Report

Current Biology

Comprehensive Longitudinal Study Challenges the Existence of Neonatal Imitation in Humans

Highlights

- Human infants were shown 11 gestures at 1, 3, 6, and 9 weeks of age
- Infant production of these gestures was independent of what was modeled
- Purported imitation effects were replicated but vanished in light of extra controls
- The findings demand a reconceptualization of the roots of human social cognition

Authors

Janine Oostenbroek, Thomas Suddendorf, Mark Nielsen, ..., Jacqueline Davis, Sally Clark, Virginia Slaughter

Correspondence

vps@psy.uq.edu.au

In Brief

Oostenbroek et al. carried out the largest-ever longitudinal study of neonatal imitation in humans. Newborns were shown a variety of gestures at four time points and found to be just as likely to produce matching and non-matching actions in response. The results challenge claims that imitation is an innate human capacity evident at birth.

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Comprehensive Longitudinal Study Challenges the Existence of Neonatal Imitation in Humans

Janine Oostenbroek,[1,2] Thomas Suddendorf,[2] Mark Nielsen,[2,3] Jonathan Redshaw,[2] Siobhan Kennedy-Costantini,[2] Jacqueline Davis,[4] Sally Clark,[2] and Virginia Slaughter[2,*]
[1]Department of Psychology, University of York, York YO10 5DD, UK
[2]Early Cognitive Development Centre, School of Psychology, University of Queensland, Brisbane, QLD 4072, Australia
[3]Faculty of Humanities, University of Johannesburg, Auckland Park 2006, South Africa
[4]Department of Psychology, University of Cambridge, Cambridge CB2 3EB, UK
*Correspondence: vps@psy.uq.edu.au
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SUMMARY

Human children copy others' actions with high fidelity, supporting early cultural learning and assisting in the development and maintenance of behavioral traditions [1]. Imitation has long been assumed to occur from birth [2–4], with influential theories (e.g., [5–7]) placing an innate imitation module at the foundation of social cognition (potentially underpinned by a mirror neuron system [8, 9]). Yet, the very phenomenon of neonatal imitation has remained controversial. Empirical support is mixed and interpretations are varied [10–16], potentially because previous investigations have relied heavily on cross-sectional designs with relatively small samples and with limited controls [17, 18]. Here, we report surprising results from the most comprehensive longitudinal study of neonatal imitation to date. We presented infants (n = 106) with nine social and two non-social models and scored their responses at 1, 3, 6, and 9 weeks of age. Longitudinal analyses indicated that the infants did not imitate any of the models, as they were just as likely to produce the gestures in response to control models as they were to matching models. Previous positive findings were replicated in limited cross-sections of the data, but the overall analyses confirmed these findings to be mere artifacts of restricted comparison conditions. Our results undermine the idea of an innate imitation module and suggest that earlier studies reporting neonatal imitation were methodologically limited.

RESULTS

With approval by the University of Queensland's Behavioural and Social Sciences Ethical Review Committee, our study was designed to chart the prevalence, time course, and social-cognitive correlates of neonatal imitation using a large sample and a comprehensive longitudinal design. Infants (n = 106) were presented with 11 models for 60 s each when the infants were 1, 3, 6, and 9 weeks of age. These models (see Figure 1) included four facial gestures (tongue protrusion, mouth opening, happy face, and sad face), two non-social objects simulating the facial gestures (a spoon protruding through a tube and a box opening), two hand gestures (index finger protrusion and grasping), and three vocal gestures ("mmm," "eee," and "click" sounds). We scored the number of times the infants displayed each of the nine facial, hand, and vocal gestures when viewing the models (see Table S1 for coding guidelines and inter-rater reliabilities). Unlike in other studies of neonatal imitation, this allowed us to compare the frequency of infants' behavior that matched the model with the frequencies of that same behavior in response to ten different control models. Imitation would be evident if matching responses (e.g., infant makes tongue protrusions while viewing a tongue protrusion model) were more frequent than non-matching responses (e.g., infant makes tongue protrusions while viewing a happy face model). We excluded from analyses all infants who were sleeping or crying during a testing session, resulting in a final sample of 64 infants for the longitudinal tests and a range of 77–90 infants for the cross-sectional tests (see Supplemental Experimental Procedures for further details).

For each gesture we ran a series of generalized linear mixed model (GLMM) analyses. The dependent variable for each series of GLMMs was the number of responses produced by the infants averaged over four 15-s trial periods for each gesture modeled. The fixed predictors of infant behavior included (1) the gesture modeled by the experimenter (i.e., the matching gesture or one of the ten control gestures), (2) the age of the infant at the time of testing, and (3) the interaction of the previous two predictors (to account for any change in imitation over time). These full GLMMs were tested against simpler nested GLMMs: gesture and age only without the interaction term, gesture only, age only, and a null model containing no fixed effects (see Supplemental Experimental Procedures for more details and justification of these statistical analyses and also for details of the model selection process for each gesture).

Contrary to expectations, the longitudinal analyses failed to uncover any evidence for imitation of any of the nine social gestures (see Figure 2). Specifically, for three gestures (mouth opening, sad face, and eee sound), there were no differences between the frequencies of the gestures in response to the matching models versus the control models and no changes in the frequencies of the gestures over time. For three other gestures (index finger protrusion, grasping, and click sound), the infants' likelihood of producing the gestures changed linearly over

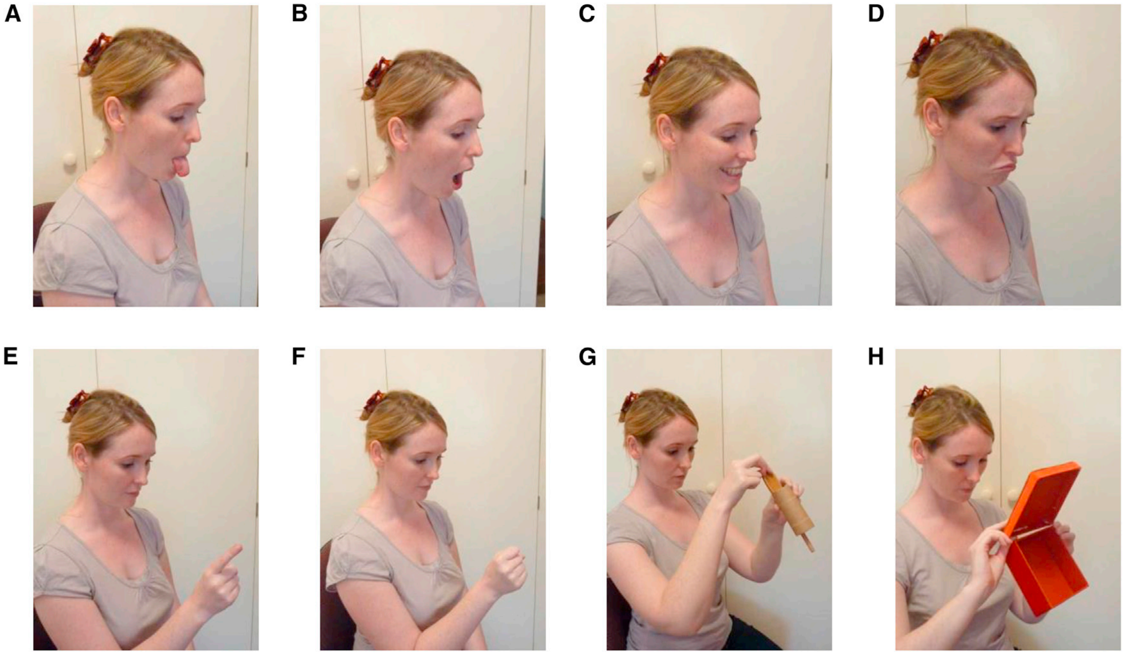

Figure 1. Gestures Modelled to Infants

(A–H) Gestures modeled to infants in imitation testing: tongue protrusion (A), mouth opening (B), happy facial expression (C), sad facial expression (D), index finger protrusion (E), grasping (F), tube protrusion (G), and box opening (H). Not represented are the three vocal gestures: mmm, eee, and click sounds. See Table S1 for coding guidelines and inter-rater reliabilities.

time, but the type of model was not an informative predictor of their behavior. For the final three gestures (tongue protrusion, happy face, and mmm sound), both time and model (but not their interaction) were predictors. However, although the infants produced these gestures significantly more often when the model demonstrated them than when she demonstrated some control gestures, there were no significant differences when compared to other control gestures (see Table 1). These null results were evident even before applying Bonferroni corrections to control for familywise error rate (comprehensive longitudinal results are reproduced in Tables S2 and S3).

Since tongue protrusion has produced the most consistent evidence for neonatal imitation in the literature [14, 19], we present a separate detailed summary of this gesture across conditions in Figure 3. At each time point, only about half of the infants (46.7%–64.2%) produced any tongue protrusions in response to the tongue protrusion model (see Figure S4), and there was no sign of intra-individual consistency of such responses (i.e., response frequency correlations across the four time periods ranged from $-.08$ to 0.28). More of the control comparisons for tongue protrusion were significant than for any other gesture (see Table 1). Yet, across time points, the frequency of infant tongue protrusion responses to the tongue protrusion model did not significantly differ from the frequencies of such responses to the mouth opening, happy face, and sad face models. Thus, there is no evidence infants were imitating the specific model. One may speculate about whether active faces in general may trigger a tongue protrusion response, but this begs the question of why infants did not respond in a similar manner to the vocal gestures.

The overall longitudinal results contradict previous reports of neonatal imitation. Nonetheless, our data do indeed replicate key cross-sectional findings, while confirming these results to be artifacts of restricted comparison conditions. When we used the most common cross-sectional procedure of comparing infants' tongue protrusions in response to the tongue protrusion model with their tongue protrusions to the single control model of mouth opening [2], for example, we found that infants were significantly more likely to produce matching responses than non-matching responses at 1 week, $t(73) = 2.25$, $p = 0.028$ ($n = 74$), and 9 weeks of age, $t(88) = 3.24$, $p = 0.002$ ($n = 89$). This need not mean that the infants imitated the tongue protrusion model at these ages, however, as the effect does not hold across all control comparisons. When we used the happy face as the control model, for instance, there were no significant cross-sectional effects at any age, all $t < 1.62$, $p > .11$. More broadly, across nine gestures and four time points (36 total cross-sections of data), there were 14 occasions on which the infants produced the gesture matching the model significantly more often than to at least one control model. On no occasion, however, did the infants produce the gesture matching the model significantly more often than to all control models, even without applying Bonferroni corrections (see Table S4). Since there is no widely accepted a priori reason to choose one control model over another, even our cross-sectional results do not provide any evidence for a true imitation effect. Yet, if we had obtained or analyzed a less comprehensive dataset (as has been done in previous studies), then we may have been impelled to conclude otherwise.

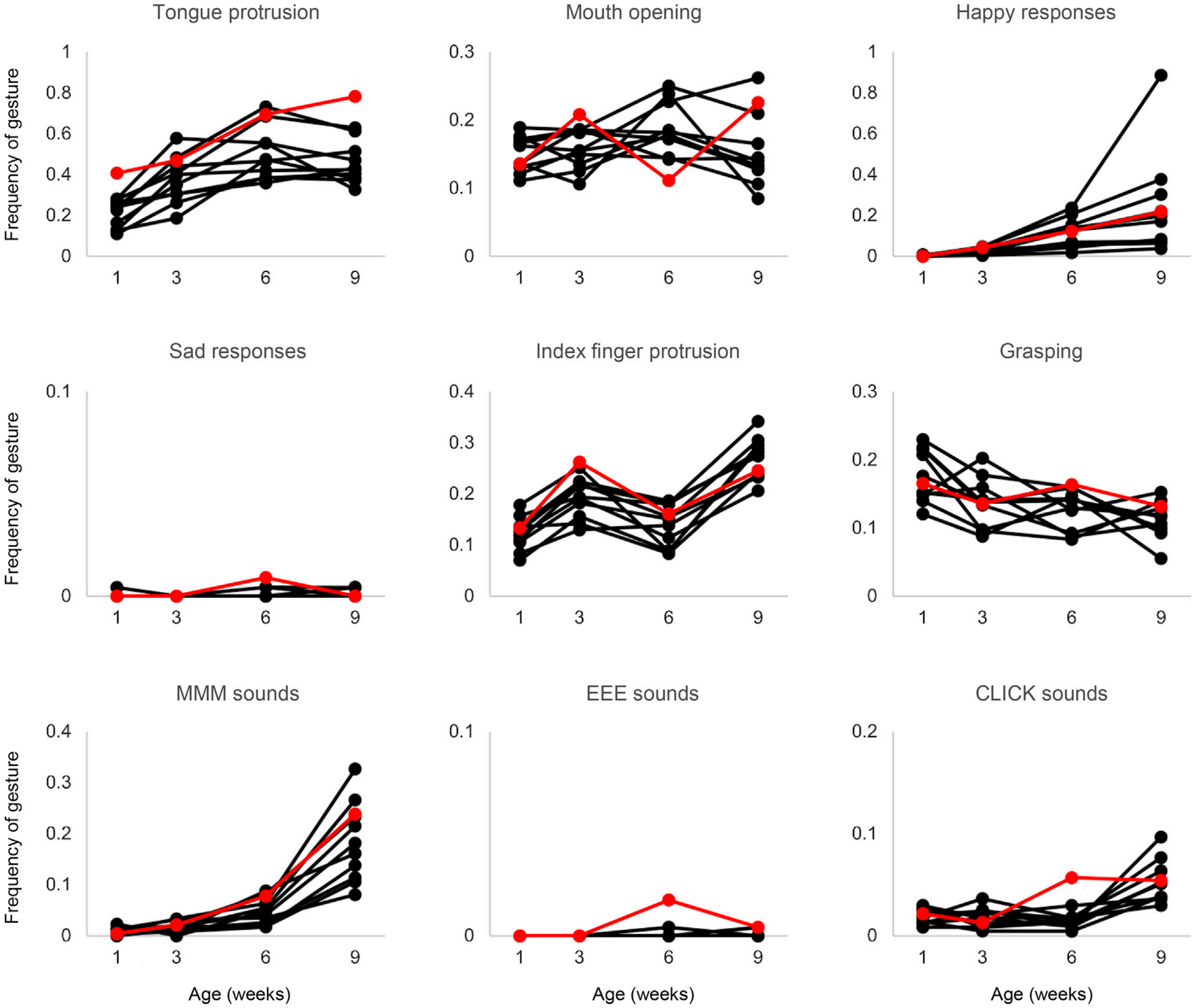

Figure 2. Red Lines Indicate Mean Response Frequencies to Matching Models with Control Models Indicated in Black

Mean frequencies of responses per 15-s trial period to matching models (red lines) and control models (black lines) for nine different infant gestures over the first 9 weeks of life. Note that the y-axes are not scaled consistently, as some gestures were produced at much lower frequencies than others. See Figure 3 and Figures S1–S3 for more detailed graphs that distinguish between control models. See Tables S2 and S4 for results of the longitudinal and cross-sectional analyses for each gesture.

DISCUSSION

Given the methodological strengths of the current study compared to previous studies [18], our results suggest that the many prominent theories built upon the assumption of neonatal imitation (e.g., [5–7]) are not empirically supported and should be modified or abandoned altogether. To continue defending the phenomenon in light of our findings would require the non-parsimonious and empirically intractable assumption that infants produce the same amounts of certain gestures (e.g., tongue protrusions, happy faces, and mmm sounds) to matching and non-matching models for different reasons (imitative and non-imitative). Previous studies reporting imitative effects appear to have been limited by inadequate controls and analyses, and/or the presence of outliers in small cross-sectional samples of infants. A few studies reporting null results like ours can be found in the literature [17], but many more may have been filed away due to publication bias [20, 21].

If neonates do not imitate, as our results suggest, then the age of first emergence for the phenomenon may actually be closer to 6 to 8 months of age [22]—around the time that Piaget [23] classically proposed. Such a developmental trajectory would challenge the idea of a specialized, nativist module for imitation [2, 5] and would instead favor the view of imitation as an emergent product of both native and environmental influences [14, 19, 24, 25]. One key driver of the nativist account was the discovery of mirror neurons in the macaque monkey [26], but it remains unclear whether these neurons

Table 1. Summary of Pairwise Comparisons between Matching and Control Models for Infants' Tongue Protrusion, Happy Face, and mmm Sound Responses, Collapsed across Longitudinal Time Points

Gesture Produced by Infants	Matching Model > Control Model*	Matching Model = Control Model	Matching Model < Control Model*
Tongue protrusion	tube protrusion, box opening, finger protrusion, grasping, mmm sound, eee sound, click sound	mouth opening, happy face, sad face	
Happy face	tube protrusion, box opening, finger protrusion, grasping	tongue protrusion, mouth opening, sad face, eee sound, click sound	mmm sound
mmm sound	box opening	tongue protrusion, mouth opening, tube protrusion, happy face, sad face, finger protrusion, grasping, eee sound, click sound	

*$p < 0.05$ (prior to Bonferroni correction). For more details, see Table S3.

are an innate adaptation for imitation and action understanding [8, 9] or a by-product of associative learning [27, 28]. Our results provide evidence against the innate view, and they also bring into question findings suggesting that macaques and other non-human primates engage in neonatal imitation [29, 30].

In summary, our comprehensive longitudinal study, contrary to expectations [18], has failed to uncover any evidence for imitation in human neonates. Instead, the results challenge the existence of this long-debated phenomenon and prompt revision of a number of influential theories placing it at the foundation of social cognition.

EXPERIMENTAL PROCEDURES

Subjects

Participants included 106 healthy infants (51 girls, 55 boys). The infants were tested at four longitudinal time points when aged approximately 1, 3, 6, and 9 weeks (mean [M] = 1 week, 4 days, SD = 2.49 days; M = 3 weeks, 4 days, SD = 3.06 days; M = 6 weeks, 2 days, SD = 2.96 days; M = 9 weeks, 3 days, SD = 4.42 days). All parents/guardians gave informed consent for their children to participate, as approved by the human ethics committee of the University of Queensland.

Materials and Methods

At each time point, infants were presented with 11 modeled actions (in one of five orders), including four facial gestures (tongue protrusion, mouth opening,

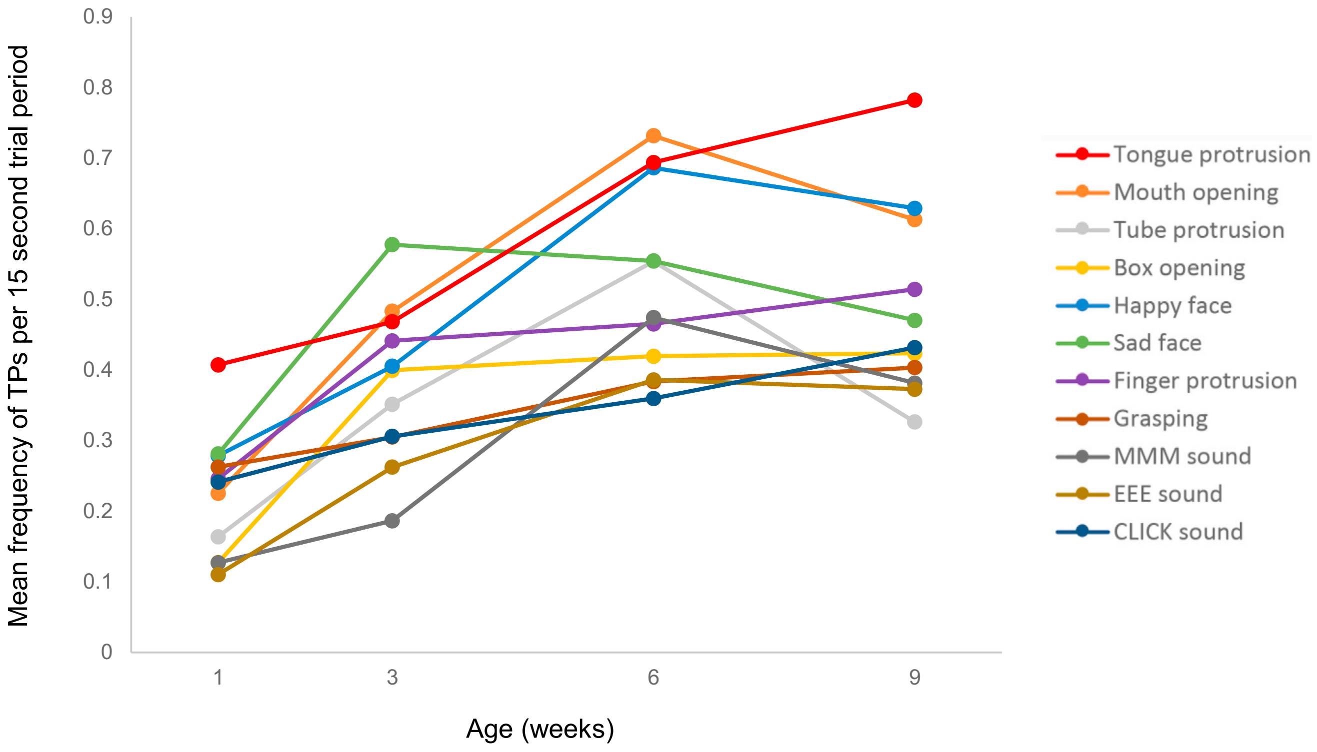

Figure 3. Red Line Indicates Mean Frequency of Tongue Protrusions to the Matching Model

Mean frequency of tongue protrusions (TPs) per 15-s trial period to the matched tongue protrusion model and the ten control models. See also Figure S4 and Tables S2 and S3.

happy face, and sad face), two non-social objects simulating the facial gestures (a spoon protruding through a tube and a box opening), two hand gestures (index finger protrusion and grasping), and three vocal gestures (mmm, eee, and click sounds). Following previous work [2], the experimenter first modeled the relevant action for 15 s (five times at 3-s intervals) before engaging in a passive position for 15 s. This process was then repeated such that the infants saw 30 total seconds of active modeling during each 1-min trial. All sessions were videotaped and infants' responses were coded by two scorers, one blind to the aims of the study (see Table S1 for coding guidelines). These coders scored the total number of each of the nine social gestures produced by the infants toward each of the 11 models, with these gesture frequencies then averaged over each 15-s trial period in which the infants were in a suitable arousal state for testing. Approximately 20% of the videos were coded by both scorers, with good levels of inter-rater reliability for all nine gestures (see Table S1). Comprehensive methodological details can be found in the Supplemental Experimental Procedures.

SUPPLEMENTAL INFORMATION

Supplemental Information includes Supplemental Experimental Procedures, four figures, and four tables and can be found with this article online at http://dx.doi.org/10.1016/j.cub.2016.03.047.

AUTHOR CONTRIBUTIONS

J.O., T.S., M.N., and V.S. designed the study. J.O. and S.K.-C. tested the infants. J.O., S.K.-C., and S.C. contributed to behavioral coding. J.R. and J.D. analyzed the data. J.O., T.S., M.N., J.R., and V.S. wrote the manuscript.

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