



Goal representation in the infant brain

Victoria Southgate^{a,*}, Katarina Begus^a, Sarah Lloyd-Fox^a, Valentina di Gangi^b, Antonia Hamilton^c

^a Centre for Brain and Cognitive Development, Birkbeck College, Malet Street, London, UK

^b Department of Developmental Psychology and Socialization, University of Padova, via Venezia 8, 35131 Padova, Italy

^c School of Psychology, University of Nottingham, University Park, Nottingham, UK

ARTICLE INFO

Article history:

Accepted 20 August 2013

Available online 28 August 2013

Keywords:

Functional near infrared spectroscopy

Goal attribution

Infants

Repetition suppression

Action understanding

ABSTRACT

It is well established that, from an early age, human infants interpret the movements of others as actions directed towards goals. However, the cognitive and neural mechanisms which underlie this ability are hotly debated. The current study was designed to identify brain regions involved in the representation of others' goals early in development. Studies with adults have demonstrated that the anterior intraparietal sulcus (aIPS) exhibits repetition suppression for repeated goals and a release from suppression for new goals, implicating this specific region in goal representation in adults. In the current study, we used a modified paired repetition suppression design with 9-month-old infants to identify which cortical regions are suppressed when the infant observes a repeated goal versus a new goal. We find a strikingly similar response pattern and location of activity as had been reported in adults; the only brain region displaying significant repetition suppression for repeated goals and a release from suppression for new goals was the left anterior parietal region. Not only does our data suggest that the left anterior parietal region is specialized for representing the goals of others' actions from early in life, this demonstration presents an opportunity to use this method and design to elucidate the debate over the mechanisms and cues which contribute to early action understanding.

© 2013 The Authors. Published by Elsevier Inc. Open access under [CC BY license](http://creativecommons.org/licenses/by/3.0/).

Introduction

From an early age, human infants interpret others' movements in terms of the goal towards which the movement is directed. Understanding the mechanisms that support action interpretation, and the development of the underlying brain systems, is important in the study of basic mechanisms of social interaction.

Previous studies of goal understanding in infants commonly measure the infant's looking responses. In one such paradigm, infants are repeatedly shown an agent acting upon one of two objects. After infants have seen this repeated action, the objects switch location, and the infant is presented with the agent acting again on the previously chosen object or acting on the previously un-chosen object. Infants from as early as three months of age respond with longer looking towards the event in which the agent acts on the previously un-chosen object (Luo, 2011; Sommerville et al., 2005), suggesting that they had encoded the prior events as movements directed towards a specific object

(Woodward, 1998). In a different paradigm, infants repeatedly observe an agent acting towards an object in an efficient manner as dictated by the environment (e.g. reaching over an obstacle to contact an object). In subsequent events, the obstacle is removed and a direct reach becomes the most efficient means to achieving the same goal. In accord with this expectation, infants from at least six months of age respond with increased looking when the agent continues to perform a detour action when it is no longer necessary (Csibra, 2008; Kamewari et al., 2005; Southgate et al., 2008). This suggests that infants interpreted the previous action as directed towards the goal object and expected the agent to continue to pursue the same goal by the most efficient means (Gergely et al., 1995).

Recently, there has been much debate over what cues and mechanisms support early goal representation (Biro and Leslie, 2007; Hernik and Southgate, 2012; Kuhlmeier and Robson, 2012; Luo and Choi, 2012). Some studies have suggested that it is the infants' own experience with an action that provides them with a concept of an action as directed towards a goal (Hernik and Southgate, 2012; Woodward, 2009). Support for this position comes from studies showing that infants more readily attribute goals to actions that are part of their own motor repertoire (e.g. reaching actions) than actions which are novel (e.g. the approaching actions of a mechanical claw or a hand approaching an object in an unusual way) (Cannon and Woodward, 2012; Kanakogi and Itakura, 2011; Luo, 2011; Woodward, 1998). However, there is also substantial evidence that young infants can represent the goals of actions that are beyond their own motor experience. For example, infants represent the

* Corresponding author.

E-mail address: v.southgate@bbk.ac.uk (V. Southgate).

goals of actions performed by animated shapes (Csibra, 2008; Hernik and Southgate, 2012; Luo and Baillargeon, 2005), mechanical claws or rods (Biro and Leslie, 2007; Southgate and Begus, in press) and hands performing actions in unusual ways (Király et al., 2003; Southgate et al., 2008), none of which they could have first person experience on which to draw. These studies suggest that early goal representation may be more dependent on the availability of certain cues than prior experience with that action.

Which cues might be important for representing an action as goal-directed, and whether some cues have supremacy over others, is unclear. For example, it is often assumed that repetition of action on the same object is required for goal attribution (Luo and Beck, 2009; Premack and Premack, 1994) but other studies have demonstrated goal attribution in the absence of repeated action (Southgate and Csibra, 2009) and repeated action on a solitary object does not appear to result in goal attribution (Luo and Baillargeon, 2005, 2007). An additional or alternative basis for goal attribution may be the presence of an action that is selective; an action that is directed towards one object in the presence of another object seems to generate an interpretation that the action is goal-directed (Biro et al., 2011; Hernik and Southgate, 2012). As mentioned earlier, numerous studies have confirmed that infants appear to exploit cues to action efficiency for goal representation (Gergely et al., 1995), and some have proposed that efficiency may take precedence over cues to selectivity because infants apparently fail to represent an inefficient action directed towards one of two objects as a goal-directed action (Verschoor and Biro, 2011). However, it is nevertheless proposed that use of these different cues results in a unitary concept of goal, even in infancy (Biro et al., 2011). Finally, in the absence of alternative measures of goal representation, infants' failure to demonstrate the typical pattern of looking (e.g. equivalent looking towards actions directed to previously chosen vs. previously un-chosen objects) has become the litmus test for goal attribution, and such a reliance on one measure may be failing to provide an accurate picture of the underlying mechanisms (Kuhlmeier and Robson, 2012).

One way to elucidate these issues is to ask whether the same brain regions are recruited during the processing of events containing different cues, that ostensibly lead to the representation of a goal. Research in adults using fMRI has highlighted the inferior frontoparietal cortex as being involved in goal representation (Hamilton, 2006; Hamilton and Grafton, 2007a; Ramsey and Hamilton, 2010). Functional near infrared spectroscopy (fNIRS) can record activity of the equivalent brain regions in typically-developing infants whilst they observe goal-directed actions, providing the opportunity to interrogate the mechanisms underlying early goal attribution without requiring overt responses from the infant. The current study is a first step towards this aim.

Here, we investigate which cortical regions of the infant brain are involved in the processing of a simple goal-directed event. To this end, we used a repetition suppression (RS) design, similar to that used with adults, and which has previously identified regions of the cortex involved in goal representation (Hamilton, 2006; Hamilton and Grafton, 2007b). RS in response to the repeated presentation of a particular aspect of a stimulus, and a release from suppression when that aspect of the stimulus is changed, indicates that a particular brain region is sensitive to that property of the stimulus (Grill-Spector et al., 2006). Thus, in adults, the anterior intraparietal sulcus (aIPS) exhibits RS when the immediate goal of an action is repeated, but a release from suppression when the goal changes, strongly suggesting that the aIPS is involved in representing the goal of an action. Whilst a traditional blocked RS design has previously been employed in infants using fNIRS (Kobayashi et al., 2011), in the current study we used a paired RS design in which activation in response to individual test events is measured following a directly preceding establishing event (Kilner et al., 2009). Based on the fact that neural suppression in adults is clearly seen on a single repeated trial (Hamilton and Grafton, 2007b), and the need to obtain

sufficient data from two conditions (Repeated Goal and New Goal) containing a lengthy dynamic event, a paradigm which measures activation on single test events that directly follow an establishing event provided the best design to localise goal representation in the infant brain.

Infants were presented with animations in which a red triangle detours around a barrier to collect one of two shapes (a blue square or a green triangle). In this way, the event contained several cues that are thought to enable infants to interpret an event as goal-directed (efficient action and selective outcome). Similar animations have previously been shown to be interpreted by 9-month-olds as goal-directed events (Hernik and Southgate, 2012), and to elicit activation in the anterior parietal cortex in adults (Ramsey and Hamilton, 2010). Based on the existing studies with adults, we hypothesized that infants would show greater activation in the left parietal cortex when viewing actions directed towards novel goals compared to actions directed towards repeated goals. This result would establish the validity and feasibility of fNIRS for exploring the mechanisms underlying the development of goal understanding in infants.

Material and methods

Participants

The final sample consisted of 18 9-month-old infants (11 males; mean age = 277 days, range = 263–297 days). An additional 22 infants were excluded due to fussiness (did not complete a minimum of 6 trials (13 infants)), positioning of the fNIRS headgear (poor placement/very large or small head (5 infants)), or due to excessive movement artefacts and/or inattention, which resulted in more than 30% of the contributed data being excluded (4 infants).

Stimuli and design

Animations were created with Maxon Cinema 4D and presented on a 102 by 58 cm plasma screen with MATLAB. Each animation showed a red cone detouring around a barrier towards either a blue cube or a green cylinder (see Fig. 1). The red cone then 'collected' its target and returned to its starting position. Each animation lasted 7.5 s and animations were separated by a 0.5 second gap, giving a total trial duration of 24 s. Each trial was interleaved with an 8 second baseline in which infants saw changing images of houses, outdoor scenes, animals and faces.

The animations were presented to infants in a modified paired repetition suppression design (Kilner et al., 2009) in which each trial was composed of a set of three animations. The first two animations (Goal-Establishing event) showed the red cone moving towards one target object (either blue cube or green cylinder). The third animation showed either the red cone moving towards the same target (Repeated Goal event) or the red cone moving towards the other target (new goal event). For example, if the red cone approached the green cylinder in the first two events of the triplet, it would either continue to approach the green cylinder in the third event (Repeated Goal trial) or would approach the blue cube in the third event (new goal trial). We included two repetitions of the goal-establishing event to maximize the chance that infants identified the goal of the red cone by the time they were presented with the third event of the triplet. This design also meant that if infants did not attend during one of these goal-establishing events, but viewed the other one and the test trial, the data from the test trial could still be used. To isolate activation that was the result of a goal change rather than a path change, we counterbalanced the path that the red cone took towards its target (the target would either be located to the left or the right of the barrier) such that on some trials the path to the new goal would remain the same as that previously taken (the red cone which had previously approached the blue cube on the left would now approach the green cylinder on the left), or it would change (the red cone which had previously approached the

Download English Version:

<https://daneshyari.com/en/article/6028806>

Download Persian Version:

<https://daneshyari.com/article/6028806>

[Daneshyari.com](https://daneshyari.com)