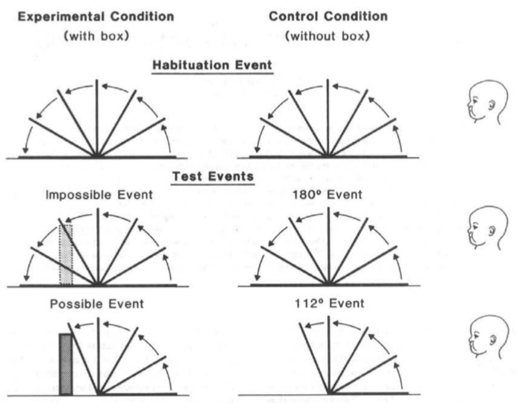
1. Either Wy believes that there's a spider behind the book, or she does not.

2. Either Wy can act for the reason that there is, or seems to be, a spider behind the book, or else she cannot.

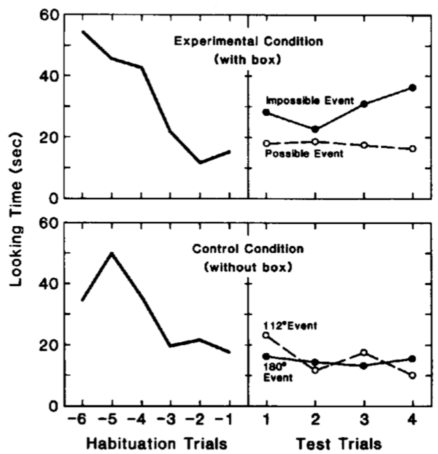
3. The first alternatives of (1) and (2) are either both true or both false.

1.6. Unperceived Objects: An Illustration of Davidson's Challenge

When do humans first come to know facts about the locations of objects they are not perceiving?



Baillargeon 1987 figure 1



Baillargeon 1987 figure 2

'action demands are not the only cause of failures on occlusion tasks' (Shinskey 2012, p. 291).

'violation-of-expectation experiments, using looking-time measures, suggested that infants have object permanence in occlusion conditions; but simplified-search studies confirm that infants fail to reach towards occluded objects, suggesting that infants do not have object permanence in occlusion conditions. This discrepancy, however, is only the tip of the iceberg. Results of studies attempting to measure infants' cognitive abilities using reaching measures often contradict results gained while using looking-time measures.' (Charles & Rivera 2009, p. 994)

'there are many separable systems of mental representations … the task … is to … [find] the distinct systems of mental representation and to understand their development and integration' (Hood et al. 2000, p. 1522).

Object permanence: the ability to know facts about objects you aren't currently perceiving.

2. Minds

2.1. Knowledge of Mind

Mindreading is the process of identifying mental states and purposive actions as the mental states and purposive actions of a particular subject.

'In saying that an individual has a theory of mind, we mean that the individual imputes mental states to himself and to others' (Premack & Woodruff 1978, p. 515)

In a standard *false belief task*, '[t]he subject is aware that he/she and another person [Maxi] witness a certain state of affairs x. Then, in the absence of the other person the subject witnesses an unexpected change in the state of affairs from x to y' (Wimmer & Perner 1983, p. 106). The task is designed to measure the subject's sensitivity to the probability that Maxi will falsely believe x to obtain.

Three-year-olds systematically fail to predict actions (Wimmer & Perner 1983) and desires (Astington & Gopnik 1991) based on false beliefs; they similarly fail to retrodict beliefs (Wimmer & Mayringer 1998) and to select arguments suitable for agents with false beliefs (Bartsch & London 2000). They fail some low-verbal and non-verbal false belief tasks Call & Tomasello 1999; Low 2010; Krachun et al. 2009, 2010; they fail whether the question concerns others' or their own (past) false beliefs (Gopnik & Slaughter 1991); and they fail whether they are interacting or observing (Chandler et al. 1989).

2.2. Infants Track False Beliefs

For a process to *track* someone's belief that p is for it to nonaccidentally depend in some way on whether she believes that p. For *someone to track beliefs* is for there to be processes in her which track some beliefs.

One-year-old children predict actions of agents with false beliefs about the locations of objects (Clements & Perner 1994; Onishi & Baillargeon 2005; Southgate et al. 2007), and about the contents of containers (He et al. 2011), taking into account verbal communication (Song et al. 2008; Scott et al. 2012). They will also choose ways of helping (Buttelmann et al. 2009) and communicating (Knudsen & Liszkowski 2012; Southgate et al. 2010) with others depending on whether their beliefs are true or false. And in much the way that irrelevant facts about the contents of others' beliefs modulate adult subjects' response times, such facts also affect how long 7-month-old infants look at some stimuli (Kovács et al. 2010).

2.3. Mindreading: a Developmental Puzzle

A *model* is a way the world could logically be, or a set of ways the world could logically be.

An *A-Task* is any false belief task that children tend to fail until around three to five years of age.

1. Children fail A-tasks because they rely on a model of minds and actions that does not incorporate beliefs.
2. Children pass non-A-tasks by relying on a model of minds and actions that does incorporate beliefs.
3. At any time, the child has a single model of minds and actions.

For adults (and children who can do this), representing perceptions and beliefs as such—and even merely holding in mind what another believes, where no inference is required—involves a measurable processing cost (Apperly et al. 2008, 2010a), consumes attention and working memory in fully competent adults Apperly et al. 2009; Lin et al. 2010; McKinnon & Moscovitch 2007, may require inhibition (Bull et al. 2008) and makes demands on executive function (Apperly et al. 2004; Samson et al. 2005).

2.4. Two Questions about Mindreading

Two questions:

1. How do observations about tracking support conclusions about models?
2. Why are there dissociations in nonhuman apes', human infants' and human adults' performance on belief-tracking tasks?

'we should be focused not on the yes–no question (do chimpanzees have a theory of mind?), but rather on a whole panoply of more nuanced questions concerning precisely what chimpanzees do and do not know about the psychological functioning of others' (Hare et al. 2001, p. 149)

2.5. Mindreading in Adults: Automaticity?

Is mindreading automatic? (More carefully: Does belief tracking in human adults depend only on processes which are automatic?)

A process is *automatic* to the degree that whether it occurs is independent of its relevance to the particulars of the subject's task, motives and aims.

There is evidence that some mindreading in human adults is entirely a consequence of relatively automatic processes (Kovács et al. 2010; Schneider et al. 2012; van der Wel et al. 2014), and that not all mindreading in human adults is (Apperly et al. 2008, 2010b; van der Wel et al. 2014).

Qureshi et al. (2010) found that automatic and nonautomatic mindreading processes are differently influenced by cognitive load, and Todd et al. (2016) provided evidence that adding time pressure affects nonautomatic but not automatic mindreading processes.

'Participants never reported belief tracking when questioned in an open format after the experiment ("What do you think this experiment was about?"). Furthermore, this verbal debriefing about the experiment's purpose never triggered participants to indicate that they followed the actor's belief state' (Schneider et al. 2012, p. 2)

2.6. Minimal Theory of Mind

Which models of minds and actions underpin which mental state tracking processes?

An agent's *field* is a set of objects related to the agent by proximity, orientation and other factors.

First approximation: an agent *encounters* an object just if it is in her field.

A *goal* is an outcome to which one or more actions are, or might be, directed.

Principle 1: one can't goal-directedly act on an object unless one has encountered it.

Applications: subordinate chimps retrieve food when a dominant is not informed of its location (Hare et al. 2001); when observed scrub-jays prefer to cache in shady, distant and occluded locations (Dally et al. 2004; Clayton et al. 2007).

First approximation: an agent *registers* an object at a location just if she most recently encountered the object at that location.

A registration is *correct* just if the object is at the location it is registered at.

Principle 2: correct registration is a condition of successful action.

Applications: 12-month-olds point to inform depending on their informants' goals and ignorance (Liszkowski et al. 2008); chimps retrieve food when a dominant is misinformed about its location (Hare et al. 2001); scrub-jays observed caching food by a competitor later re-cache in private (Clayton et al. 2007; Emery & Clayton 2007).

Principle 3: when an agent performs a goal-directed action and the goal specifies an object, the agent will act as if the object were actually in the location she registers it at.

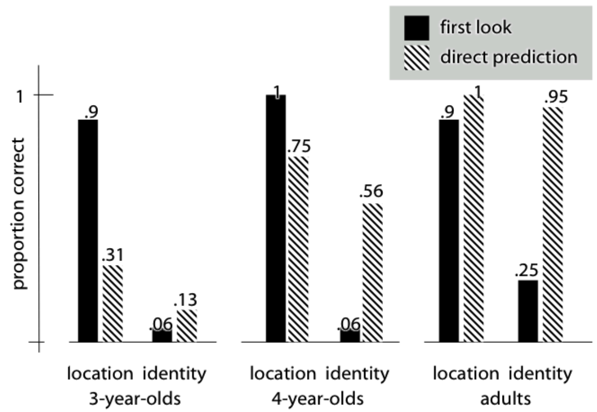
Applications: some false belief tasks (Onishi & Baillargeon 2005; Southgate et al. 2007; Buttelmann et al. 2009).

2.7. Signature Limits

A *signature limit of a model* is a set of predictions derivable from the model which are incorrect, and which are not predictions of other models under consideration.

Automatic belief-tracking in adults and belief-tracking in infants are both subject to signature limits associated with minimal theory of mind (Wang et al. 2015; Low & Watts 2013; Low et al. 2014; Mozuraitis et al. 2015; Edwards & Low 2017; Fizke et al. 2017; Oktay-Gür et al. 2018; contrast Scott et al. 2015).

	Propositional attitude	Relational attitude
level-1 perspective taking	Y	Y
level-2 perspective taking	Y	N
false beliefs about non-existence	Y	N
false beliefs about location	Y	Y
false beliefs about identity	Y	N



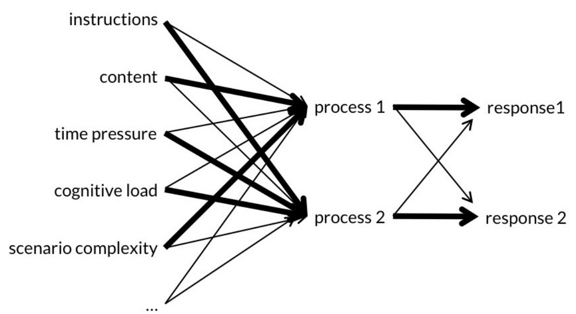
source: Low & Watts (2012)

Objection: 'the theoretical arguments offered [...] are [...] unconvincing, and [...] the data can be explained in other terms' (Carruthers 2015b; see also Carruthers 2015a).

'A cooperative multi-system architecture is better able to explain infant belief representation than a parallel architecture, and causal representation, schemas and models provide a more promising basis for flexible belief representation than does a rule-based approach of the kind described by Butterfill and Apperly' (Christensen & Michael 2016; see also Michael & Christensen 2016; Michael et al. 2013).

2.8. Dual Process Theory of Mindreading (Schema)

Two (or more) mindreading processes are distinct: the conditions which influence whether they occur, and which outputs they generate, do not completely overlap.



Dual Process Theory of Mindreading. Automatic and nonautomatic mindreading processes are independent in this sense: different conditions influence whether they occur and which ascriptions they generate (e.g. Todd et al. 2016; Qureshi et al. 2010).

2.9. A Developmental Theory

1. Automatic and nonautomatic mindreading processes both occur from the first year of life onwards.

2. The model of minds and actions underpinning automatic mindreading process does not significantly change over development.

3. In the first three or four years of life, nonautomatic mindreading processes involve relatively crude models of minds and actions, models which do not enable belief tracking.

4. What changes over development is typically just that the model underpinning nonautomatic mindreading becomes gradually more sophisticated and eventually comes to enable belief tracking.

3. Objects

3.1. Objects: Three Requirements

Knowledge of objects depends on abilities to:

1. segment objects,

2. represent them as persisting, and

3. track their interactions.

How do humans come to meet the three requirements on knowledge of objects?

3.2. Segmentation

'infants perceive the boundaries of a partly hidden object by analyzing the movements of its surfaces: infants perceived a connected object when its ends moved in a common translation behind the occluder. Infants do not appear to perceive a connected object by analyzing the colors and forms of surfaces: they did not perceive a connected object when its visible parts were stationary, its color was homogeneous, its edges were aligned, and its shape was simple and regular' (Kellman & Spelke 1983).

3.3. The Principles of Object Perception

cohesion—'two surface points lie on the same object only if the points are linked by a path of connected surface points'

boundedness—'two surface points lie on distinct objects only if no path of connected surface points links them'

rigidity—'objects are interpreted as moving rigidly if such an interpretation exists' no action at a distance—‘separated objects are interpreted as moving independently of one another if such an interpretation exists’ (Spelke 1990)

What is the status of these principles?

1. We (as perceivers) start with a cross-modal representation of three-dimensional perceptual features which includes their locations and trajectories.
2. Our task is to get from these representations of features to representations of objects.
3. *Descriptive component* We do this as if in accordance with certain principles (cohesion, boundedness, rigidity, and no action at a distance).
4. *Explanatory component* We acquire representations of objects because we apply the principles to representations of features and draw appropriate inferences.

Three Questions:

1. How do four-month-old infants model physical objects?
2. What is the relation between the model and the infants?
3. What is the relation between the model and the things modelled (physical objects)?

3.4. The Simple View

‘Chomsky’s nativism is primarily a thesis about knowledge and belief; it aligns problems in the theory of language with those in the theory of knowledge. Indeed, as often as not, the vocabulary in which Chomsky frames linguistic issues is explicitly epistemological. Thus, the grammar of a language specifies what its speaker/hearers have to know qua speakers and hearers; and the goal of the child’s language acquisition process is to construct a theory of the language that correctly expresses this grammatical knowledge.’ (Fodor 2000, p. 11)

The Simple View The principles of object perception are things that we know or believe, and we generate expectations from these principles by a process of inference.

‘objects are conceived: Humans come to know about an object’s unity, boundaries, and persistence in ways like those by which we come to know about its material composition or its market value’ (Spelke 1988, p. 198).

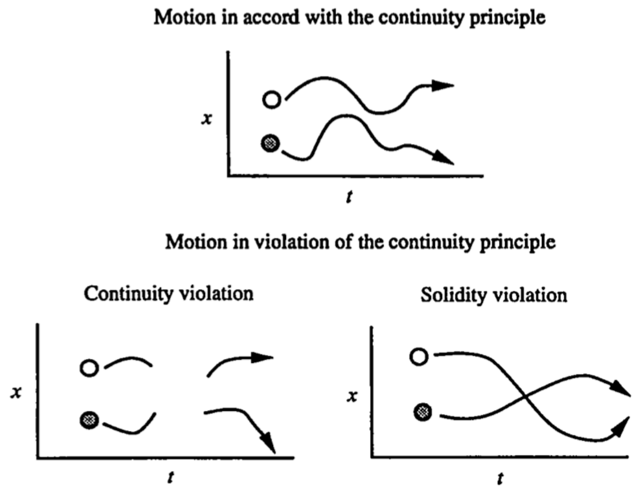
Interpreting violation-of-expectation experiments: ‘evidence that infants look reliably longer at the unexpected than at the expected event is taken to indicate that they (1) possess the expectation under investigation; (2) detect the violation in the unexpected event; and (3) are surprised by this violation. The term surprise is used here simply as a short-hand descriptor, to denote a state of heightened attention or interest caused by an expectation violation.’ (Wang et al. 2004, p. 168)

‘To make sense of such results [i.e. the results from violation-of-expectation tasks], we … must assume that infants, like older learners, formulate … hypotheses about physical events and revise and elaborate these hypotheses in light of additional input.’ (Aguiar & Baillargeon 2002, p. 329)

3.5. Object Permanence

Object permanence is the ability to know things about, or represent, objects you aren’t currently perceiving.

The Principle of Continuity An object traces exactly one connected path over space and time (Spelke et al. 1995, p. 113).



Object permanence is found in nonhuman animals including

1. monkeys (Santos et al. 2006)
2. lemurs (Deppe et al. 2009)
3. crows (Hoffmann et al. 2011)
4. dogs and wolves (Fiset & Plourde 2013)
5. cats (Triana & Pasnak 1981)
6. chicks (Chiandetti & Vallortigara 2011)
7. dolphins (Jaakkola et al. 2010)
8. …

3.6. A Problem

'action demands are not the only cause of failures on occlusion tasks' (Shinskey 2012, p. 291)

'A similar permanent dissociation in understanding object support relations might exist in chimpanzees. They identify impossible support relations in looking tasks, but fail to do so in active problem solving.' (Gómez 2005)

'to date, adult primates' failures on search tasks appear to exactly mirror the cases in which human toddlers perform poorly.' (Santos & Hood 2009, p. 17)

3.7. Like Knowledge and Like Not Knowledge

'no concept causes more problems in discussions of infant cognition than that of representation' (Haith 1998).

3.8. What Is Core Knowledge?

'there is a third type of conceptual structure, dubbed "core knowledge" … that differs systematically from both sensory/perceptual representation[s] … and … knowledge.' (Carey 2009, p. 10)

3.8.1. Two-part definition

'Just as humans are endowed with multiple, specialized perceptual systems, so we are endowed with multiple systems for representing and reasoning about entities of different kinds.' (Carey & Spelke 1996, p. 517)

'core systems are:

1. largely innate
2. encapsulated
3. unchanging
4. arising from phylogenetically old systems
5. built upon the output of innate perceptual analyzers' (Carey & Spelke 1996, p. 520)

Note There are other, slightly different statements (e.g. Carey 2009).

For someone to have *core knowledge of a particular principle or fact* is for her to have a core system where either the core system includes a representation of that principle or else the principle plays a special role in describing the core system.

'We hypothesize that uniquely human cognitive achievements build on systems that humans share with other animals: core systems that evolved before the emergence of our species. The internal functioning of these systems depends on principles and processes that are distinctly non-intuitive. Nevertheless, human intuitions about space, number, morality and other abstract concepts emerge from the use of symbols, especially language, to combine productively the representations that core systems deliver' (Spelke & Lee 2012, pp. 2784-5).

3.8.2. The Core Knowledge View

The *Core Knowledge View*: the principles of object perception are not knowledge, but they are core knowledge. And we generate expectations from these principles by a process of inference.

3.9. Objections to Core Knowledge

'there is a paucity of … data to suggest that they are the only or the best way of carving up the processing, and it seems doubtful that the often long lists of correlated attributes should come as a package' (Adolphs 2010, p. 759)

'we wonder whether the dichotomous characteristics used to define the two-system models are … perfectly correlated … [and] whether a hybrid system that combines characteristics from both systems could not be … viable' (Keren & Schul 2009, p. 537)

3.10. Modularity

'In Fodor's (1983) terms, visual tracking and preferential looking each may depend on modular mechanisms.' (Spelke et al. 1995, p. 137)

Fodor's three claims about modules:

1. they are 'the psychological systems whose operations present the world to thought';
2. they 'constitute a natural kind'; and
3. there is 'a cluster of properties that they have in common' (Fodor 1983, p. 101).

Properties of modules:

- domain specificity (modules deal with 'eccentric' bodies of knowledge)
- limited accessibility (representations in modules are not usually inferentially integrated with knowledge)
- information encapsulation (modules are unaffected by general knowledge or representations in other modules)
- innateness (roughly, the information and operations of a module not straightforwardly consequences of learning; but see Samuels (2004)).

3.11. Objects: Interim Summary

Knowledge of objects probably requires abilities to (i) segment objects, (ii) represent them as persisting and (iii) track their interactions.

Question 1 When do humans come to meet the three requirements on knowledge of objects?

Discovery 1 Infants manifest all three abilities from around four months of age or earlier.

Question 2 How do humans come to meet the three requirements on knowledge of objects?

Discovery 2 Although abilities to segment objects, to represent them as persisting through occlusion and to track their causal interactions are conceptually distinct, they are all characterised by the Principles of Object Perception and they may all be consequences of a single mechanism.

Question 3 What is the relation between the model specified by the Principles of Object Perception and the infants?

The Simple View The principles of object perception are things that we know or believe, and we generate expectations from these principles by a process of inference.

The *Core Knowledge View* The principles of object perception are not knowledge, but they are core knowledge. And we generate expectations from these principles by a process of inference.

Discovery 3 The Simple View generates systematically false predictions. (And the Core Knowledge View generates no relevant predictions by itself.)

Question 4 What is the relation between adults' and infants' abilities concerning physical objects and their causal interactions?

3.12. Causal Interactions

'object perception reflects basic constraints on the motions of physical bodies …' (Spelke 1990, p. 51)

'A single system of knowledge … appears to underlie object perception and physical reasoning' (Carey & Spelke 1994, p. 175)

3.13. Perception of Causation: Key Findings

'There are some cases … in which a causal impression arises, clear, genuine, and unmistakable, and the idea of cause can be derived from it by simple abstraction in just the same way as the idea of shape or movement can be derived from the perception of shape or movement' (Michotte 1963, p. 270–1)

Infants at around six months of age seem also to distinguish launching from other sequences, much as adults do (Leslie & Keeble 1987).

'… why it is that in our experiments certain particular conditions were found necessary in order to give rise to a causal impression. They correspond to the different characteristics of reproduction. … anyone not very familiar with the procedure involved in framing the physical concepts of inertia, energy, conservation of energy, etc., might think that these concepts are simply derived from the data of immediate experience' (Michotte 1963)

3.14. Object Indexes & Perception of Causation

'the movement performed by object B appears simultaneously under two different guises: (i) as a movement (belonging to object A), (ii) as a change in relative position (by object B)' (Michotte 1963, p. 136)

'the physical movement of the object struck gives rise to a double representation. This movement appears at one and the same time (a) as a continuation of the previous movement of the motor object, and (b) as a change of relative position (a purely spatial withdrawal) of the projectile in relation to the motor object.' (Michotte 1963, p. 140)

Causal Object Index Conjecture: Effects associated with the 'perception of causation' are consequences of errors (or error-like patterns) in the assignments of object indexes and their phenomenal effects.

Predictions: (i) Where there is perception of causation, there will be errors (or error-like patterns) in the assignments of object indexes. (ii) Factors that can influence how object indexes are assigned or maintained can influence perception of causation.

Objection: adaptation (Rolfs et al. 2013). But see further **?**.

'Michotte and his followers worked out many of the factors which mediate the perception of causality, such as the role of absolute and relative speeds, spatial and temporal gaps in the objects' trajectories, differences in the durations and angles of each object's trajectory, etc … 'This research has generally shown that many different spatiotemporal parameters are critical for perceiving causality, but that featural parameters (eg colors, shapes, sizes) play little or no role.' (Scholl & Nakayama 2004, p. 456)

'when there is a launching event beneath the overlap (or underlap event) timed such that the launch occurs at the point of maximum overlap, observers inaccurately report that the overlap is incomplete, suggesting that they see an illusory crescent.' (Scholl & Nakayama 2004, p. 461)

Why does the illusory causal crescent appear? Scholl and Nakayama suggest a 'a simple categorical explanation for the Causal Crescents illusion: the visual system, when led by other means to perceive an event as a causal collision, effectively 'refuses' to see the two objects as fully overlapped, because of an internalized constraint to the effect that such a spatial arrangement is not physically possible. As a result, a thin crescent of one object remains uncovered by the other one-as would in fact be the case in a straight-on billiard-ball collision where the motion occurs at an angle close to the line of sight.' (Scholl & Nakayama 2004, p. 466)

'object perception reflects basic constraints on the motions of physical bodies ...' (Spelke 1990, p. 51)

'A single system of knowledge ... appears to underlie object perception and physical reasoning' (Carey & Spelke 1994, p. 175)

3.15. Object Indexes, Motor Representations & Metacognitive Feelings

See handout from colloquium talk (which is also part of this lecture series.)

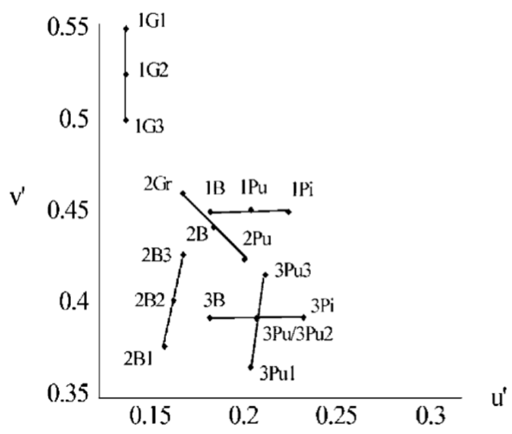
4. Colour

4.1. Categorical Perception of Colour

What is categorical perception of colour commonly taken to explain?

The diagram below represents sequences of three colours.

The vertical sequence shows three greens and the uppermost horizontal sequence shows a blue, a purple and a pink.



Daoutis et al. 2006 figure A1

Each colour differs from its neighbours by the same amount according to a standard measure based on the human eye's abilities to discriminate wavelengths.

Yet the greens are often judged to look quite similar and the blue-pink-purple to look very different (Roberson et al. 1999, p. 12–7).

When people are asked to name these colours, they often give the same name to the greens but different names to members of the blue-pink-purple sequence.

And people are generally faster and more accurate in discriminating between members of the blue-pink-purple sequence than members of the green sequence (faster: Bornstein & Korda 1984; more accurate: Roberson et al. 1999, p. 22–7).

pop-out 'Such targets pop out of the display, so that the time it takes to find them is independent of the number of distractors' (Treisman 1986, p. 117).

When target and distractors differ in colour category there can be pop-out effects (Daoutis et al. 2006).

vMMN (visual mismatch negativity): an event-related potential thought to index pre-attentive change detection in the visual cortex

4.2. Categorical Perception in Infancy

Categorical perception of colour emerges early in infancy. This has been demonstrated with four-month-olds using habituation (Bornstein et al. 1976) and visual search (Franklin et al. 2005).

Slightly older infants can make use of colour properties such as red and green to recognise objects.

For instance, nine-months-olds can determine whether an object they saw earlier is the same as a subsequently presented object on the basis of its colour (Wilcox et al. 2008).

By the time they are two years old, toddlers who do not comprehend any colour words can use colour categories implicitly in learning and using proper names; for instance, they are able to learn and use proper names for toy dinosaurs that differ only in colour (Soja 1994, Experiment

3).

So infants and toddlers enjoy categorical perception of colour and may benefit from it in recognising and learning about objects.

However children only acquire concepts of, and words for, colours some time later; and colour concepts, like colour words, are acquired gradually (Pitchford & Mullen 2005; Kowalski & Zimiles 2006; Sandhofer & Smith 1999; Sandhofer & Thom 2006).

Infants enjoy categorical perception not only of colour but also of orientation (Franklin et al. 2010), speech (Kuhl 1987, 2004; Jusczyk 1995) and facial expressions of emotion (Etcoff & Magee 1992; Kotsoni et al. 2001; Campanella et al. 2002).

4.3. Categorical Perception and Knowledge

Claims to consider:

1. Categorical perception provides 'the building blocks—the elementary units—for higher-order categories' (Harnad 1987, p. 3).
2. 'The building blocks of all our complex representations are the representations that are constructed from individual core knowledge systems.' (Spelke 2003, p. 307)
3. 'The module ... automatically provides a conceptual identification of its input for central thought ... in exactly the right format for inferential processes' (Leslie 1988, pp. 193–4)
4. 'the earliest conceptual functioning consists of a redescription of perceptual structure' (Mandler 1992)

Acquiring colour concepts depends on acquiring colour words (Kowalski & Zimiles 2006).

'the course of acquisition for color is protracted and errorful' (Sandhofer & Thom 2006)

Colour words shape adults' categorical perception (Roberson & Hanley 2007; Winawer et al. 2007).

4.4. Categorical Perception in Infants and Adults

In adults, categorical perception of colour disappears in the face of predictable verbal interference but not non-verbal interference (Roberson & Davidoff 2000; Pilling et al. 2003; Wiggett & Davies 2008).

'surprising it would be indeed if I have a perceptual experience as of red because I call the perceived object 'red'' (Stokes 2006, pp. 324–5)

There is (contested) evidence that the infant mode of categorical perception of colour continues to operate in adults, although it is often inhibited or overshadowed by the adult mode (Gilbert et al. 2006).

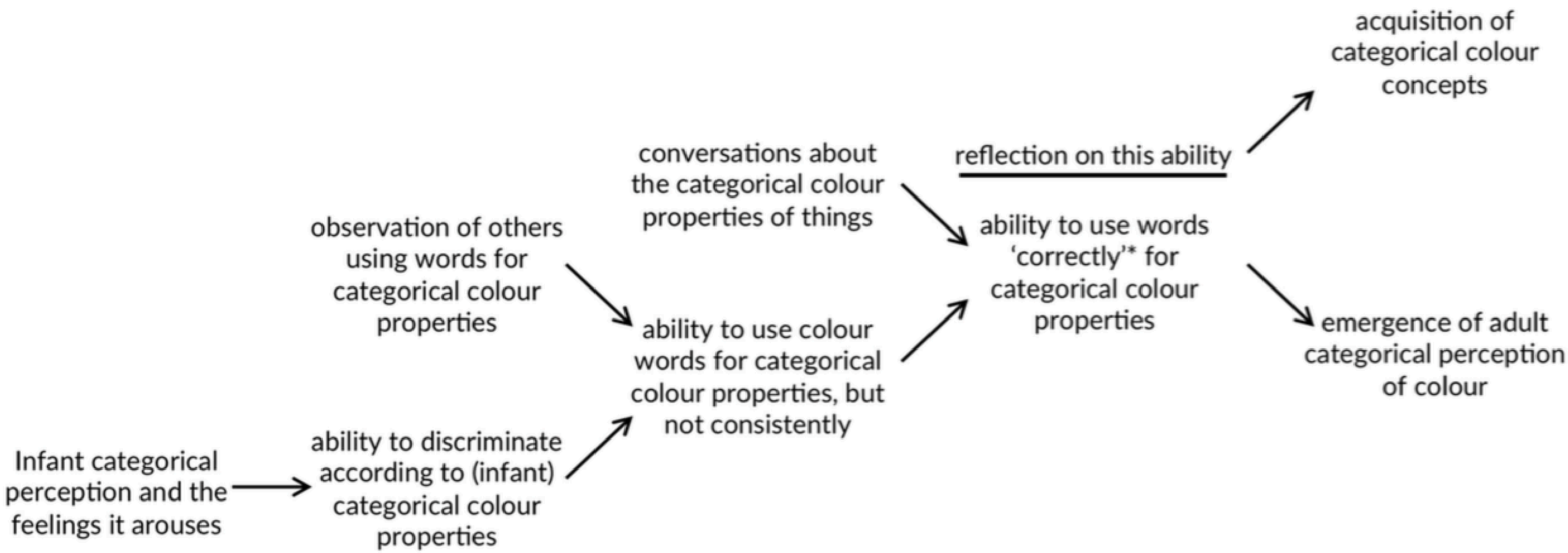


Figure 6.7: A conjecture about the developmental emergence of knowledge of colour. (* – by the lights of adults around you)

5. Action

5.1. Crossing the Gap

1. Core knowledge exists.
2. There is a gap between core knowledge and knowledge knowledge.
3. Crossing the gap involves social interactions, perhaps involving words.

5.2. When can infants first track goals?

When do human infants first track goal-directed actions rather than mere movements only?

Background assumption: 'intention attribution and action understanding are two separable processes' (Uithol & Paulus 2014, p. 617).

'by the end of the first year infants are indeed capable of taking the intentional stance (Dennett, 1987) in interpreting the goal- directed behavior of rational agents.' (Gergely et al. 1995, p. 184)

'12-month-old babies could identify the agent's goal and analyze its actions causally in relation to it' (Gergely et al. 1995, p. 190)

'Six-month-olds and 9-month-olds showed a stronger novelty response (i.e., looked longer) on new-goal trials than on new-path trials (Woodward 1998). That is, like toddlers, young infants selectively attended to and remembered the features of the event that were relevant to the actor's goal.' (Woodward et al. 2001, p. 153)

'Early in life, action expectations measured online seem to be organized around goal locations whereas action expectations measured post-hoc around goal identities. With increasing age, children then generally organize their action expectations primarily around goal identities' (Daum et al. 2012, p. 10)

5.3. The Teleological Stance

'in perceiving one object as having the intention of affecting another, the infant attributes to the object [...] intentions' (Premack 1990, p. 14) (Woodward 2009, p. 53)

'to the extent that young infants are limited [...], their understanding of intentions would be quite different from the mature concept of intentions' (Woodward et al. 2001, p. 168).

'by taking the intentional stance the infant can come to represent the agent's action as intentional without actually attributing a mental representation of the future goal state' (Gergely et al. 1995, p. 188)

'an action can be explained by a goal state if, and only if, it is seen as the most justifiable action towards that goal state that is available within the constraints of reality' (Csibra & Gergely 1998, p. 255)

5.4. Marr's Threefold Distinction

If I apply the Teleological Stance successfully, do I thereby come to know a fact about the goal of an action?

Marr (1982, p. 22ff) distinguishes:

- computational description—What is the thing for and how does it achieve this?
- representations and algorithms—How are the inputs and outputs represented, and how is the transformation accomplished?
- hardware implementation—How are the representations and algorithms physically realised?

'when taking the teleological stance one-year-olds apply the same inferential principle of rational action that drives everyday mentalistic reasoning about intentional actions in adults' (Gergely & Csibra 2003; compare Csibra et al. 2003, Csibra & Gergely 1998, p. 259)

'Such calculations require detailed knowledge of biomechanical factors that determine the motion capabilities and energy expenditure of agents. However, in the absence of such knowledge, one can appeal to heuristics that approximate the results of these calculations on the basis of knowledge in other domains that is certainly available to young infants.

5.5. A signature limit of infant goal tracking?

Flanagan & Johansson (2003) showed that 'patterns of eye–hand coordination are similar when performing and observing a block stacking task'.

From at least three months of age, some of infants' abilities to identify the goals of actions they observe are linked to their abilities to perform actions (Woodward 2009).

In adults, tying the hands impairs proactive gaze (Ambrosini et al. 2012); in infants, boosting grasping with 'sticky mittens' facilitates proactive gaze (Sommerville et al. 2005; see also Sommerville et al. 2008, Ambrosini et al. 2013; Skerry et al. 2013).

5.6. The Motor Theory of Goal Tracking

According to the Motor Theory, infants' (and adults') pure goal-tracking sometimes depends on the double life of motor processes (see Sinigaglia & Butterfill 2015, for details).

More carefully the *Motor Theory of Goal Tracking* states that:

1. in action observation, possible outcomes of observed actions are represented motorically;
2. these representations trigger motor processes much as if the observer were performing actions directed to the outcomes;
3. such processes generates predictions;
4. a triggering representation is weakened if the predictions it generates fail.

The result is that, often enough, the only only outcomes to which the observed action is a means are represented strongly.

5.7. A Puzzle about Goal-Tracking

'by the end of the first year infants are indeed capable of taking the intentional stance (Dennett, 1987) in interpreting the goal- directed behavior of rational agents.' (Gergely et al. 1995, p. 184)

'12-month-old babies could identify the agent's goal and analyze its actions causally in relation to it' (Gergely et al. 1995, p. 190)

5.8. Perceptual Animacy

Perceptual animacy is the detection by broadly perceptual processes of animate objects and their targets Gao et al. (e.g. 2009).

In adults, abilities to perceptually detect chasing depend on several cues including whether the chaser 'faces' its target ('directionality') and how directly the chaser approaches its target ('subtlety').

The detection of animacy appears to be a broadly perceptual phenomena since it depends on areas of the brain associated with vision and influences how perceptual attention is allocated (Scholl & Gao 2013) irrespective of your beliefs and intentions (van Buren et al. 2016).

6. Joint Action

A Conjecture 'humans acquire knowledge at a pace far outstripping that found in any other species. Recent evidence indicates that interpersonal understanding––in particular, skill at inferring others' intentions—–plays a pivotal role in this achievement.' (Baldwin 2000, p. 40)

'functions traditionally considered hallmarks of individual cognition originated through the need to interact with others … perception, action, and cognition are grounded in social interaction.' (Knoblich & Sebanz 2006, p. 103)

'human cognitive abilities … [are] built upon social interaction' (Sinigaglia & Sparaci 2008)

Vygotskian Intelligence Hypothesis: 'the unique aspects of human cognition … were driven by, or even constituted by, social co-operation.' (Moll & Tomasello 2007, p. 1)

6.1. What Is Joint Action? Bratman's Account

'I take a collective action to involve a collective [shared] intention.' (Gilbert 2006, p. 5)

'The sine qua non of collaborative action is a joint goal [shared intention] and a joint commitment' (Tomasello 2008, p. 181)

'the key property of joint action lies in its internal component [...] in the participants' having a "collective" or "shared" intention.' (Alonso 2009, pp. 444–5)

'Shared intentionality is the foundation upon which joint action is built.' (Carpenter 2009, p. 381)

'I will … adopt Bratman's … influential formulation of joint action … each partner needs to intend to perform the joint action together ''in accordance with and because of meshing subplans'' (p. 338) and this needs to be common knowledge between the participants.' (Carpenter 2009, p. 281)

6.2. What Joint Action Could Not Be

Objection: Meeting the sufficient conditions for joint action given by Bratman's account could not significantly *explain* the development of an understanding of minds because it already *presupposes* too much sophistication in the use of psychological concepts.

The objection arises because not all of the following claims are true:

> (1) joint action fosters an understanding of minds;
>
> (2) all joint action involves shared intention; and
>
> (3) a function of shared intention is to coordinate two or more agents' plans.

These claims are inconsistent because if the second and third were both true, abilities to engage in joint action would presuppose, and so could not significantly foster, an understanding of minds.

What are our options?

6.3. Development of Joint Action: Planning

Objection: 'Despite the common impression that joint action needs to be dumbed down for infants due to their ''lack of a robust theory of mind'' … all the important social-cognitive building blocks for joint action appear to be in place: 1-year-old infants understand quite a bit about others' goals and intentions and what knowledge they share with others' (Carpenter 2009, p. 383).

'I … adopt Bratman's (1992) influential formulation of joint action or shared cooperative activity. Bratman argued that in order for an activity to be considered shared or joint each partner needs to intend to perform the joint action together ''in accordance with and because of meshing subplans'' (p. 338) and this needs to be common knowledge between the participants' (Carpenter 2009, p. 381).

'shared intentional agency [i.e. 'joint action'] consists, at bottom, in interconnected planning agency of the participants' (Bratman 2011).

'3- and 5-year-old children do not consider another person's actions in their own action planning (while showing action planning when acting alone on the apparatus). Seven-year-old children and adults however, demonstrated evidence for joint action planning. … While adult participants demonstrated the presence of joint action planning from the very first trials onward, this was not the case for the 7-year-old children who improved their performance across trials.' (Paulus 2016, p. 1059)

'by age 3 children are able to learn, under certain circumstances, to take account of what a partner is doing in a collaborative problem-solving context. By age 5 they are already quite skillful at attending to and even anticipating a partner's actions' (Warneken et al. 2014, p. 57). 'proactive planning for two individuals, even when they share a common goal, is more difficult than planning ahead solely for oneself' (Gerson, Bekkering & Hunnius Gerson et al., p. 128).

6.4. Development of Joint Action: Years 1-2

'By 12–18 months, infants are beginning to participate in a variety of joint actions which show many of the characteristics of adult joint action.' (Carpenter 2009, p. 388)

'infants learn about cooperation by participating in joint action structured by skilled and knowledgeable interactive partners before they can represent, understand, or generate it themselves. Cooperative joint action develops in the context of dyadic interaction with adults in which the adult initially takes responsibility for and actively structures the joint activity and the infant progressively comes to master the structure, timing, and communications involved in the joint action with the support and guidance of the adult. … Eager participants from the beginning, it takes approximately 2 years for infants to become autonomous contributors to sustained, goal-directed joint activity as active, collaborative partners' (Brownell 2011, p. 200).

'While 4-year-olds coordinated the timing of drum hits, children between 2- and 4 years of age showed indications of interpersonal coordination as indicated by the beginnings and endings of drumming bouts. Children showed more overlap in their bouts than would be expected by chance' (Endedijk, Ramenzoni, Cox, Cillessen, Bekkering & Hunnius Endedijk et al., p. 720).

'The 14-month-olds of this study displayed coordinated behaviors in the elevator task Role A of positioning themselves in the right location and retrieving the target object from the cylinder when the partner pushed it up, but they had major problems performing Role B, pushing the cylinder up and holding it in place until the partner could fetch the object. If they pushed up the cylinder at all, they would repeatedly drop it when the other person was just about to take the object out' (Warneken & Tomasello 2007).

Infants' 'attempts to reactivate the partner in interruption periods indicate that they were aware of the interdependency of actions—that the execution of their own actions was conditional on that of the partner … these instances might also exemplify a basic understanding of shared intentionality' (Warneken & Tomasello 2007, p. 290–1).

'advances in infants' ability to coordinate their behavior with one another are associated with multiple measures of developing self-other representations. One- and two-year olds' symbolic representation of self and other in pretend play (e.g., pretending that a doll is feeding itself) was related to the amount of coordinated behavior they produced with a peer on the structured cooperation tasks described above (Brownell and Carriger 1990)' (Brownell 2011, p. 206).

'children who better produced and comprehended language about their own and others' feelings and actions, and who could refer to themselves and others using personal pronouns likewise monitored their peer's behavior more often and produced more joint activity with the peer (Brownell et al 2006)' (Brownell 2011, p. 206).

6.5. Collective Goals vs Shared Intentions

'all sorts of joint activity is possible without conscious goal representations, complex reasoning, and advanced self-other understanding … both in other species and in our own joint behavior as adults, some of which occurs outside of reflective awareness … In studying its development in children the problem is how to characterize and differentiate primitive, lower levels of joint action operationally from more complex and cognitively sophisticated forms' (Brownell 2011, p. 195).

An outcome is a *collective goal* of two or more actions involving multiple agents if it is an outcome to which those actions are collectively directed (Butterfill 2016).

For us to have a *shared goal* G is for G to be a collective goal of our present or future actions in virtue of the facts that:

1. We each expect the other(s) to perform an action directed to G.
2. We each expect that if G occurs, it will occur as a common effect of all of our actions (compare Butterfill 2012; Vesper et al. 2010).

'the basic skills and motivations for shared intentionality typically emerge at around the first birthday from the interaction of two developmental trajectories, each representing an evolutionary adaptation from some different point in time. The first trajectory is a general primate (or perhaps great ape) line of development for understanding intentional action and perception, which evolved in the context of primates' crucially important competitive interactions with one another over food, mates, and other resources (Machiavellian intelligence; Byrne & Whiten, 1988). The second trajectory is a uniquely human line of development for sharing psychological states with others, which seems to be present in nascent form from very early in human ontogeny as infants share emotional states with others in turn-taking sequences (Trevarthen, 1979). The interaction of these two lines of development creates, at around 1 year of age, skills and motivations for sharing psychological states with others in fairly local social interactions, and then later skills and motivations for reacting to and even internalizing various kinds of social norms, collective beliefs, and cultural institutions' (Tomasello & Carpenter 2007, p 124).

7. Referential Communication

7.1. Pointing: Reference and Context

The *block–slab* model of infant pointing (compare Wittgenstein 1953, §2): (a) the activity occurs in a fixed context (e.g. buliding) and (b) there is a fixed thing to be done in response to a point.

Comprehending pointing is not just a matter of locking onto the thing pointed to; it also involves some sensitivity to context (see Liebal et al. 2009).

7.2. Pointing: referent and context

'Already by age 14 months, then, infants interpret communication cooperatively, from a shared rather than an egocentric perspective' (Liebal et al. 2009, p. 269).

'The fact that infants rely on shared experience even to interpret others' nonverbal pointing gestures suggests that this ability is not specific to language but rather reflects a more general social-cognitive, pragmatic understanding of human cooperative communication' (Liebal et al. 2009, p. 270).

7.3. A Puzzle about Pointing

'infant pointing is best understood—on many levels and in many ways—as depending on uniquely human skills and motivations for cooperation and shared intentionality, which enable such things as joint intentions and joint attention in truly collaborative interactions with others (Bratman, 1992; Searle, 1995).' (Tomasello et al. 2007, p. 706)

'to understand pointing, the subject needs to understand more than the individual goal-directed behaviour. She needs to understand that by pointing towards a location, the other attempts to communicate to her where a desired object is located' (Moll & Tomasello 2007, p. 6).

7.4. pointing vs linguistic communication

'the most fundamental aspects of language that make it such a uniquely powerful form of human cognition and communication—joint attention, reference via perspectives, reference to absent entities, cooperative motives to help and to share, and other embodiments of shared intentionality—are already present in the humble act of infant pointing.' (Tomasello et al. 2007, p. 719)

'cooperative communication does not depend on language, [...] language depends on it.' (Tomasello et al. 2007, p. 720)

'Pointing may [...] represent a key transition, both phylogenetically and ontogenetically, from nonlinguistic to linguistic forms of human communication.' (Tomasello et al. 2007, p. 720)

7.5. What is a communicative action?

The confederate means something in pointing at the left box if she intends:

1. that you open the left box;

2. that you recognize that she intends (1), that you open the left box; and
3. that your recognition that she intends (1) will be among your reasons for opening the left box.

An inconsistent tetrad

1. 11- or 12-month-old infants produce and understand declarative pointing gestures.
2. Producing or understanding pointing gestures involves understanding communicative actions.
3. A communicative action is an action done with an intention to provide someone with evidence of an intention with the further intention of thereby fulfilling that intention.
4. Pointing facilitates the developmental emergence of sophisticated cognitive abilities including mindreading

8. Words

How do humans first come to communicate with words?

8.1. Shipwreck Survivor vs Lab Rat

'children learn words through the exercise of reason' (Bloom 2001, p. 1103; see Bloom 2000)

'Augustine describes the learning of human language as if the child came into a strange country and did not understand the language of the country; that is, as if it already had a language, only not this one. Or again: as if the child could already think, only not yet speak.' (Wittgenstein 1953, 15–16, §32)

'[t]he child learns this language from the grown-ups by being trained to its use. I am using the word 'trained' in a way strictly analogous to that in which we talk of an animal being trained to do certain things. It is done by means of example, reward, punishment, and suchlike' (Wittgenstein 1972, p. 77)

'the child's early learning of a verbal response depends on society's reinforcement of the response in association with the stimulations that merit the response' ((Quine 1960, p. 82); compare (Quine 1974, pp. 28–9))

'A child learning to speak is learning habits and associations which are just as much determined by the environment as the habit of expecting dogs to bark and cocks to crow' (Russell 1921, p. 71)

Children acquiring language create their own words before they learn to use those of the adults around them.

'Some children are so impatient that they coin their own demonstrative pronoun. For instance, at the age of about 12 months, Max would point to different objects and say "doh?," some¬times with the intent that we do something with the objects, such as bring them to him, and sometimes just wanting us to appreciate their existence' (Bloom 2000, p. 122; see further Clark 1981, 1982).

Even where children have mastered a lexical convention, they will readily violate it in their own utterances in order to get a point across.

'From the time they first use words until they are about two or two-and-a-half, children noticeably and systematically overextend words. For example, one child used the word "apple" to refer to balls of soap, a rubber-ball, a ball-lamp, a tomato, cherries, peaches, strawberries, an orange, a pear, an onion, and round biscuits' (Clark 1993, p. 35)

Children with no experience of others' languages can create their own languages. (Kegl et al. 1999; Senghas & Coppola 2001; Goldin-Meadow 2003)

8.2. Thinking Depends on Talking?

1. If someone can think, she must be capable of having a false belief.
2. To be capable of having a false belief it is necessary to understand the possibility of false belief.
3. Understanding the possibility of false belief entails being able to communicate by

language.

’belief is central to all kinds of thought. If someone is glad that, or notices that, or remembers that, or knows that, the gun is loaded, then he must believe that the gun is loaded. Even to wonder whether the gun is loaded, or to speculate on the possibility that the gun is loaded, requires belief, for example, that a gun is a weapon, that it is a more or less enduring physical object, and so on. … it is necessary that there be endless interlocked beliefs’ (Davidson 1984, p. 157); cf. (Davidson 1982, pp. 320–1)

‘We, observing and describing … a creature …, say that it discriminates certain shapes, objects, colors, and so forth, by which we mean that it reacts in ways we find similar to shapes, objects, and colors which we find similar. But we would be making a mistake if we were to assume that because the creature discriminates and reacts in much the way we do, that it has the corresponding concepts.The difference, as I keep emphasizing, lies in the fact that we, unlike the creature I am describing, can, from our point of view, make mistakes in classification’ (Davidson 2001a, p. 11).

‘we grasp the concept of truth only when we can communicate the contents—the propositional contents—of the shared experience, and this requires language’ (Davidson 1997, p. 27).

8.3. Training

‘The ability to discriminate, to act differentially in the face of clues to the presence of food, danger or safety, is present in all animals and does not require reason. Nor does the learning, even of complex routines, require reason, for it is possible to learn how to act without learning that anything is the case’ (Davidson 1982, p. 326).

‘A child learning to speak is learning habits and associations which are just as much determined by the environment as the habit of expecting dogs to bark and cocks to crow’ (Russell 1921, p. 71).

‘[t]he child learns this language from the grownups by being trained to its use. I am using the word ‘trained’ in a way strictly analogous to that in which we talk of an animal being trained to do certain things. It is done by means of example, reward, punishment, and suchlike’ (Wittgenstein 1972, p. 77).

‘the child’s early learning of a verbal response depends on society’s reinforcement of the response in association with the stimulations that merit the response’ ((Quine 1960, p. 82); compare (Quine 1974, pp. 28–9)).

‘Before we have an idea of truth or error, before the advent of concepts or propositional thought, there is a rudiment of communication in the simple discovery that sounds produce results. Crying is the first step toward language when crying is found to procure one or another form of relief or satisfaction. More specific sounds, imitated or not, are rapidly associated with more specific pleasures. Here use //p. 71// would be meaning, if anything like intention and meaning were in the picture. A large further step has been taken when the child notices that others also make distinctive sounds at the same time the child is having the experiences that provoke its own volunteered sounds. For the adult, these sounds have a meaning, perhaps as one word sentences. The adult sees herself as doing a little ostensive teaching: “Eat,” “Red,” “Ball,” “Mamma,” “Milk,” “No.” There is now room for what the adult views as error: the child says “Block” when it is a slab. This move fails to be rewarded, and the conditioning becomes more complex’ (Davidson 2000, pp. 70–1).

8.4. Hypothesis Testing

‘children learn words through the exercise of reason’ (Bloom 2001, p. 1103; see Bloom 2000)

‘Augustine describes the learning of human language as if the child came into a strange country and did not understand the language of the country; that is, as if it already had a language, only not this one. Or again: as if the child could already think, only not yet speak.’ (Wittgenstein 1953, 15–16, §32)

‘Augustine’s proposal is no longer seen as the goofy idea that it once was’ (Bloom 2000, p. 61).

‘the process of language acquisition [is] coming to know the meanings of words, where at a given stage the learner’s conception is an hypothesis about the meaning’ (Higginbotham 1998, p. 153)

’The tutor names things in accordance with the semantic customs of the community. The player forms hypotheses about the categorical nature of the things named. He tests his hypotheses by trying to name new things correctly. The tutor compares the player’s utterances with his own anticipations of such utterances and, in this way, checks the accuracy of fit between his own categories and those of the player. He improves the fit by correction.’ (Brown 1958, p. 194 as quoted by (Clark 1993, p. 19))

8.5. Mapping words to concepts

‘much of what goes on in word learning is establishing a correspondence between the symbols of a natural language and concepts that exist prior to, and independently of, the acquisition of that language’ (Bloom 2000, p. 242)

‘to know the meaning of a word is to have: 1. a certain mental representation or concept 2. that is associated with a certain form’ (Bloom 2000, p. 17)

‘One of the first problems children take on is the MAPPING of meanings onto forms … They must identify possible meanings, isolate possible forms, and then map the meanings onto the relevant forms.’ (Clark 1993, p. 14)

8.6. Grice & Tomasello

‘children acquire linguistic symbols as a kind of by-product of social interaction with adults’ (Tomasello 2003, p. 90)

Infants ‘begin to comprehend and use … linguistic symbols on the basis of their skills of social cognition and cultural learning’ (Tomasello et al. 1999, p. 582)

‘language is itself one type-albeit a very special type-of joint attentional skill’ (Tomasello 2001, p. 1120)

‘the kind of rational activity which the use of language involves is a form of rational cooperation’ (Grice 1989, p. 341)

8.7. Lexical Innovation

Children acquiring language create their own words before they learn to use those of the adults around them.

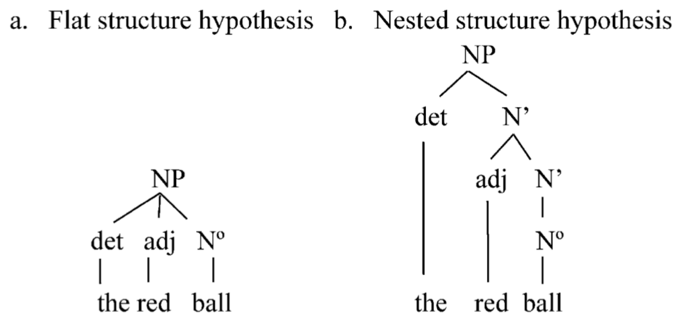
‘From the time they first use words until they are about two or two-and-a-half, children noticeably and systematically overextend words. For example, one child used the word “apple” to refer to balls of soap, a rubber-ball, a ball-lamp, a tomato, cherries, peaches, strawberries, an orange, a pear, an onion, and round biscuits’ (Clark 1993, p. 35)

Children can create their own languages with no experience of others’ languages (Kegl et al. 1999; Senghas & Coppola 2001; Goldin-Meadow 2003).

9. Innateness (of Syntax)

9.1. A Case Study

Is the syntactic structure of ‘the red ball’ (a) flat or (b) hierarchical?



from Lidz et al. 2003

1. ‘red ball’ is a constituent on (b) but not on (a)

2. anaphoric pronouns can only refer to constituents

3. In the sentence ‘I’ll play with this red ball and you can play with that one.’, the word ‘one’ is an anaphoric prononun that refers

to 'red ball' (not just ball). (Lidz et al. 2003; Lidz & Waxman 2004).

'The assumption in the preferential looking task is that infants prefer to look at an image that matches the linguistic stimulus, if one is available' (Lidz et al. 2003).

9.1.1. Poverty of stimulus arguments

How do poverty of stimulus arguments work? See Pullum & Scholz (2002).

1. Human infants acquire X.
2. To acquire X by data-driven learning you'd need this Crucial Evidence.
3. But infants lack this Crucial Evidence for X.
4. So human infants do not acquire X by data-driven learning.
5. But all acquisition is either data-driven or innately-primed learning.
6. So human infants acquire X by innately-primed learning .

'the APS [argument from the poverty of stimulus] still awaits even a single good supporting example' (Pullum & Scholz 2002, p. 47)

References

Adolphs, R. (2010). Conceptual challenges and directions for social neuroscience. *Neuron*, *65*(6), 752–767.

Aguiar, A. & Baillargeon, R. (2002). Developments in young infants' reasoning about occluded objects. *Cognitive Psychology*, *45*, 267–336.

Alonso, F. M. (2009). Shared intention, reliance, and interpersonal obligations. *Ethics*, *119*(3), 444–475.

Ambrosini, E., Reddy, V., de Looper, A., Costantini, M., Lopez, B., & Sinigaglia, C. (2013). Looking Ahead: Anticipatory Gaze and Motor Ability in Infancy. *PLoS ONE*, *8*(7), e67916.

Ambrosini, E., Sinigaglia, C., & Costantini, M. (2012). Tie my hands, tie my eyes. *Journal of Experimental Psychology: Human Perception and Performance*, *38*(2), 263–266.

Apperly, I. A., Back, E., Samson, D., & France, L. (2008). The cost of thinking about false beliefs: Evidence from adults' performance on a non-inferential theory of mind task. *Cognition*, *106*(3), 1093–1108.

Apperly, I. A., Carroll, D., Samson, D., Humphreys, G., Qureshi, A., & Moffitt, G. (2010a). Why are there limits on theory of mind use? evidence from adults' ability to follow instructions from an ignorant speaker. *The Quarterly Journal of Experimental Psychology*, *63*(6), 1201–1217.

Apperly, I. A., Carroll, D. J., Samson, D., Humphreys, G. W., Qureshi, A., & Moffitt, G. (2010b). Why are there limits on theory of mind use? evidence from adults' ability to follow instructions from an ignorant speaker. *The Quarterly Journal of Experimental Psychology*, *63*, 1201–1217.

Apperly, I. A., Samson, D., Chiavarino, C., & Humphreys, G. (2004). Frontal and temporo-parietal lobe contributions to theory of mind: Neuropsychological evidence from a false-belief task with reduced language and executive demands. *Journal of Cognitive Neuroscience*, *16*(10), 1773–1784.

Apperly, I. A., Samson, D., & Humphreys, G. W. (2009). Studies of adults can inform accounts of theory of mind development. *Developmental Psychology*, *45*(1), 190–201.

Astington, J. & Gopnik, A. (1991). Developing understanding of desire and intention. In A. Whiten (Ed.), *Natural Theories of the Mind: evolution, development and simulation of everyday mindreading* (pp. 39–50). Oxford: Blackwell.

Baillargeon, R. (1987). Object permanence in 3.5-and 4.5-month-old infants. *Developmental psychology*, *23*(5), 655–664.

Baillargeon, R., Scott, R. M., & He, Z. (2010). False-belief understanding in infants. *Trends in Cognitive Sciences*, *14*(3), 110–118.

Baldwin, D. (2000). Interpersonal understanding fuels knowledge acquisition. *Current Directions in Psychological Science*, *9*(2), 40–5.

Bartsch, K. & London, K. (2000). Children's use of mental state information in selecting persuasive arguments. *Developmental Psychology*, *36*(3), 352–365.

Bloom, P. (2000). *How children learn the meanings of words*. Learning, development, and conceptual change. Cambridge, Mass. ; London: MIT Press.

Bloom, P. (2001). Controversies in the study of word learning. *Behavioral and Brain Sciences*, *24*(6), 1124–1130.

Bornstein, M., Kessen, W., & Weiskopf, S. (1976). Color vision and hue categorization in young human infants. *Journal of Experimental Psychology: Human Perception and Performance*, *2*(1), 115–129.

Bornstein, M. & Korda, N. (1984). Discrimination and matching within and between hues measured by reaction times: some implications for categorical perception and levels of information processing. *Psychological Research*, *46*(3), 207–222.

Bratman, M. E. (2011). Acting over time, acting together. *(draft)*, *0*(0), 0.

Brownell, C. A. (2011). Early Developments in Joint Action. *Review of Philosophy and Psychology*, *2*, 193–211.

Bull, R., Phillips, L., & Conway, C. (2008). The role of control functions in mentalizing: Dual-task studies of theory of mind and executive function. *Cognition*, *107*(2), 663–672.

Buttelmann, D., Carpenter, M., & Tomasello, M. (2009). Eighteen-month-old infants show false belief understanding in an active helping paradigm. *Cognition*, *112*(2), 337–342.

Butterfill, S. A. (2012). Joint action and development. *Philosophical Quarterly*, *62*(246), 23–47.

Butterfill, S. A. (2016). Joint action: A minimalist approach. In J. Kiverstein (Ed.), *Routledge Handbook on the Social Mind* (pp. 357–369). London: Routledge.

Call, J. & Tomasello, M. (1999). A nonverbal false belief task: The performance of children and great apes. *Child Development*, *70*(2), 381–395.

Campanella, S., Quinet, P., Bruyer, R., Crommelinck, M., & Guerit, J. M. (2002). Categorical perception of happiness and fear facial expressions: An ERP study. *The Journal of Cognitive Neuroscience*, *14*(2), 210–227.

Carey, S. (2009). *The Origin of Concepts*. Oxford: Oxford University Press.

Carey, S. & Spelke, E. (1994). Domain-specific knowledge and conceptual change. In L. Hirschfeld & S. Gelman (Eds.), *Mapping the Mind: domain specificity in cognition and culture*. Cambridge: Cambridge University Press.

Carey, S. & Spelke, E. (1996). Science and core knowledge. *Philosophy of Science*, *63*, 515–533.

Carpenter, M. (2009). Just how joint is joint action in infancy? *Topics in Cognitive Science*, *1*(2), 380–392.

Carruthers, P. (2015a). Mindreading in adults: evaluating two-systems views. *Synthese*, *forthcoming*, 1–16.

Carruthers, P. (2015b). Two systems for mindreading? *Review of Philosophy and Psychology*, *7*(1), 141–162.

Chandler, M., Fritz, A., & Hala, S. (1989). Small scale deceit: Deception as a marker of two-, three-, and four-year-olds' early theories of mind. *Child Development*, *60*, 1263–1277.

Charles, E. P. & Rivera, S. M. (2009). Object permanence and method of disappearance: looking measures further contradict reaching measures. *Developmental Science*, *12*(6), 991–1006.

Chiandetti, C. & Vallortigara, G. (2011). Intuitive physical reasoning about occluded objects by inexperienced chicks. *Proceedings of the Royal Society B: Biological Sciences*, *278*(1718), 2621–2627.

Christensen, W. & Michael, J. (2016). From two systems to a multi-systems architecture for mindreading. *New Ideas in Psychology*, *40*, 48–64.

Clark, E. V. (1981). Lexical innovations: How children learn to create new words. In W. Deutsch (Ed.), *The Child's Construction of Language*. London: Academic Press.

Clark, E. V. (1982). The young word maker: a case study of innovation in the child's lexicon. In E. Wanner & L. R. Gleitman (Eds.), *Language acquisition: the state of the art*. Cambridge: Cambridge University Press.

Clark, E. V. (1993). *The Lexicon in Acquisition*. Cambridge: Cambridge University Press.

Clayton, N. S., Dally, J. M., & Emery, N. J. (2007). Social cognition by food-caching corvids. the western scrub-jay as a natural psychologist. *Philosophical Transactions of the Royal Society B*, *362*, 507–552.

Clements, W. & Perner, J. (1994). Implicit understanding of belief. *Cognitive Development*, *9*, 377–395.

Csibra, G., Bíró, S., Koós, O., & Gergely, G. (2003). One-year-old infants use teleological representations of actions productively. *Cognitive Science*, *27*(1), 111–133.

Csibra, G. & Gergely, G. (1998). The teleological origins of mentalistic action explanations: A developmental hypothesis. *Developmental Science*, *1*(2), 255–259.

Csibra, G. & Gergely, G. (2009). Natural pedagogy. *Trends in Cognitive Sciences*, *13*(4), 148–153.

Dally, J. M., Emery, N. J., & Clayton, N. S. (2004). Cache protection strategies by western scrub-jays (aphelocoma californica): hiding food in the shade. *Proceedings of the Royal Society B: Biological Sciences*, *271*(0), S387–S390–S387–S390.

Daoutis, C. A., Franklin, A., Riddett, A., Clifford, A., & Davies, I. R. L. (2006). Categorical effects in children's colour search: A cross-linguistic comparison. *British Journal of Developmental Psychology*, *24*, 373–400.

Daoutis, C. A., Pilling, M., & Davies, I. R. L. (2006). Categorical effects in visual search for colour. *Visual Cognition*, *14*, 217–240.

Daum, M. M., Attig, M., Gunawan, R., Prinz, W., & Gredeback, G. (2012). Actions Seen through Babies' Eyes: A Dissociation between Looking Time and Predictive Gaze. *Frontiers in Psychology*, *3*.

Davidson, D. (1975 [1984]). Thought and talk. In *Inquiries into Truth and Interpretation* (pp. 155–170). Oxford: Oxford University Press.

Davidson, D. (1982). Rational animals. In *Subjective, Intersubjective, Objective* (pp. 95–106). Oxford: Clarendon Press.

Davidson, D. (1997). Seeing through language. In J. Preston (Ed.), *Thought and Language*, Royal Institute of Philosophy Supplement, vol. 42. Oxford: Oxford University Press.

Davidson, D. (1999). The emergence of thought. *Erkenntnis*, *51*, 7–17.

Davidson, D. (2000). Truth rehabilitated. In R. Brandom (Ed.), *Rorty and his Critics* (pp. 65–80). Oxford: Blackwell.

Davidson, D. (2001a). Externalisms. In P. Kotatko, P. Pagin, & G. Segal (Eds.), *Interpreting Davidson*. Stanford, CA: CSLI Publications.

Davidson, D. (2001b). *Subjective, Intersubjective, Objective*. Oxford: Clarendon Press.

Deppe, A. M., Wright, P. C., & Szelistowski, W. A. (2009). Object permanence in lemurs. *Animal Cognition*, *12*(2), 381–388.

Dewey, J. (1938). *Logic: The Theory of Inquiry*. New York: Henry Holt.

Edwards, K. & Low, J. (2017). Reaction time profiles of adults' action prediction reveal two mindreading systems. *Cognition*, *160*, 1–16.

Emery, N. J. & Clayton, N. S. (2007). How to build a scrub-jay that reads minds. In S. Itakura & K. Fujita (Eds.), *Origins of the Social Mind: Evolutionary and Developmental Perspectives*. Tokyo: Springer.

Endedijk, H. M., Ramenzoni, V. C. O., Cox, R. F. A., Cillessen, A. H. N., Bekkering, H., & Hunnius, S. Development of interpersonal coordination between peers during a drumming task. *51*(5), 714–721.

Etcoff, N. L. & Magee, J. J. (1992). Categorical perception of facial expressions. *Cognition*, *44*(3), 227–40.

Fiset, S. & Plourde, V. (2013). Object permanence in domestic dogs (canis lupus familiaris) and gray wolves (canis lupus). *Journal of Comparative Psychology*, *127*(2), 115–127.

Fizke, E., Butterfill, S. A., van de Loo, L., Reindl, E., & Rakoczy, H. (2017). Signature limits in early theory of mind: Toddlers spontaneously take into account false beliefs about an objects' location but not about its identity. *Journal of Experimental Child Psychology, forthcoming*.

Flanagan, J. R. & Johansson, R. S. (2003). Action plans used in action observation. *Nature*, *424*(6950), 769–771.

Fodor, J. (1975). *The Language of Thought*. New York: Harvard University Press.

Fodor, J. (1983). *The Modularity of Mind: an Essay on Faculty Psychology*. Bradford book. Cambridge, Mass ; London: MIT Press.

Fodor, J. (2000). *The mind doesn't work that way : the scope and limits of computational psychology*. Representation and mind. Cambridge, Mass.: MIT Press.

Franklin, A., Catherwood, D., Alvarez, J., & Axelsson, E. (2010). Hemispheric asymmetries in categorical perception of orientation in infants and adults. *Neuropsychologia*, *48*(9), 2648–2657.

Franklin, A., Pilling, M., & Davies, I. (2005). The nature of infant color categorization: Evidence from eye movements on a target detection task. *Journal of Experimental Child Psychology*, *91*(3), 227–248.

Gao, T., Newman, G. E., & Scholl, B. J. (2009). The psychophysics of chasing: A case study in the perception of animacy. *Cognitive Psychology*, *59*(2), 154–179.

Gergely, G. & Csibra, G. (2003). Teleological reasoning in infancy: the naive theory of rational action. *Trends in Cognitive Sciences*, *7*(7), 287–292.

Gergely, G., Nadasky, Z., Csibra, G., & Biro, S. (1995). Taking the intentional stance at 12 months of age. *Cognition*, *56*, 165–193.

Gerson, S. A., Bekkering, H., & Hunnius, S. Social context influences planning ahead in three-year-olds. *40*, 120–131.

Gilbert, A. L., Regier, T., & Ivry, R. B. (2006). Whorf hypothesis is supported in the right visual field but not the left. *PNAS*, *103*(2), 489–494.

Gilbert, M. P. (2006). Rationality in collective action. *Philosophy of the Social Sciences*, *36*(1), 3–17.

Goldin-Meadow, S. (2003). *The resilience of language : what gesture creation in deaf children can tell us about how all children learn language*. Essays in developmental psychology. New York, N.Y.: Psychology Press.

Gómez, J.-C. (2005). Species comparative studies and cognitive development. *Trends in Cognitive Sciences*, *9*(3), 118–125.

Gopnik, A. & Slaughter, V. (1991). Young children's understanding of changes in their mental states. *Child Development*, *62*, 98–110.

Grice, P. (1989). *Studies in the way of words*. Cambridge, Mass ; London: Harvard University Press.

Haith, M. (1998). Who put the cog in infant cognition? is rich interpretation too costly? *Infant Behavior and Development*, *21*(2), 167–179.

Hare, B., Call, J., & Tomasello, M. (2001). Do chimpanzees know what conspecifics know? *Animal Behaviour*, *61*(1), 139–151.

Harnad, S. (1987). Psychophysical and cognitive aspects of categorical perception: A critical overview. In S. Harnad (Ed.), *Categorical Perception: The Groundwork of Cognition*. Cambridge: Cambridge University Press.

He, Z., Bolz, M., & Baillargeon, R. (2011). False-belief understanding in 2.5-year-olds: evidence from violation-of-expectation change-of-location and unexpected-contents tasks. *Developmental Science*, *14*(2), 292–305.

Higginbotham, J. (1998). Conceptual competence. *Philosophical Issues*, *9*, 149–162.

Hoffmann, A., Rüttler, V., & Nieder, A. (2011). Ontogeny of object permanence and object tracking in the carrion crow, corvus corone. *Animal Behaviour*, *82*(2), 359–367.

Hood, B., Carey, S., & Prasada, S. (2000). Predicting the outcomes of physical events: Two-year-olds fail to reveal knowledge of solidity and support. *Child Development*, *71*(6), 1540–1554.

Jaakkola, K., Guarino, E., Rodriguez, M., Erb, L., & Trone, M. (2010). What do dolphins (tursiops truncatus) understand about hidden objects? *Animal Cognition*, *13*(1), 103–120.

Jusczyk, P. W. (1995). Language acquisition: Speech sounds and the beginning of phonology. In L. Miller, Joanne & P. D. Eimas (Eds.), *Speech, Language and Communication*. San Diego: Academic Press.

Kegl, J., Senghas, A., & Coppola, M. (1999). Creation through contact: Sign language emergence and sign language change in nicaragua. In M. DeGraff (Ed.), *Language creation and language change: Creolization, diachrony, and development*. Cambridge, Mass.: MIT Press.

Kellman, P. J. & Spelke, E. S. (1983). Perception of partly occluded objects in infancy. *Cognitive Psychology*, *15*(4), 483–524.

Keren, G. & Schul, Y. (2009). Two is not always better than one. *Perspectives on Psychological Science*, *4*(6), 533 –550.

Knoblich, G. & Sebanz, N. (2006). The social nature of perception and action. *Current Directions in Psychological Science*, *15*(3), 99–104.

Knudsen, B. & Liszkowski, U. (2012). 18-Month-Olds predict specific action mistakes through attribution of false belief, not ignorance, and intervene accordingly. *Infancy*, *17*, 672–691.

Kotsoni, E., Haan, M. d., & Johnson, M. H. (2001). Categorical perception of facial expressions by 7-month-old infants. *Perception*, *30*(9), 1115–1125.

Kovács, Á. M., Téglás, E., & Endress, A. D. (2010). The social sense: Susceptibility to others' beliefs in human infants and adults. *Science*, *330*(6012), 1830 –1834.

Kowalski, K. & Zimiles, H. (2006). The relation between children's conceptual functioning with color and color term acquisition. *Journal of Experimental Child Psychology*, *94*, 301–321.

Krachun, C., Carpenter, C. M., Call, J., & Tomasello, M. (2010). A new change-of-contents false belief test: Children and chimpanzees compared. *International Journal of Comparative Psychology*, *23*(2).

Krachun, C., Carpenter, M., Call, J., & Tomasello, M. (2009). A competitive nonverbal false belief task for children and apes. *Developmental Science*, *12*(4), 521–535.

Kuhl, P. K. (1987). The special-mechanisms debate in speech research: Categorization tests on animals and infants. In S. Harnad (Ed.), *Categorical Perception: The Groundwork of Cognition*. Cambridge: Cambridge University Press.

Kuhl, P. K. (2004). Early language acquisition: cracking the speech code. *Nature Reviews: Neuroscience*, *5*(11), 831–843.

Leibniz, G. W. (1996). *New essays on human understanding*. Cambridge texts in the history of philosophy. Cambridge: Cambridge University Press.

Leslie, A. M. (1988). The necessity of illusion: Perception and thought in infancy. In L. Weiskrantz (Ed.), *Thought Without Language* (pp. 185–210). Oxford: Clarendon.

Leslie, A. M. & Keeble, S. (1987). Do six-month-old infants perceive causality? *Cognition*, *25*, 265–288.

Lidz, J. & Waxman, S. (2004). Reaffirming the poverty of the stimulus argument: a reply to the replies. *Cognition*, *93*(2), 157–165.

Lidz, J., Waxman, S., & Freedman, J. (2003). What infants know about syntax but couldn't have learned: experimental evidence for syntactic structure at 18 months. *Cognition*, *89*(3), 295–303.

Liebal, K., Behne, T., Carpenter, M., & Tomasello, M. (2009). Infants use shared experience to interpret a pointing gesture. *Developmental Science*, *12*(2), 264–271.

Lin, S., Keysar, B., & Epley, N. (2010). Reflexively mindblind: Using theory of mind to interpret behavior requires effortful attention. *Journal of Experimental Social Psychology*, *46*(3), 551–556.

Liszkowski, U., Carpenter, M., & Tomasello, M. (2008). Twelve-month-olds communicate helpfully and appropriately for knowledgeable and ignorant partners. *Cognition*, *108*(3), 732–739.

Locke, J. (1975 [1689]). *An Essay Concerning Human Understanding*. Oxford: Oxford University Press.

Low, J. (2010). Preschoolers' implicit and explicit False-Belief understanding: Relations with complex syntactical mastery. *Child Development*, *81*(2), 597–615.

Low, J., Drummond, W., Walmsley, A., & Wang, B. (2014). Representing how rabbits quack and competitors act: Limits on preschoolers' efficient ability to track perspective. *Child Development*, *forthcoming*.

Low, J. & Watts, J. (2013). Attributing false-beliefs about object identity is a signature blindspot in humans' efficient mindreading system. *Psychological Science*, *24*(3), 305–311.

Mandler, J. M. (1992). How to build a baby: Ii. conceptual primitives. *Psychological Review*, *99*(4), 587–604.

Marr, D. (1982). *Vision : a computational investigation into the human representation and processing of visual information*. San Francisco: W.H. Freeman.

McKinnon, M. C. & Moscovitch, M. (2007). Domain-general contributions to social reasoning: Theory of mind and deontic reasoning re-explored. *Cognition*, *102*(2), 179–218.

Meltzoff, A. N. (2007). 'like me': a foundation for social cognition. *Developmental Science*, *10*(1), 126–134.

Michael, J. & Christensen, W. (2016). Flexible goal attribution in early mindreading. *Psychological Review*, *123*(2), 219–227.

Michael, J., Christensen, W., & Overgaard, S. (2013). Mindreading as social expertise. *Synthese*, *191*(5), 817–840.

Michotte, A. (1946 [1963]). *The Perception of Causality*. London: Meuthen.

Moll, H. & Tomasello, M. (2007). Cooperation and human cognition: the vygotskian intelligence hypothesis. *Philosophical Transactions of the Royal Society B*, *362*(1480), 639–648.

Mozuraitis, M., Chambers, C. G., & Daneman, M. (2015). Privileged versus shared knowledge about object identity in real-time referential processing. *Cognition*, *142*, 148–165.

Oktay-Gür, N., Schulz, A., & Rakoczy, H. (2018). Children exhibit different performance patterns in explicit and implicit theory of mind tasks. *Cognition*, *173*, 60–74.

Onishi, K. H. & Baillargeon, R. (2005). Do 15-month-old infants understand false beliefs? *Science*, *308*(8), 255–258.

Paulus, M. (2016). The development of action planning in a joint action context. *Developmental Psychology*, *52*(7), 1052–1063.

Pilling, M., Wiggett, A., Özgen, E., & Davies, I. R. L. (2003). Is color "categorical perception" really perceptual? *Memory & Cognition*, *31*, 538–551.

Pitchford, N. J. & Mullen, K. T. (2005). The role of perception, language, and preference in the developmental acquisition of basic color terms. *Journal of Experimental Child Psychology*, *90*(4), 275–302.

Premack, D. (1990). The infant's theory of self-propelled objects. *Cognition*, *36*(1), 1–16.

Premack, D. & Woodruff, G. (1978). Does the chimpanzee have a theory of mind? *Behavioral and Brain Sciences*, *1*(04), 515–526.

Pullum, G. K. & Scholz, B. C. (2002). Empirical assessment of stimulus poverty arguments. *The Linguistic Review*, *18*(1-2).

Quine, W. V. O. (1960). *Word and object*. Studies in communication. Cambridge, Mass.: MIT Press.

Quine, W. V. O. (1974). *The roots of reference*. Paul Carus lectures ; no, 14. La Salle, Ill.: Open Court.

Qureshi, A., Apperly, I. A., & Samson, D. (2010). Executive function is necessary for perspective selection, not level-1 visual perspective calculation: Evidence from a dual-task study of adults. *Cognition*, *117*(2), 230–236.

Roberson, D. & Davidoff, J. (2000). The categorical perception of colors and facial expressions: The effect of verbal interference. *Memory*, *28*(6), 977–986.

Roberson, D., Davidoff, J., & Braisby, N. (1999). Similarity and categorisation: neuropsychological evidence for a dissociation in explicit categorisation tasks. *Cognition*, *71*(1), 1–42.

Roberson, D. & Hanley, J. R. (2007). Color vision: Color categories vary with language after all. *Current Biology*, *17*(15), R605–R607.

Rolfs, M., Dambacher, M., & Cavanagh, P. (2013). Visual Adaptation of the Perception of Causality. *Current Biology*, *23*(3), 250–254.

Russell, B. (1921). *The Analysis of Mind*. www.blackmask.com: Muirhead Library Of Philosophy / electronic edition by Blackmask Online.

Samson, D., Apperly, I. A., Kathirgamanathan, U., & Humphreys, G. W. (2005). Seeing it my way: a case of a selective deficit in inhibiting self-perspective. *Brain*, *128*(5), 1102–1111.

Samuels, R. (2004). Innateness in cognitive science. *Trends in Cognitive Sciences*, *8*(3), 136–41.

Sandhofer, C. M. & Smith, L. B. (1999). Learning color words involves learning a system of mappings. *Developmental Psychology*, *35*(3), 668–79.

Sandhofer, C. M. & Thom, E. E. (2006). Taking the task seriously: Reflections on measures of color acquisition. *Journal of Experimental Child Psychology*, *94*(4), 344–348.

Santos, L. R. & Hood, B. M. (2009). Object representation as a central issue in cognitive science. In B. M. Hood & L. R. Santos (Eds.), *The Origins of Object Knowledge* (pp. 1–23). Oxford: Oxford University Press.

Santos, L. R., Seelig, D., & Hauser, M. D. (2006). Cotton-top tamarins' (saguinus oedipus) expectations about occluded objects: A dissociation between looking and reaching tasks. *Infancy*, *9*(2), 147–171.

Schneider, D., Bayliss, A. P., Becker, S. I., & Dux, P. E. (2012). Eye movements reveal sustained implicit processing of others' mental states. *Journal of Experimental Psychology: General*, *141*(3), 433–438.

Scholl, B. J. & Gao, T. (2013). Perceiving animacy and intentionality: Visual processing or higher-level judgment. In M. D. Rutherford & V. A. Kuhlmeier (Eds.), *Social Perception: Detection and Interpretation of animacy, agency, and intention* (pp. 197–230). Cambridge, MA: MIT Press.

Scholl, B. J. & Nakayama, K. (2004). Illusory causal crescents: Misperceived spatial relations due to perceived causality. *Perception*, *33*, 455–469.

Scott, R. M., He, Z., Baillargeon, R., Cummins, D., Scott, R. M., He, Z., Baillargeon, R., & Cummins, D. (2012). False-belief understanding in 2.5-year-olds: evidence from two novel verbal spontaneous-response tasks. *Developmental Science*, *15*(2), 181–193.

Scott, R. M., Richman, J. C., & Baillargeon, R. (2015). Infants understand deceptive intentions to implant false beliefs about identity: New evidence for early mentalistic reasoning. *Cognitive Psychology*, *82*, 32–56.

Senghas, A. & Coppola, M. (2001). Children creating language: How nicaraguan sign language acquired a spatial grammar. *Psychological Science*, *12*(4), 323–328.

Shinskey, J. L. (2012). Disappearing décalage: Object search in light and dark at 6 months. *Infancy*, *17*(3), 272–294.

Sinigaglia, C. & Butterfill, S. A. (2015). On a puzzle about relations between thought, experience and the motoric. *Synthese*, *192*(6), 1923–1936.

Sinigaglia, C. & Sparaci, L. (2008). The mirror roots of social cognition. *Acta philosophica*, *17*(2), 307–330.

Skerry, A. E., Carey, S. E., & Spelke, E. S. (2013). First-person action experience reveals sensitivity to action efficiency in prereaching infants. *Proceedings of the National Academy of Sciences*, *110*(46), 18728–18733.

Soja, N. N. (1994). Young children's concept of color and its relation to the acquisition of color words. *Child Development*, *65*(3), 918–937.

Sommerville, J. A., Hildebrand, E. A., & Crane, C. C. (2008). Experience matters: The impact of doing versus watching on infants' subsequent perception of tool-use events. *Developmental Psychology*, *44*(5), 1249–1256.

Sommerville, J. A., Woodward, A. L., & Needham, A. (2005). Action experience alters 3-month-old infants' perception of others' actions. *Cognition*, *96*(1), B1–B11.

Song, H.-j., Onishi, K. H., Baillargeon, R., & Fisher, C. (2008). Can an agent's false belief be corrected by an appropriate communication? psychological reasoning in 18-month-old infants. *Cognition*, *109*(3), 295–315.

Southgate, V., Chevallier, C., & Csibra, G. (2010). Seventeen-month-olds appeal to false beliefs to interpret others' referential communication. *Developmental Science*, *13*(6), 907–912.

Southgate, V., Senju, A., & Csibra, G. (2007). Action anticipation through attribution of false belief by two-year-olds. *Psychological Science*, *18*(7), 587–592.

Spelke, E. (1988). Where perceiving ends and thinking begins: The apprehension of objects in infancy. In A. Yonas (Ed.), *Perceptual Development in Early Infancy* (pp. 197–234). Hillsdale, NJ: Erlbaum.

Spelke, E. (1990). Principles of object perception. *Cognitive Science*, *14*, 29–56.

Spelke, E. (2003). What makes us smart? In D. Gentner & S. Goldin-Meadow (Eds.), *Advances in the Study of Language and Thought*. Cambridge, MA: MIT Press.

Spelke, E. & Kinzler, K. D. (2007). Core knowledge. *Developmental Science*, *10*(1), 89–96.

Spelke, E. S., Kestenbaum, R., Simons, D. J., & Wein, D. (1995). Spatiotemporal continuity, smoothness of motion and object identity in infancy. *British Journal of Developmental Psychology*, *13*(2), 113–142.

Spelke, E. S. & Lee, S. A. (2012). Core systems of geometry in animal minds. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *367*(1603), 2784–2793.

Stokes, D. (2006). Review of "seeing, doing and knowing" by mohan matthen. *British Journal of Aesthetics*, *3*(46), 323–5.

Todd, A. R., Cameron, C. D., & Simpson, A. (2016). Dissociating processes underlying level-1 visual perspective taking in adults. *Cognition*, *in press*.

Tomasello, M. (2001). Could we please lose the mapping metaphor, please? *Behavioral and Brain Sciences*, *24*(6), 1119–20.

Tomasello, M. (2003). *Constructing a language*. Cambridge, Mass: Harvard University Press.

Tomasello, M. (2008). *Origins of human communication*. The MIT Press.

Tomasello, M. & Carpenter, M. (2007). Shared intentionality. *Developmental Science*, *10*(1), 121–5.

Tomasello, M., Carpenter, M., Call, J., Behne, T., & Moll, H. (2005). Understanding and sharing intentions: The origins of cultural cognition. *Behavioral and Brain Sciences*, *28*, 675–735.

Tomasello, M., Carpenter, M., & Liszkowski, U. (2007). A new look at infant pointing. *Child Development*, *78*(3), 705–722.

Tomasello, M., Striano, T., & Rochat, P. (1999). Do young children use objects as symbols? *British Journal of Developmental Psychology*, *17*, 563–584.

Treisman, A. (1986). Features and objects in visual processing. *Scientific American*, *255*(5), 114–125.

Triana, E. & Pasnak, R. (1981). Object permanence in cats and dogs. *Animal Learning & Behavior*, *9*(1), 135–139.

Uithol, S. & Paulus, M. (2014). What do infants understand of others' action? A theoretical account of early social cognition. *Psychological Research*, *78*(5), 609–622.

van Buren, B., Uddenberg, S., & Scholl, B. J. (2016). The automaticity of perceiving animacy: Goal-directed motion in simple shapes influences visuomotor behavior even when task-irrelevant. *Psychonomic Bulletin & Review*, *23*(3), 797–802.

van der Wel, R. P. R. D., Sebanz, N., & Knoblich, G. (2014). Do people automatically track others' beliefs? evidence from a continuous measure. *Cognition*, *130*(1), 128–133.

Vesper, C., Butterfill, S., Knoblich, G., & Sebanz, N. (2010). A minimal architecture for joint action. *Neural Networks*, *23*(8-9), 998–1003.

Wang, B., Hadi, N. S. A., & Low, J. (2015). Limits on efficient human mindreading: Convergence across chinese adults and semai children. *British Journal of Psychology*, *106*(4), 724–740.

Wang, S.-h., Baillargeon, R., & Brueckner, L. (2004). Young infants' reasoning about hidden objects: evidence from violation-of-expectation tasks with test trials only. *Cognition*, *93*(3), 167–198.

Warneken, F., Steinwender, J., Hamann, K., & Tomasello, M. (2014). Young children's planning in a collaborative problem-solving task. *Cognitive Development*, *31*, 48–58.

Warneken, F. & Tomasello, M. (2007). Helping and Cooperation at 14 Months of Age. *Infancy*, *11*(3), 271–294.

Wiggett, J. A. & Davies, I. R. L. (2008). The effect of stroop interference on the categorical perception of color. *Memory & Cognition*, *36*(2), 231–239.

Wilcox, T., Woods, R., & Chapa, C. (2008). Color-function categories that prime infants to use color information in an object individuation task. *Cognitive Psychology*, *57*(3), 220–261.

Wimmer, H. & Mayringer, H. (1998). False belief understanding in young children: Explanations do not develop before predictions. *International Journal of Behavioral Development*, *22*(2), 403–422.

Wimmer, H. & Perner, J. (1983). Beliefs about beliefs: Representation and constraining function of wrong beliefs in young children's understanding of deception. *Cognition*, *13*, 103–128.

Winawer, J., Witthoft, N., Frank, M. C., Wu, L., Wade, A. R., & Boroditsky, L. (2007). Russian blues reveal effects of language on color discrimination. *Proceedings of the National Academy of Sciences of the United States of America*, *104*(19), 7780–5.

Wittgenstein, L. (1953). *Philosophical Investigations.* Oxford: Blackwell.

Wittgenstein, L. (1972). *The Blue and Brown books* (2nd ed.). Oxford: Blackwell.

Woodward, A. L. (2009). Infants' Grasp of Others' Intentions. *Current Directions in Psychological Science*, *18*(1), 53–57.

Woodward, A. L., Sommerville, J. A., & Guajardo, J. J. (2001). Making sense of human behavior: Action parsing and intentional inference. In B. F. Malle, L. Moses, & D. Baldwin (Eds.), *Intentions and Intentionality* (pp. 149–169). Cambridge, MA: MIT Press.