

Using eye-tracking technology with babies to address socio-economic status associated educational disadvantages

A final report on projects exploring early screening and training of infants in children's centres in East London



Derek Moore

Haiko Ballieux, Przemek Tomalski, Elena Kushnerenko, Deirdre Birtles, Sam Wass,
Annette Karmiloff-Smith, Mark Johnson

School of Psychology, University of Surrey
Institute for Research in Child Development, University of East London
Centre for Brain and Cognitive Development, Birkbeck College

Table of contents

1. About the authors	3
2. Executive Summary	4
3. Acknowledgements	6
Funding	6
Partners	6
4. Rationale	7
5. What is eye-tracking?	7
6. Primary aims of the studies	8
Screening study	8
Training study	8
Study design	9
7. Working with Children’s Centres	11
Training staff to use eye-trackers	12
Engaging staff with the assessment of infants	12
8. Recruiting and working with parents and infants	13
Recruitment	13
Demographic details of participants recruited	15
Details of testing facilities across CCs	18
User feedback on testing sessions in Screen study	19
9. Eye- tracking tasks	21
Screening study.	21
Training study.	24
Quality of eye-tracking data	28
10. Screening study - Infant performance on screening eye-tracking tasks	29
11. Screening study (cont.) - Associations of tasks performance with socio-economic status	32
12. Screening study (cont.) - Associations with language outcomes in toddlers	33
13. Training study - Effectiveness of training tasks	35
14. Conclusions	38
Using eye-tracking for screening	38
Using eye-tracking for training	39
15. Publications and presentations from the study	40
16. References	41

1. About the authors

Professor Derek Moore is Pro-Vice-Chancellor Education and Health at the University of Greenwich. Previously he was Professor of Psychology and Head of School of Psychology at the University of Surrey, before that he was Director of the Institute for Research in Child Development at the University of East London.

Professor Mark Johnson is Head of the Department of Psychology at Cambridge University. Before that, and Associate Director of the Centre for Brain and Cognitive Development at Birkbeck College. In 2008 he was awarded the British Psychological Society President's Award for distinguished contributions to psychological knowledge, and in 2011, he was elected as Fellow of the British Academy (FBA).

Professor Annette Karmiloff-Smith was a professorial research fellow at the Developmental Neurocognition Lab at Birkbeck College. Before moving to Birkbeck, she was Head of the Neurocognitive Development Unit at Institute of Child Health, University College, London. Professor Karmiloff-Smith passed away in 2016.

Dr Przemek Tomalski is a Lecturer in Psychology at the University of Warsaw. Previously he was a Research Fellow at the Institute for Research in Child Development at the University of East London, and before that he was at the Centre for Brain and Cognitive Development at Birkbeck College.

Dr Haiko Ballieux is a Senior Lecturer in Psychology at the University of Westminster. He previously was a Research Fellow at the Institute for Research in Child Development at the University of East London, and before that at the Centre for Brain and Cognitive Development at Birkbeck College.

Dr Sam Wass is a Senior Lecturer and ESRC Future Research Leader Fellow in Psychology at the University of East London, and previously was a British Academy Postdoctoral Fellow at the MRC Cognition and Brain Sciences Unit in Cambridge.

Dr Elena Kushnerenko was a Research Fellow at the University of East London, UEL Babylab Leader and EEG Lab Coordinator. Previously, she was a Research Fellow at the Centre for Brain and Cognitive Development at Birkbeck College.

2. Executive Summary

This report summarises findings from a set of studies undertaken in East London Children's Centres (CCs) that have important implications for future approaches to screening and intervention of children from disadvantaged areas who are most at risk for poor educational outcomes.

A large screening study performed with a final sample of 174 infants aimed to examine the feasibility of using eye-tracking assessments in community settings. The specific aim was to improve our understanding of early cognitive development in infants growing up in low socio-economic status (SES) families, as well as to encourage these families to participate and to learn more about their babies. A smaller training study with a final sample of 23 infants aimed to examine the feasibility of attention training in community settings using eye-tracking technology.

In these studies, we demonstrated that:

- it is possible to use eye-tracking technology to screen infants for possible deficits in early attention
- it is possible to run training sessions targeting attention control development in infants at elevated risk of atypical development with a community setting
- that children's centre staff are willing and capable of being trained to use this technology
- that parents found the use of eye-tracking an engaging method for them to learn about their infant's emerging abilities to control their attention

The results we obtained suggested that:

- differences in infants' processing of visual and auditory information contingent on SES are already discernible by 6/7 months of age. However, the size of these differences was relatively small.
- the training effects that obtained with our low-SES sample were highly comparable to those observed in previous studies with high-SES infants.

We also conducted, under separate funding, a follow-up assessment in which the infants that we had originally assessed as part of the screening study in this project were tested again when they were 2 years of age. These analyses identified a number of significant associations between infants' performance on the eye-tracking tasks at 6/7 months and their language outcomes at 2 years. This suggests that the CC assessments that we administered can successfully predict children's subsequent language development outcomes.

The report includes previously published data (see References section, below) as well as other previously unpublished data.

3. Acknowledgements

Funding

The two linked studies reported here were supported by grants from the Nuffield Foundation.



The Nuffield Foundation is an endowed charitable trust that aims to improve social well-being in the widest sense. It supports research and innovation in education and social policy and also works to build capacity in education, science and social science research. The Nuffield Foundation has funded this project, but the views expressed are those of the authors and not necessarily those of the Foundation (more information available at www.nuffieldfoundation.org).

This work was also supported by a British Academy Postdoctoral Fellowship to SW, and we acknowledge additional support of the Wellcome Trust (098330/Z/12/Z, AKS), the UK Medical Research Council (G0701484, MJ), and the University of East London School of Psychology.

Partners

We would like to thank all participating families for their contribution, as well as management and staff in CCs in Tower Hamlets and Newham (London, UK).

We would especially like to thank Sally Parkinson, Head of Commissioning in Newham, for helping with setting up partnerships with CCs, and Monica Forty and her team for support in children's services in Tower Hamlets.

We would also like to acknowledge the help and support of Acuity who are providers of Tobii eye-tracking equipment in the UK who provided training material for CC staff.



4. Rationale

One of the key challenges for society today is identifying, as early as possible, precursors to cognitive, language and communication difficulties so that problems can be addressed at as early a stage in development as is possible. This is particularly important for infants reared in families facing economic hardship where research shows that early difficulties are far more likely to lead to negative long-term consequences for a variety of mental health and wellbeing outcomes (Noble et al., 2005, 2007). The importance of early intervention is increasingly recognised by governments, and there is cross-party political momentum for developing targeted early social-emotional interventions for low socio-economic status (SES) groups.

The work presented here was intended to develop new eye-tracking technology currently used within laboratory settings in the UK and the US, and to assess its potential transformational impact on early assessment and intervention within community settings. We also wished to assess the further potential for this technology to engage parents with their infants' cognitive development, and to directly train early attentional difficulties that could underpin both social and cognitive outcomes. Ultimately, eye-tracking could be used in three ways: first, as part of a 'toolkit' for identifying potential attention, language and social perception problems in infants even before language production emerges. Second, as an intervention tool for directly training attentional processes in infants. Third, as a tool to intervene with, and engage, parents in their infant's development.

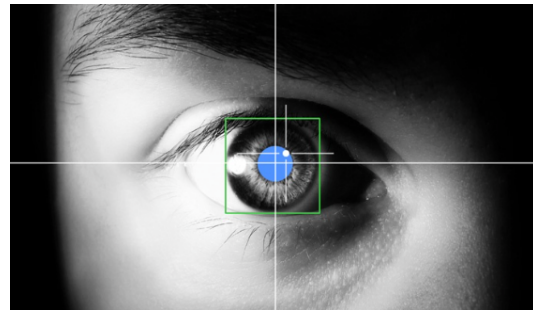
We anticipate that, in the long term, this work will contribute significantly to the quality of life of people from low-SES backgrounds and will have associated economic benefits for society; up to 7% of children entering school have some form of learning or behavioural difficulty and many of these may be alleviated if identified earlier. Alleviating potential educational problems before children enter the school system will improve the quality of life for children, their families and communities. If we can engage early-years professionals to use this technology as part of their assessments, then, as the paradigms and methods improve, those children with potential difficulties could be identified even before they speak. This would also help us in developing early interventions targeted at these infants and their mothers. In this way, we could have a significant positive impact by reducing the proportion of children presenting with problems at entry to school.

Consequently, the potential longer-term social and economic impact of a successful programme of screening and training interventions using these new technologies could be large. US and UK reviews suggest that to date returns on successful early intervention may be ten-fold for cost expended in terms of long-term educational and health outcomes. They also suggest that this return increases the earlier the interventions start, and the more targeted the interventions are. If this technology can be rapidly and effectively integrated into CCs, then this could have significant long-term health and educational implications.

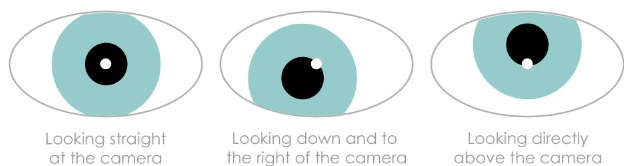
5. What is eye-tracking?

Eye-tracking is a term used to refer to the use of remote scanning equipment that can tell precisely where someone is looking.

Eye-tracking equipment uses low-level infra-red light which simultaneously reflects off the cornea and the retina at the back of the eye (Gervain et al., 2011). The reflection from the retina reveals the outline of the pupil.



A detector picks up the reflection of the cornea and computes the relative position of the corneal reflection to the outline of the pupil. As someone moves their eye to look in different places the relative location of the two reflections changes and this can be used to work out where someone is looking.



An initial procedure is used to calibrate these angles against a set of reference points displayed on a video screen. With babies, attractive animated attention-grabbers are used as calibration reference points, as we know infants will look at these.

One of the issues with older generation eye-trackers was that, since the calibration was only performed to match eye movements when the eye was within a particular 2-D plane, the calibration would rapidly lose accuracy when the participant moved either closer to, or further away from, the eye-tracker. More recent eye-trackers, including the Tobii T120 eye-tracker used in this study, also track the position of the participant's head in 3-D space. This makes it possible to correct, online, for the movement of the head, thus substantially improving the accuracy of tracking.

The uses of eye-tracking for studying infants has increased rapidly over the last 10 years. Increasingly, eye-tracking is used for detailed studies to establish which parts of stimuli are most salient to infants and how they control their attention as stimuli change, as well as to see how infant attention changes with age. The Tobii T120 is currently employed in a number of leading infant research centres around the world, but to our knowledge had yet to be employed *in situ* in the community as a screening and training tool.

6. Primary aims of the studies

In partnership with local CCs we carried out two studies using Tobii T120 eye-tracking equipment. The Screening study involved 174 6-month-old infants and their parents. The aim of this study was to explore the feasibility of delivering eye-tracking assessments within CCs, and to explore the potential of eye-tracking to engage staff and parents from lower socio-economic status to participate in these activities.

The Training study, specifically examined the feasibility of delivering targeted intervention in CCs. The training was delivered over five weekly sessions and used computerised paradigms to train attention control in infants. 33 12-month-old infants were recruited, 23 of whom completed the training.

Screening study¹

The primary aims of this study were:

1. To determine the feasibility of delivering eye-tracking assessments that had previously been performed in the lab within 'real world', community settings.
2. To use these techniques to engage parents from lower socio-economic class groups to help them better to understand their infants' development.
3. To build partnerships with Early Years providers and to engage them with these techniques, thereby fostering interest in incorporating these techniques in targeted screening and intervention programmes.
4. To examine the longitudinal relationships between eye-tracking performance and language outcomes and, if found, to examine how these associations were mediated by factors associated with economic, social and community deprivation.
5. To investigate where further refinement of these paradigms is required if associations are not clear.

Training study²

The aims of the training study were:

1. To investigate the feasibility of using eye-tracking to deliver targeted early interventions in CCs.

¹ Title of funded project: **Using new technologies to engage parents from disadvantaged areas in the assessment of the language and social development of their babies (Take a Look Baby Study, TALBY).**

² Title of funded project: **Training infant attentional control in a community setting: a pilot study using eye-tracking technology to deliver gaze-contingency training in children's centres (iSTARs)**

2. To investigate whether attention training could be shown to lead to improvements in attentional control in infants from families with varied SES background, and to compare the improvements observed with those documented in previous studies targeting high-SES infants.
3. To demonstrate that parental engagement and attendance could be maintained across a 5-week-long training programme.

Study design

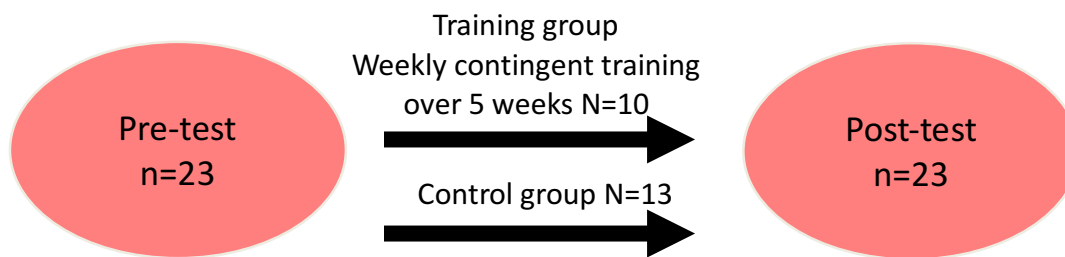
The screening study consisted of three elements:

- 1) Working with the staff in six CCs in East London to train them to use eye-tracking equipment.
- 2) Creating and delivering new eye-tracking assessments to the babies, assessing the quality of the data produced, and determining the range of differences in infant attention.
- 3) Assessing the level of engagement of parents with these methods.

In addition, under separate funding, we conducted a follow-up assessment in which a subset of the infants from the present study were tested again when they were 2 years of age. The aim of this study was to determine whether the data collected at age 6-7months is able to predict emerging differences in language and communication.

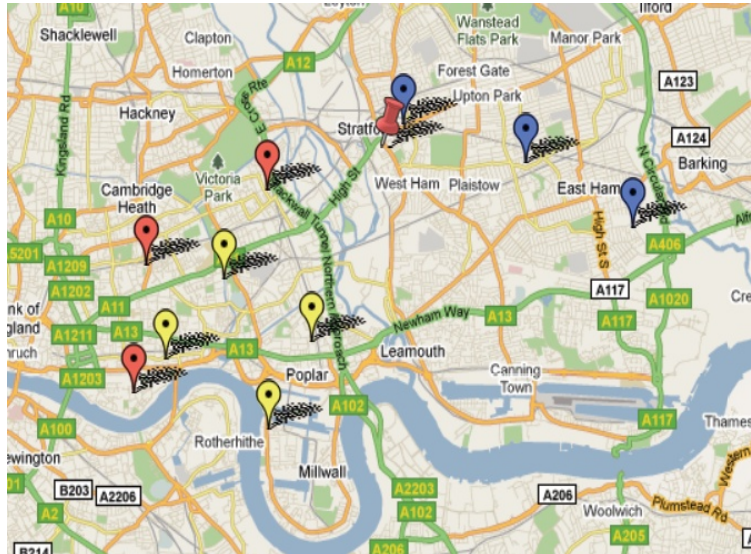
The intention was to recruit 200 infants for the initial training study. We slightly under-recruited relative to these initial aims: the final sample constituted 174 infants at 6-7 months. For the follow-up assessment, 45 of the children who participated in the original study attended a subsequent testing session at 24 months of age.

For the Training study, our aim was to recruit a separate cohort of 30 infants aged 11 to 12 months. All infants participating in the training study were to complete an initial assessment of their attention control capacities ('pre-test'). Then, over the next five weeks, half were allocated to receive attention training, and the remaining half were allocated to a matched, active control group. On completion of the training program, all infants repeated the initial assessment of their attention control capacities as presented ('post-test'). We slightly under-recruited relative to our initial aims: although we initially recruited 33 infants, only 23 infants completed the full program and the post-test assessment.



7. Working with Children’s Centres (CCs)

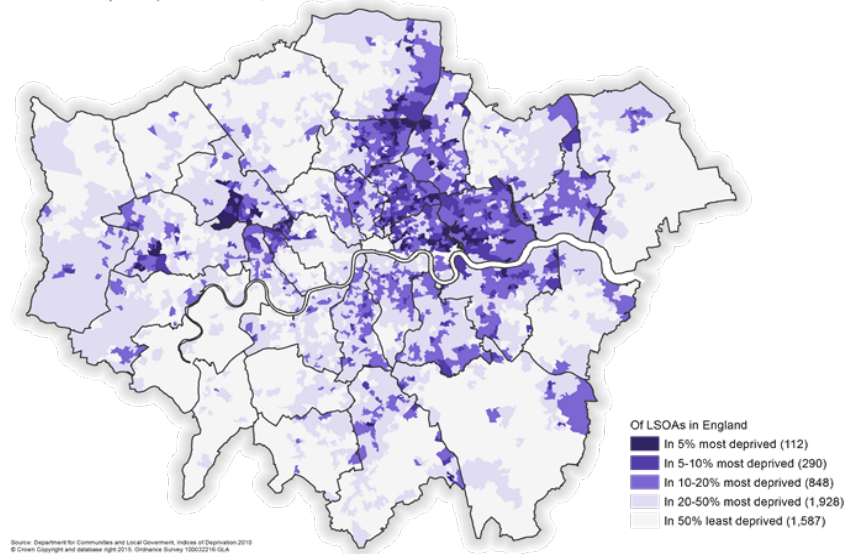
This study was undertaken in partnership with six CCs (see coloured locations on the map, with the red pin indicating the location of UEL). These CCs were supported by Children’s Services and local Health Services in the London boroughs of Newham and Tower Hamlets. Local authorities in the UK follow different models of CC management, and the CCs in our study reflect this diversity.



In Newham, CCs are semi-independent and often set up by existing schools and nurseries responsible for their management and budget. Managers and staff in three CCs in Newham were approached separately, all responding positively to the idea of participation in the project. They indicated that they valued the project’s goals and could see how it could potentially benefit families in their centres. Commitment to the project in the borough of Tower Hamlets was also good. The management of CCs in this borough was more centralised, with a clear management structure overseeing all governance, research, and external collaborations. At the early stages of the project we approached and received formal support from the Head of Early Years in both boroughs and delivered formal presentations at their CC managers’ meeting and to each centre individually. When applying for funds for the project we received a commitment in kind in staff time to allow staff to take part in training and assessments.

These two boroughs chosen for the study are in the top five for social and economic deprivation in England (see IMD density map DCLG, 2010), and have around 42% of children living below the poverty line (Aldridge et al., 2013).

Index of Multiple Deprivation 2010, London



Training staff to use eye-trackers

One aim of this project was to establish the feasibility of engaging CC staff with eye-tracking technology, in order to ascertain whether they would be comfortable with undertaking assessments. To facilitate this process, we worked closely with eye-tracking technology specialists (Acuity Ltd.) to develop a short training programme, and created study materials to educate and engage the staff.

The training lasted 2-3 hours, and usually took place in the CC. It comprised a seminar on infant cognitive research to contextualise the work, followed by basic training of practical skills on loading and running the eye-tracker paradigms. This included information on how to set up and to undertake eye-tracking recording, as well as how to replay to parents the video of the infant eye-tracking trace.

Staff members in all but one CC (due to time restrictions) participated in the training sessions at the beginning of the project. In total, we conducted five training sessions attended by 16 CC staff members. We asked all participants to give feedback by answering questions on the quality of the training, its ability to hold attention and its usefulness. Each question was coded 1 to 5 (poor to excellent). Our feedback suggested that:

- 15/16 staff reported the level of content of training good, very good or excellent
- 16/16 found the ability of the training to hold their attention good, very good or excellent
- 16/16 found the usefulness of the training for their work to be very good or excellent.

Overall, these findings indicate that staff thought that the training was generally good quality and was relevant to their work.

Engaging staff with the assessment of infants

On the whole, engagement of staff members and their managers was high. Most managers were interested in the project and were keen to let staff members take time to conduct the eye-tracking sessions with infants. The participation of staff members who took part in training in assessments was good, with 75% (n= 12) sitting in on (i.e., observing) and/or partly running (i.e., actively delivering) at least one session. In one CC, staff were very engaged and set up a rota for staff members to participate in the sessions in a given week. In two other CCs, we had one staff member participate. Staff members included nursery and teaching staff, with ages ranging from 20 to 47 years. However, in three CCs (including the one mentioned earlier that did not participate in training sessions due to time restrictions) staff members did not participate in the sessions delivered by the experimenter. This was not due to lack of interest, but rather reflected increased workload in Tower Hamlets in 2010-11 as a result of re-organisation caused by national budget cuts.

8. Recruiting and working with parents and infants

Recruitment

Both studies received clearance from the University of East London ethics committee, and additional clearance was obtained from the Research Governance Directorate of Tower Hamlets.

For the Screening study all participating CCs advertised our 'Learn About Your Baby' sessions (see advertisement, below). These sessions were advertised as a potential learning experience for parents. Sessions were scheduled and advertised in CC quarterly activities

Learn about your baby!

At [xxx] Children's Centre
Aug/Sept 2011



Calling all babies!

Convidamos todos os bebés!

සමූහ 0-9 ක්‍රීඩා ක්‍රීඩා කිරීමේ කාලයේ සහභාගී වන්න!

Zapraszamy wszystkie niemowlęta!

Приглашаем всех малышей!

രീശ്വരൻ ക്രിസ്ത്യൻ അക്കാദമിയിൽ
കാലാവസ്ഥ.

INSTITUTE FOR RESEARCH IN
CHILD DEVELOPMENT



www.uel.ac.uk/ircd/talby



Come to our free 'Learn About Your Baby' sessions and spend an interesting hour with us finding out a bit more about how your baby sees the world.

Watch for yourselves how they control where they look.

You will receive a £10 gift voucher, a picture of your baby, and a baby book

For more information and to book your session call
020 7364 0423

or ask at [xxx] Children's Centre,
[address]

All procedures have been approved by the ethics committee of the University of East London and Tower Hamlets CSF Directorate

calendars for parents alongside other baby-targeted activities (e.g. baby yoga, baby club, parent and toddler group).

We provided the CCs with our required age-range and inclusion criteria: age range, 6 months 0 days to 7 months 30 days; no pre-term infants; no major medical condition; and no major delivery complications. Then, the CCs accessed their own database and sent the flyer and a study information sheet to all parents with infants fitting these criteria. In addition, flyers and posters were distributed in the CC reception areas.

The information materials were written in English except for the 'calling all babies' phrase on the flyer and poster³. Many CC staff members were able to speak other languages, and were therefore able to explain the study in more detail to parents who had queries after seeing the flyer. Parents who wished to take part contacted the CC, or researcher directly, to book an appointment. Since the parents often already knew the staff members working at the CCs, this may have made them more inclined to join the sessions.

The CC managers estimated that around 50% of the total number of the parents on their databases whom they contacted actually took part in the study (this estimate varied from 33% to 65% across the centres). All parents were briefed prior to taking part in the study that this was a research project and the results could not be used in diagnosing any difficulties of individual babies before these methods had been validated.

One disadvantage of being part of the timetable was that this restricted us to the same slot each week when we could test participants in a given centre. If this once-weekly slot was not convenient for parents, then they could not always be tested. In a few cases, we assessed infants in another CC if the timing of the session and location were more convenient.

Groups of sessions were timetabled either for a morning or afternoon, or in some cases all day. As we were using one set of equipment, and one team of researchers, it was essential to carefully coordinate the timetabling of sessions throughout the week across CCs. Overall, this allowed us to comfortably assess on average three infants a week in each CC, or approximately 20 infants per week across the six CCs.

The testing session itself consisted of an introduction by the experimenter, administration of the five eye-tracking tasks, each lasting 5 minutes, a scripted playback of videos of the infant performance, the completion of parent questionnaires and a session evaluation. Parents were given a certificate of participation for their baby, a £10 shopping

³ Given the diversity of languages in East London it was not possible to create materials translated for all. However, in future studies it would be possible to target specific language groups with translated materials if this were the focus of the study.

voucher, and a children's book. In addition, with permission, we took a picture of the baby and sent an A4 printout on photo paper to the parent's home.

Demographic details of participants recruited

Screening study

Our initial target was to recruit 200 infants over seven months. We recruited 12 who took part in initial piloting, a further 9 who were assessed but later excluded from analysis as they did not meet age and/or health criteria, and a further 174 who completed a full assessment session, and from whom eye-tracking data were collected. All participants included in the final sample were born full-term (36-42 weeks gestational age). A comparable proportion of participants came from each of the two boroughs (Newham 54.5%; Tower Hamlets 45.5%). The table below shows key demographic details for our screening study participants:

Demographic details for our screening study participants. Results show mean values for key demographic details for our screening study participants. Results in brackets show the standard deviations, indicating the variance in these values across the population sampled.

Measure		Measure			
Age (days)		209.3 (19.7)	Gender	Female	39.1%
				Male	60.9%
Gestational age (weeks)		39.5 (1.5)	Birth weight (g)		3229.1 (501.5)
Infant Ethnicity	White British	15.3%	Mother Ethnicity	White British	19.0%
	Other white	11.2%		Other white	14.9%
	Afro-Caribbean	11.8%		Afro-Caribbean	11.5%
	Asian, Indian & Pakistani	21.2%		Asian Indian & Pakistani	23.6%
	Asian Bangladeshi	14.0%		Asian Bangladeshi	14.9%
	Mixed/Other	26.5%		Mixed/Other	16.1%
Mother's age at birth (years)		30.1 (4.9)	Time at present residence in months		42.1 (40.5)
No of older siblings	0	57.5%	Residence	Own house/flat	28.7%
	1	29.3%		Rented house/flat	39.7%
	2	6.9%		Council housing	25.9%
	3	5.7%		Rented room	2.3%
	4	0.6%		Other	3.4%
Average gross household income		£49,487 (65,456)	Average gross income per family member		£15,226 (21,774)
Mother SOC *	(1)	32.8%	Father SOC *	(1)	47.2%
	(2)	8.0%		(2)	8.1%
	(3)	1.1%		(3)	4.3%
	(4)	2.3%		(4)	6.2%
	(5)	11.5%		(5)	21.1%
	(6)	44.3%		(6)	13.0%

Mother's education level**	(1)	20.1%	Father's education level**	(1)	19.0%
	(2)	35.1%		(2)	31.6%
	(3)	14.4%		(3)	11.5%
	(4)	10.3%		(4)	12.1%
	(5)	14.4%		(5)	13.8%
	(6)	5.7%		(6)	4.6%
Breast-feeding	0-3 months	84.5%	Age introduced solid food	3 months	2.2%
	4-6 months	70.1%		4 months	21.8%
	Currently	58.0%		5 months	24.7%
				6 months	47.2%

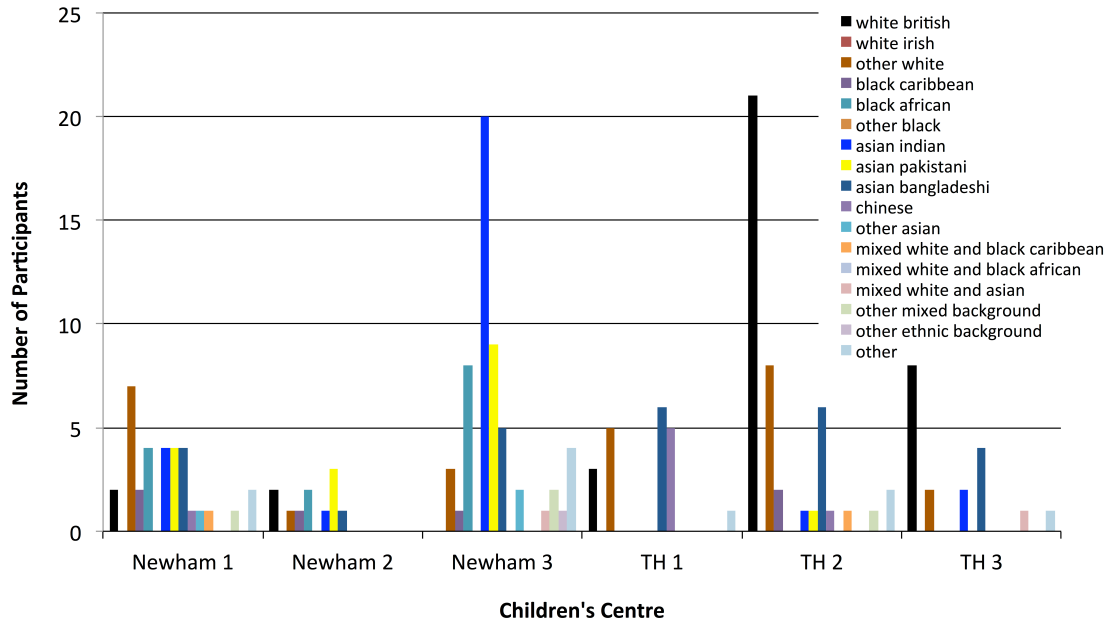
*Social Occupation Classification (UK Office for National Statistics, 2010) as: (1) higher managerial or professional, (2) intermediate occupations (3) small employers and own account workers (4) lower supervisory and technical occupations (5) routine/semi-routine and (6) long-term unemployed.

** Education bands: (1) postgraduate degree (2) degree (university) (3) F.E. qualification (4) A-levels, (5) GCSE (6) no formal education

The table below shows the primary and second languages of the research participants who participated in the final cohort:

Primary Language	English	58.6%	Secondary Language	No second language	28.7%
	Bengali	8.0%		English	30.5%
	Hindi/Urdu	6.9%		Bengali	5.7%
	Gujarati/Punjabi	4.0%		Gujarati/Punjabi	6.9%
	Polish	1.7%		Mandarin/Cantonese	4.6%
	Mandarin/Cantonese	1.7%		Hindi/Urdu	2.9%
	Romanian	1.1%		French	2.9%
	Bulgarian	1.1%		Spanish	2.9%
	Tamil	1.1%		German	1.1%
	Lithuanian/Latvian	1.1%		Arabic	1.1%
Other	14.7%	Other	12.7%		

The figure below shows a break-down of parent ethnicity across the six CCs we used:



Parent ethnicity across the six CCs recruited.

This information shows that all CCs attracted a highly diverse sample – but that, as each CC was located within a different community, they recruited sub-samples with different profiles of ethnicities. This reflects the many different population ‘pockets’ of ethnicity found across these two boroughs in East London and indicates that the study managed to reflect well the local diversity of each CC⁴.

Training study

In addition, we also recruited a further separate cohort of 33 11- to 12-month-old infants for the Training study. Of these 33 enrolled infants, 8 dropped out after one session and a further 2 after 2 sessions. Reasons for drop-out included equipment failure, sickness in the family, and lack of parental engagement in the programme. The final sample, therefore, constituted 23 infants. The table below shows the demographic profile of the final sample.

Of the 23 infants completed the Training study, 10 were in the training group and 13 in the control group. Gender ratios were 5 male/5 female for the training group, and 5 male/8 female for the control group. The average ages were 347 (SD=14.3) and 362 (SD=17.6) days for the trained and control groups respectively.

⁴ The data is available at the latest Census 2011 data for individual wards. Census data for Tower Hamlets can be found here

http://www.towerhamlets.gov.uk/Documents/Borough_statistics/Ward_profiles/Census-2011/RB-Census2011-Ethnicity-2013-01.pdf

And for Newham

<http://www.newham.info/dataviews/view?viewId=576>

Demographic details for our training study participants. Results show mean values for key demographic details for our screening study participants. Results in brackets show the standard deviations, indicating the variance in these values across the population sampled.

Measure	
N	23
Age in days	352 (14.8)
Gender (% female/male)	57%/43%
Infant ethnicity (% white.non-white)	21.7%/71.3%
Mean family income	£22,911 (27838)
Median family income	£10,702
Range of income	£0-10,6250
Gestational age in weeks	38.7 (1.7)
Birth weight in grams	3100.5 (573.8)
Mother's education level ^a	1: 9.1%
	2: 36.4%
	3: 27.3%
	4: 0%
	5: 13.6%
	6: 13.6%
Father's education level ^a	1: 5.0%
	2: 55.0%
	3: 25.0%
	4: 5.0%
	5: 10.0%
	6: 0%

^a Parental education: (1) – post-graduate; (2) – higher education degree; (3) – further education; (4) - high school A-levels; (5) – GCSE; (6) no qualification.

Details of testing facilities across CCs

One of the potential challenges of testing in CCs is the potential variability of available facilities. Testing was conducted in rooms varying in size, background noise, lighting, temperature, and visual distraction. The rooms were normally employed for group activities (minimum 4x5 meters), or as consulting rooms by health visitors or midwives (on average 3x3 meters).

The background noise in most rooms was low, apart from one centre located next to a busy road. Staff members understood the importance of noise levels and were very cooperative in keeping them to a minimum in the corridor during testing sessions. We measured ambient sound levels in 7% of sessions at a position equivalent to that of the infant's head to the

screen. The average overall sound level in the testing rooms was 49.5dB, ranging from 40.2 to 55.1dB.

Any obvious visual distractions (colourful posters etc.) were moved out of sight. In three CCs, the amount of daylight entering the room was not easy to control. Lighting conditions were therefore slightly different in each centre. The figure below contains two photos illustrating the range of testing facilities available at the various sites.



Pictures illustrating the testing set-ups used at two CCs

User feedback on testing sessions in the Screening study

Following completion of their participation in the Screening study, all participating parents were asked to give feedback on the session. Their answers to the questions presented are shown in the table below.

These results, documented above, were consistent with our expectations: we did not expect parents to radically change how they thought about their baby merely following a 1/2-hour assessment session, but we did expect them to change to some extent their understanding of what kinds of things their baby was interested in and capable of doing, even at such a young age (e.g. attention shifting, deciding what to observe). Particularly noteworthy is the fact that parents of lower SES considered the session more important and influential on their knowledge of their baby. Unemployed mothers or those with manual jobs more often reported that it very much changed their understanding compared to employed mothers with more skilled jobs (Chi-squared = 26.89, $p = .001$). Similar differences emerged for fathers with routine jobs or long-term unemployed compared to working fathers (Chi-squared = 18.3, $p = .019$).

Results of questionnaire examining parents' satisfaction with participation in the Screening study, broken down by maternal SES

		% of parents responding (n = 174)				
		1 – not at all; 2 – a little; 3 – neutral; 4 – quite a lot; 5 - very				
		1	2	3	4	5
Q1. How interesting did you find this session?	Overall	0	0.6	2.3	26.6	70.5
	SES grp 1 & 2	0	0	1.4	31.5	67.1
	SES grp 3	0	1.0	3.0	23.0	73.0
Q2. How much did you enjoy the session?	Overall	0	0.6	7.5	37.6	54.3
	SES grp 1 & 2	0	0	9.6	38.4	52.0
	SES grp 3	0	1.0	6.0	37.0	56.0
Q3. How much has this session changed the way you understand your baby?	Overall	1	2	3	4	5
	SES grp 1 & 2	5.4	6.8	37.0	48.0	2.8
	SES grp 3	2.0	14.0	24.0	40.0	20.0
Q4. How much has this session changed the way you think about your baby?	Overall	1	2	3	4	5
	SES grp 1 & 2	36.4	11.0	23.7	21.4	7.7
	SES grp 3	39.6	9.6	27.4	22.0	1.4
	SES grp 3	34.0	12.0	21.0	21.0	12.0

SEC classifications (1) – higher managerial and professional occupations; (2) – intermediate occupations; (3) – routine and manual occupations or long-term unemployed.

9. Eye-tracking tasks

For the Screening study, we used adapted versions of tasks that are widely in use in other projects around the world that track early cognitive development in infants. We selected these five ‘candidate’ tasks in order to assess whether they might be useful for identifying potential individual differences in early social attention and communication in non-lab settings. SES has been associated with differences in the quality of early mother-infant interactions, which may also be associated with differences in attention to faces (Gliga et al., 2009), and in the emergence of differences in joint attention behaviours, particularly gaze monitoring (Elsabbagh et al., 2012), as well as differences in audio-visual speech integration and auditory discrimination (Guiraud et al., 2012). The following tasks measure parameters of social attention such as attention to faces, eye gaze, joint attention behaviours, and gaze monitoring. They also examine audio-visual speech integration and auditory discrimination which are precursors for successful language development.

Screening study

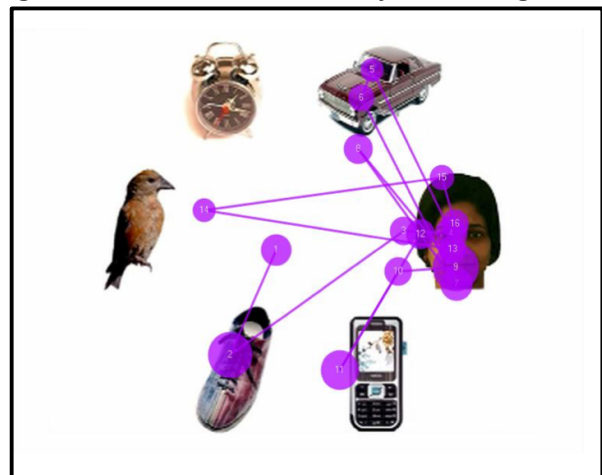
Assessing early sensitivity to social cues.

Task 1: Focus on faces (‘Pop-out’)

In this task, infants are presented with arrays of images of different classes of objects arranged in a circle. In half the trials one of the images is a face. The aim is to assess the extent to which infants show a preference for looking at faces over other classes of objects (birds, cars, shoes, etc.).

Measures of individual differences in face ‘pop-out’ include the number of looks, duration of first look, and total looking to the face compared to objects over trials.

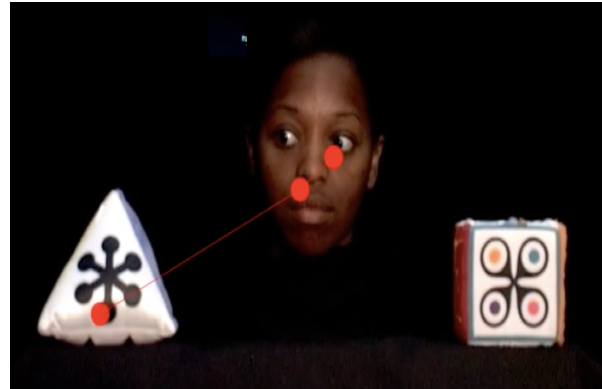
Group differences have been found in measures of pop-out between infants with and without autism (Gliga et al., 2009; see also Frank, Amso & Johnson, 2014; and Frank, Vul & Johnson, 2009). In our version, we adapted the task for use with a diverse population by including a wider variety of ethnicities of faces (Ballieux et al., 2013).



A screenshot from the ‘pop-out’ task. Purple areas show the gaze locations of the infant.

Task 2: Eye-Gaze following

From the age of 6 months, infants increasingly use the direction of a person's gaze as a cue for looking towards objects of attention (Senju & Csibra, 2008), and treat gaze references as cues for learning new words (e.g. Gliga & Csibra, 2009; see also Gillespie-Lynch et al., 2013). Differences in infant sensitivity to dynamic eye gaze have been associated with later emerging autism (Elsabbagh et al., 2012).



In this task, we measured the frequency of orienting responses towards the location of an object congruent with the direction of gaze, either to the left or right, shown by a face on a video screen. Again, we adapted this task to be appropriate for more diverse samples by including a range of ethnicities of faces.

A screenshot from the gaze following task. Red shows the gaze locations of the infant.

Task 3: Viewing a social interaction

Short (30 seconds) video clips showing talking and interacting people were presented to measure infants' orienting to social cues in naturalistic settings as well as tracking of interaction partners.

The analysis of fixation distributions (that is, how long and often eye gaze is fixed on different parts of the image or video) allows us to study the allocation of attention to the eyes and mouth and other sources of information in a display (Võ et al., 2012). Individual differences in allocation of attention to these naturalistic scenes can predict later social and cognitive difficulties (Wass & Smith, 2014).



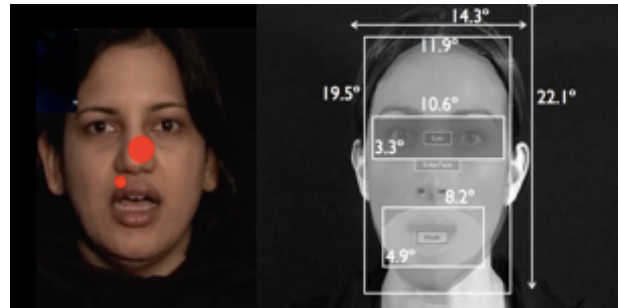
A screenshot from the movie 'Charlie bit my finger', used in Task 3

Assessing early sensitivity to speech and phonemes

Task 4: Audio-visual speech integration (AVSI)

This task assessed infants' expectations of the relationship between pronounced speech sounds and expected lip movements. We used an eye-tracking version (Tomalski et al., 2012) of an audio-visual speech integration task developed by Kushnerenko et al. (2008).

We adapted this task for more diverse samples by including a range of ethnicities of faces (Moore et al., 2014). Infants were presented with four types of videos: 2 congruent videos where the auditory track matches the seen articulatory lip movements (using sounds /ba/ and /ga/) and 2 incongruent videos (visual /ba/ dubbed onto auditory /ga/ and vice versa) along with a silent face control condition.



*Left - a screenshot from the AVSI task.
Right – the areas used for the Area of Interest coding*

Looking times to the eyes and mouth at 6-9 months of age in this task have been shown to be predictors of receptive language development in toddlers and found to be associated with distinctive patterns of brain activity during AVSI (Kushnerenko et al., 2013a,b; also see Lewkowicz & Hansen-Tift, 2012). In addition, infants at risk for developing autism show atypical face scanning during audio-visual integration (Guiraud et al., 2012).

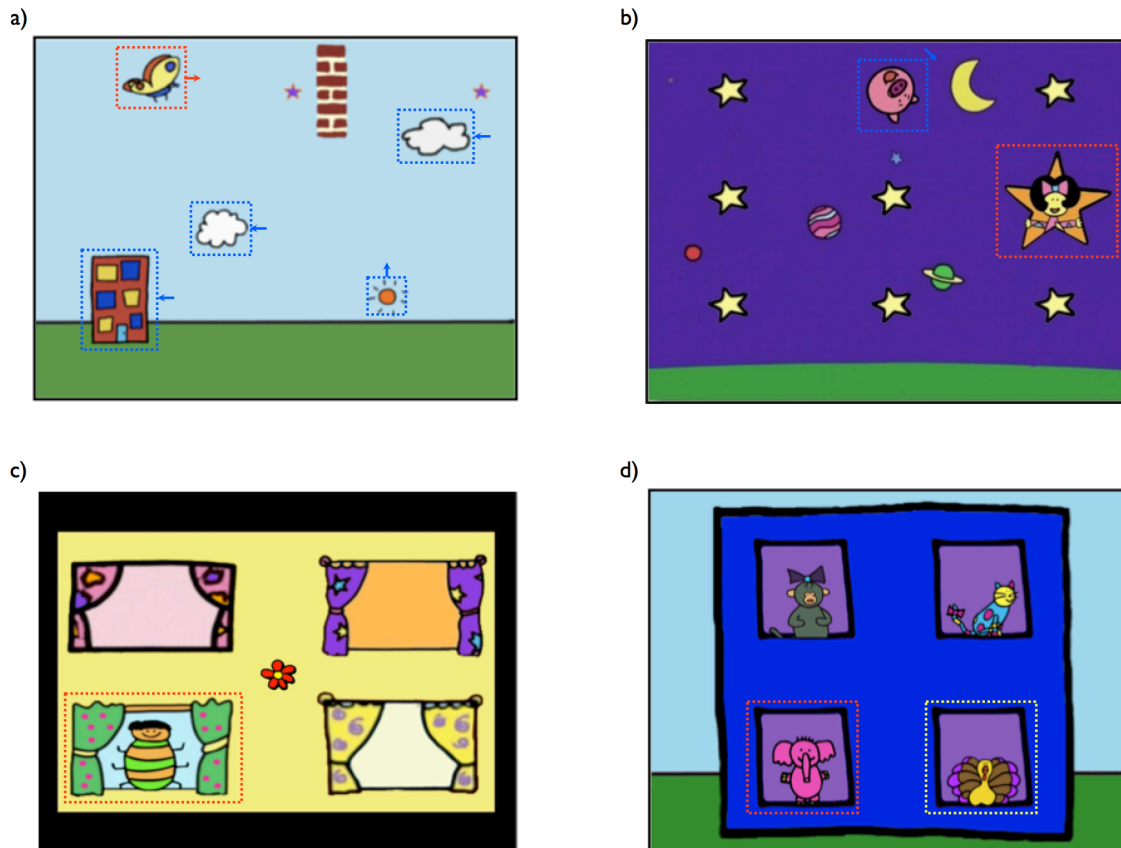
Task 5: Vowel discrimination task

A preferential listening procedure (modelled after Polka et al., 2008; Mattock et al., 2008) was used to test the discrimination of two vowels embedded in a word ('dog' vs. 'dug' and 'bet' vs. 'bat'), while infants saw a picture of a mobile phone on the screen. Infants were familiarised with one word presented repeatedly for 30 seconds and then were presented with two test trials – one with the familiarised word only, and another with the novel word presented between instances of the familiarised one. Preference (longer looking times) for the novel vowel/word was treated as an indication of vowel discrimination. The reason for including this task was to assess whether delays in the emergence of vowel discrimination may predict later language difficulties.

Training Study

Training tasks

The training study used an identical set of training stimuli to those used in previously published research with high-SES children (Wass et al., 2011). The following four training tasks were included:



Screenshots from the four training tasks used. a) Butterfly Task; b) Stars Task; c) Windows Task; d) Suspects Task.

Task 1: Butterfly

The butterfly (indicated in red) scrolled from left to right as long as the child looked directly at it, with static and moving (indicated in blue) distractors presented in the child's peripheral visual field. If the child looked to any of the distractors, all of the distractors disappeared, and the scrolling stopped. As indicated by the rectangles, all distractors on screen were moving (in the direction indicated by the arrows) with the exception of the wall and stars, which were static.

Task 2: Stars

A target (indicated red) was presented on-screen along with static and moving distractors. Moving distractors are highlighted in blue; in the image shown only one distractor is moving, but other trials featured up to eight moving distractors. If the child looked to the target within a time window, they received an audio-visual reward. Both target and distractors changed between trials.

Task 3: Windows

A target (indicated red) was presented in one location on the screen. All four windows then closed and fixation target (the red flower) appeared for a variable inter-stimulus interval. After the fixation target disappeared, a look back to the cued window triggered an audio-visual reward (a cartoon animation).

Task 4: Suspects

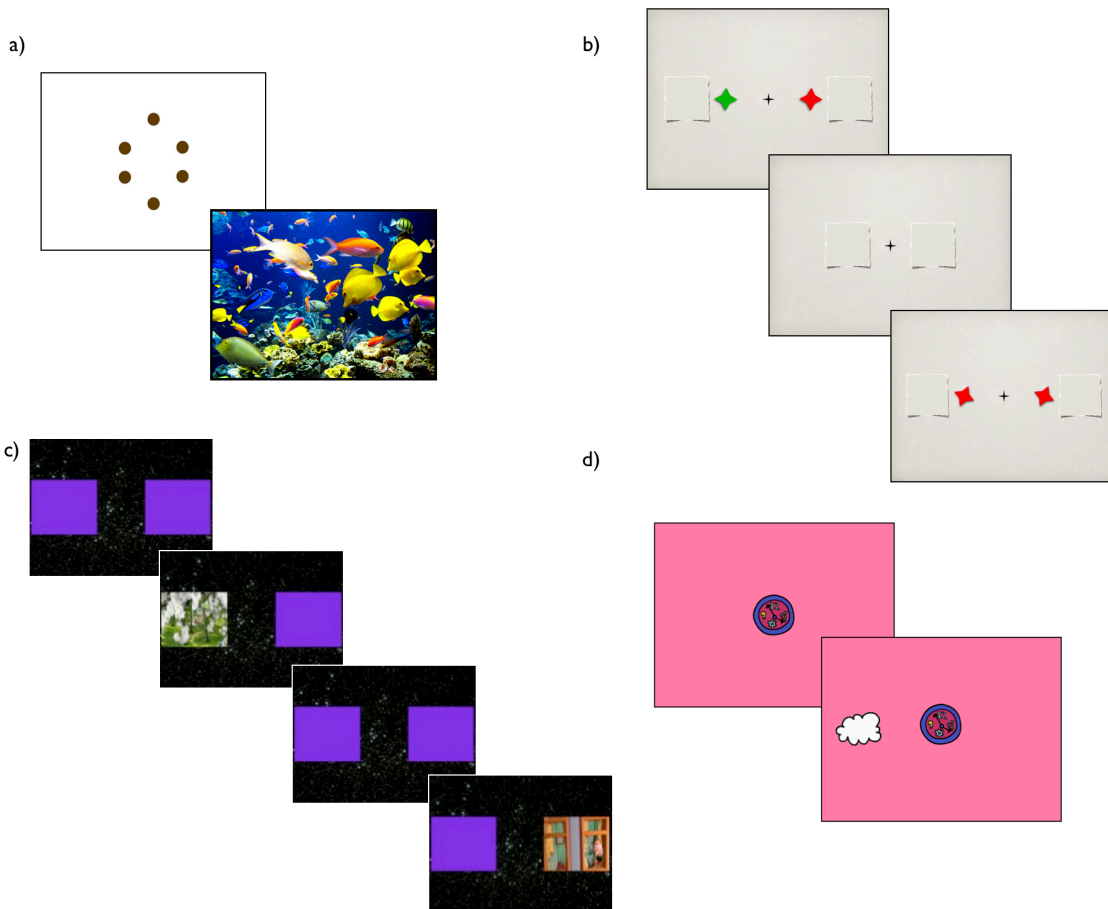
A target (indicated red) was presented along with a range of distractors. If the child looked to the target within a time window, they received an audio-visual reward. Once per block of 12 trials the target changed. Targets from the previous block (indicated yellow) were presented concurrently with the current target, as distractors.

Pre- and post-test assessment tasks

In order to assess transfer of training effects, the following tasks were presented to all participating infants before and after their completion of the intervention. The tasks were presented interleaved with one another in order, in a battery that lasted approximately 20 minutes in total. In order to maintain engagement during testing, a number of short clips from TV programmes were also presented between experimental blocks.

Task 1: Sustained Attention

Four different still images were presented: two per block in two blocks. Each block contained one of two 'interesting' images (i.e. attractive, detailed images of flowers and fish) and one of two 'boring' images (i.e. low-detail, monochrome outlines of a diamond and a cross). Trials commenced once the baby had fixated a central target. Trials ended when the baby had looked away from the screen for 1 second, as judged by an experimenter, or when 15 seconds had elapsed. At the end of each trial, a fixation target and brief auditory stimulus (<1 second) were presented. If the baby fixated the target, the next trial started immediately; if not, a sequence of different fixation targets and auditory attention getters was repeated. Stimuli were re-presented until: i) two successive looks were less than 50% of the longest unbroken look so far, ii) eight successive looks had taken place without reaching the aforementioned criterion, or iii) the total presentation length exceeded 120 seconds.



Screenshots from the four pre- and post-test assessment tasks administered in the training study. a) Examples of the stimuli in the Sustained Attention task: ‘Boring’ (top) and ‘Interesting’ (bottom) stimuli. b) Schematic showing the screen layout for a trial in the Short-Term Memory task. c) Schematic showing the Cognitive Control task. d) Illustration of screen layout for the overlap condition Gap-Overlap task. In the baseline condition, the central target disappeared as the lateral target was presented.

Task 2: Short-term memory

Short-term memory (STM) was assessed in two blocks, each consisting of seven trials. In each trial, two targets (each subtending 5°) were presented for 6500 milliseconds (ms). Two separate occluders then appeared and covered the objects for 2500 ms. The occluders then revealed the objects; one of the objects had changed colour. The two objects were then presented for 7000 ms. The dependent variable was whether the first look was to the side where the colour of the target had changed following the occlusion period, or to the side where the target was the same colour as prior to the occlusion (following Kaldy & Blaser, 2013). The location of the change side varied between trials.

Task 3: Cognitive control

This task was presented in two blocks, each lasting 18 trials. After fixating a central target (a cartoon flower subtending 4.5° of visual angle from the perspective of the infant), the trial commenced following a 300 ms delay. Two blank rectangles ($10.8^\circ \times 9^\circ$ of visual angle) were presented left and right, concurrently with an auditory stimulus for 2000 ms (the anticipatory window). A visual reward animation (lasting 4000 ms) then appeared on one side (in either the left or right rectangle) for nine trials in a row (the pre-switch phase) before swapping sides for the next nine trials (the post-switch phase). If the participant correctly anticipated the presentation of the reward (defined as a saccade beginning between 300 and 2300 ms after trial onset and subject to a minimum look duration of 400 ms), then the visual reward stimulus appeared immediately. The outcome measure was the proportion of correct anticipatory looks.

Task 4: Gap-overlap

This task was presented in three blocks. The first two blocks lasted 20 trials; the third continued until either enough valid trials had been collected (12 usable trials per condition) or 80 trials had been presented, or the child became inattentive. After fixating a central target (CT, a cartoon flower, 4.5° of visual angle from the perspective of the infant), following a variable Inter-Stimulus Interval (see below) a lateral target (LT, a cartoon cloud, 3° of visual angle from the perspective of the infant) was presented to the left or right; when the participant fixated the LT they received a brief animation as an audio-visual reward. Three conditions were presented: Gap – CT disappears 200 ms before LT appears; Baseline – CT disappears concurrently with LT appearance; Overlap – CT remains onscreen with LT appearance. The order of trials was randomised between conditions. The reaction time (RT) was the time elapsed between LT appearance and the reported position of gaze leaving the central fixation area (a 9° box around the CT). Disengagement latencies were calculated as the participant's average reaction time in the overlap condition subtracted from their average reaction time in the baseline condition (following Elsabbagh et al., 2008).

Quality of eye-tracking data

One of the key issues for determining the effectiveness of using eye-tracking for screening purposes in CCs is the extent to which the data produced is near to the quality obtained in a lab setting.

To evaluate the quality of eye-tracking data obtained, we compared the data on the AVSI task from the Screening study, for which we had also collected data in a laboratory situation as part of an earlier study and on the AVSI task from the Screening study, carried out in CCs. The same equipment and experimental paradigm were employed in both studies (see Tomalski et al., 2013b; Ballieux et al., 2015).

Comparison of results in laboratory and CC settings

	ELAS laboratory study	CC Screening study
Proportion of participants completing task	84.2%	82.8%
Proportion of valid trials per participant (SD)	94.4% (9.39)	88.8% (16.43)
Proportion of time points at which the eye-tracker collected valid gaze data (SD)	76.5% (16.39)	60.5% (21.61)

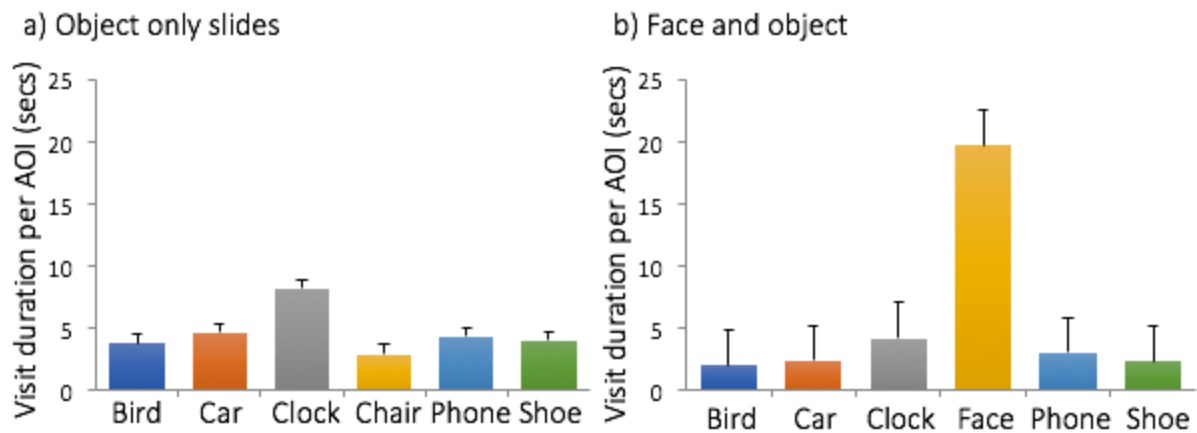
Comparing performance on the same audio-visual speech integration (AVSI) task in two kinds of settings, lab versus CC, did not lead to an increase in participant dropout, nor to a reduction in the proportion of valid trials per participant. Both datasets were comparable in this regard. However, one difference was that testing in CCs led to a lower proportion of time points at which the eye-tracker recorded valid gaze data (the TobiiT120 eye-tracker was sampling gaze position at 120Hz; proportion of valid samples M=60.5% versus ELAS study M=76.5%), and a corresponding increased variability within the sample (the ELAS study SD=16.39, range 26-97%; TALBY study SD=21.61 and range 0-99%).

We conclude that testing in a CC setting does not significantly alter infant engagement with the eye-tracking tasks nor completion rates, but that variable conditions (e.g. light levels, noise, general distractions) and greater sample variability may somewhat reduce data integrity.

10. Screening study - infant performance on eye-tracking tasks

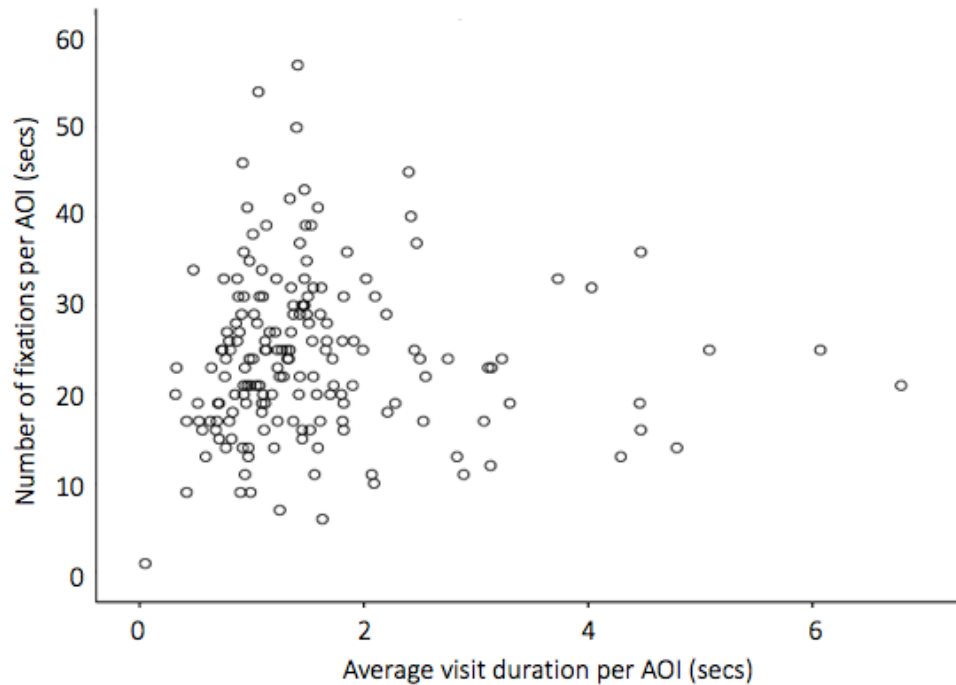
Face pop-out effect

Based on previous work (discussed above) we hypothesised that, for the majority of infants, the first fixation would be more likely to be towards the face, but that some infants may show differences in the total amount of time looking at the face, may show reduced or increased fixation durations, and different visitation-foraging patterns that could reveal sub-groups of infants at risk for later difficulties. The basic face pop-out effect was clearly evident in our cohort (see figure below) indicating that the tasks obtained the expected result when conducted in CCs. In those slides where only objects were presented, we found a small preference for looking towards an image of a clock.



Visit duration to each Area of Interest (AOI) in seconds for a) object only slides and b) face and object slides.

Although all infants looked longer at the face than other objects in the arrays, the task revealed a range of individual differences in measures that may be early indicators of potential problems. Indicators of potential differences are the average duration of each fixation or visit to the face and the total number of fixations and visits. Previous studies have suggested that those infants who make many shorter or longer visits or fixations could be at risk. Small sub-groups of infants can be identified in our sample (see figure, below) that made longer average visits and those who made larger numbers of fixations. These infants may be at risk in the longer term.



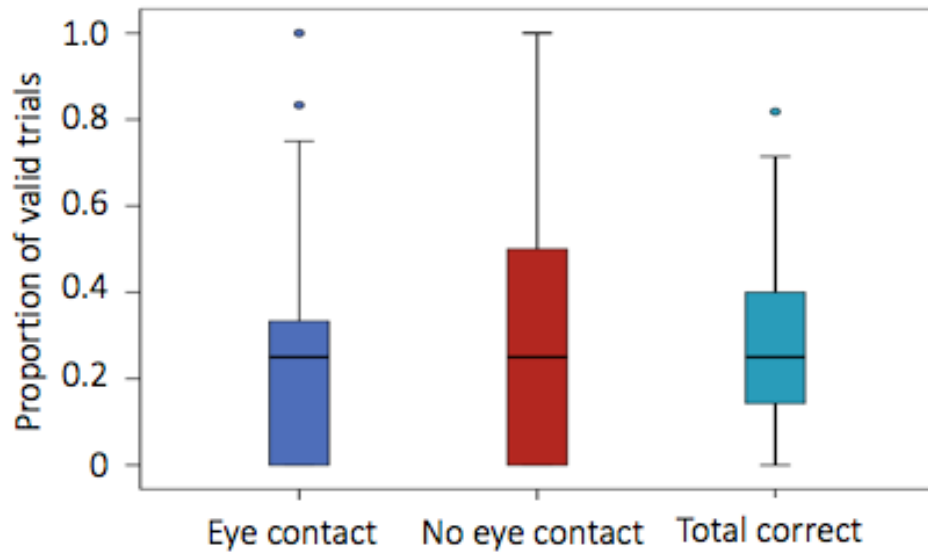
Scatterplot showing the relationship between average visit duration per Area of Interest (AOI) and the number of fixations per AOI. This figure illustrates the variability observed across different individual infants that we tested.

Audio-visual speech integration

Consistent with previous studies, we found that infants showed strong patterns of looking to the mouth and the eyes in dynamic speaking faces across the different conditions of the AVSI task. We also successfully replicated other effects observed in previous studies, such as the fact that infants' looking behavior discriminated between congruent of auditory and visual cues whilst looking at a person speaking and incongruent matches, a phenomenon known as the McGurk effect (McGurk & MacDonald, 1976).

Eye-Gaze following

The condition in the gaze following task proved to be difficult for infants of this age with infants following gaze only around 25% of trials (see figure, below). Infants were marginally more likely to follow a gaze if preceded by eye contact than not. This revealed individual differences that relate to SES and outcomes at age 2 (see section 12, Eye Gaze Task).

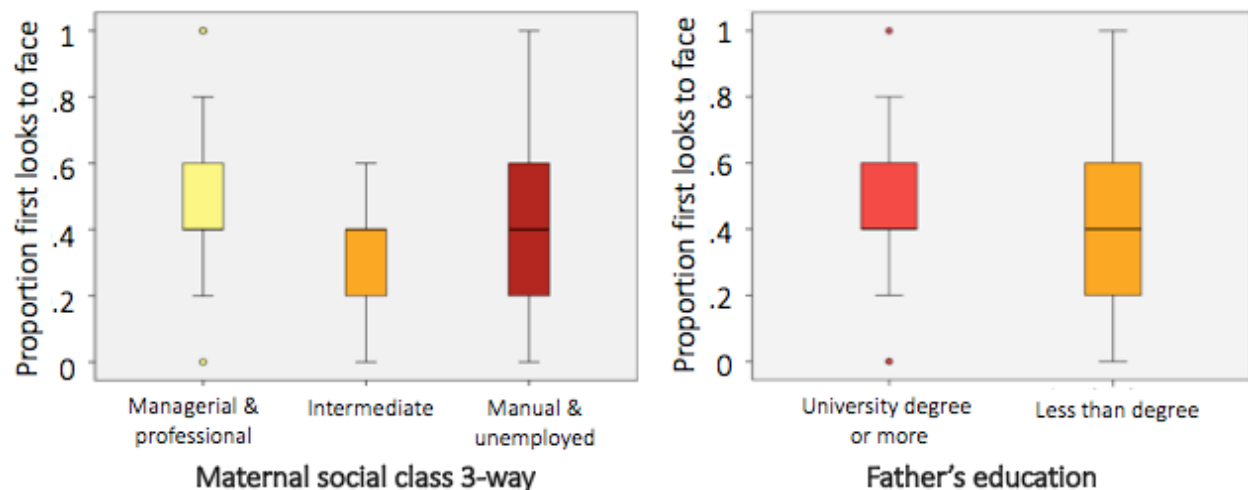


Proportion of valid trials by condition for the gaze following task. Blue dots indicate datapoints that were identified as outliers following the standard criteria (as described in Barnett & Lewis, 1974)

11. Screening study (cont.) - associations of tasks performance with socio-economic status

Face pop-put

Our analyses revealed that differences are found in the pop-out task in performance by SES (see figures, below). High-SES groups showing a reduced range in proportions of first looks on face, and low SES groups showing a wider range of responses. This suggests that the task may be useful for identifying sub-groups within at-risk populations of lower-SES groups. Significant effects of father's education were also noted. These results suggest that effects of SES are discernible, even by the age range of 6-7 months tested in the study, on infants' processing of social stimuli.



Proportion of infants' first looks to face subdivided by maternal social class (left) and father's education (right)

Audio-visual speech integration

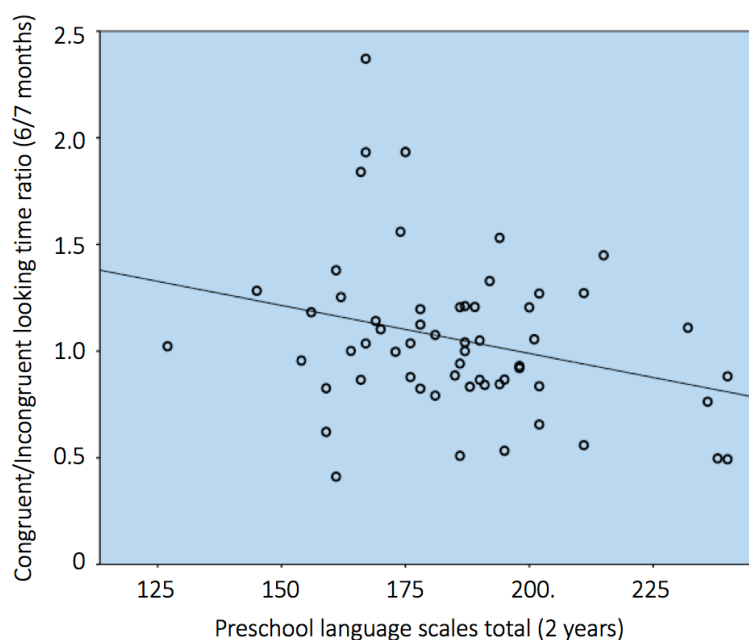
The AVSI task also identified small associations between SES measures and the ratio of looking time observed for congruous relative to incongruous visual stimuli, for both household income ($R^2 = -.15$) and maternal occupational level ($R^2 = -.18$). This suggests that, even by the age range of 6-7 months tested in the study, there are small effects of SES discernible in infants' processing of language and speech.

12. Screening study (cont.) - associations with language outcomes in toddlers

We have, in a separate project not otherwise described in this report, followed up the infants who participated in the TALBY project at a separate assessment, conducted when they were two years of age. The data we have collected has identified significant associations between infants' performance on the eye-tracking tasks described above, administered at 6-7 months of age, and children's' emerging language and communication outcomes, measured with Preschool Language Scales PLS-4 inventory and Communicative Developmental Inventories (CDI) respectively at two years. While these effects are small, they do suggest that this approach may offer some additional diagnostic tool for those most at risk.

AVSI task

A significant relationship was observed between infants' ability to differentiate between congruent and incongruent auditory and visual cues whilst looking at a person speaking at 6-7 months and their performance on Pre-school Language Scales at age 2 ($R^2=0.29$, $p=.03$) (see figure). This suggests that aspects of infants' early ability to process speech information during infancy can predict their later language outcomes.

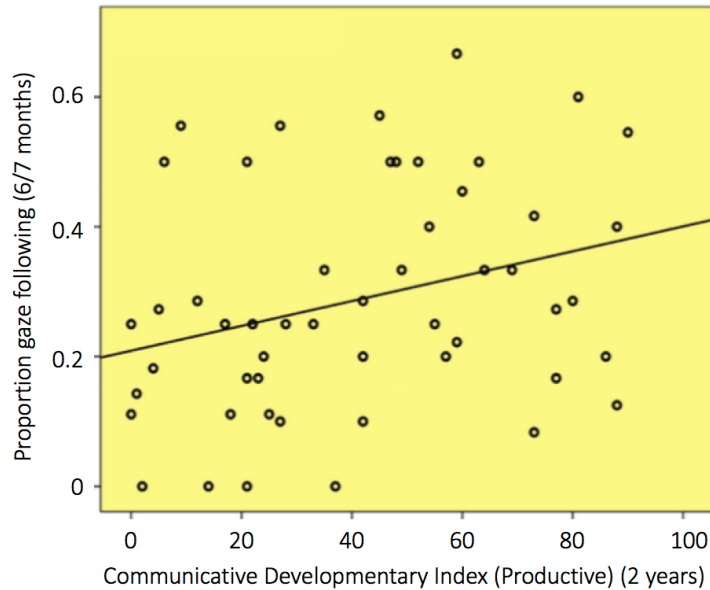


Scatterplot showing the relationship between processing of speech sounds at 6/7 months, as assessed in the TALBY study, and children's' later language performance at 2 years.

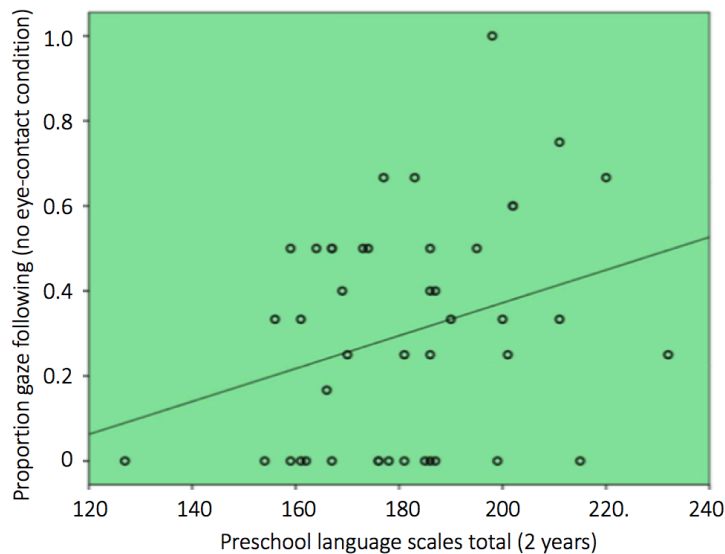
Eye-Gaze following task

The eye-gaze following task, administered as part of the TALBY project at 6-7 months, also significantly predicted infants' subsequent language outcomes when assessed at a follow-up assessment at two years (see figure, below). Infants' likelihood of following the gaze of the actor during infancy correlated with their productive vocabulary on the Communicative

Development Inventory as assessed at two years ($R^2=0.30$, $p=.03$). Infants' likelihood of following gaze after no eye-contact also predicted children's subsequent scores on the Pre-School Language scales ($R^2=0.29$, $p=.05$). These results further confirm our conclusions that the CC assessments administered to infants as part of the TALBY project can successfully predict children's subsequent language development outcomes.



Scatterplot illustrating the relationship observed between infants' Eye-Gaze following observed at 6/7 months and later productive language development

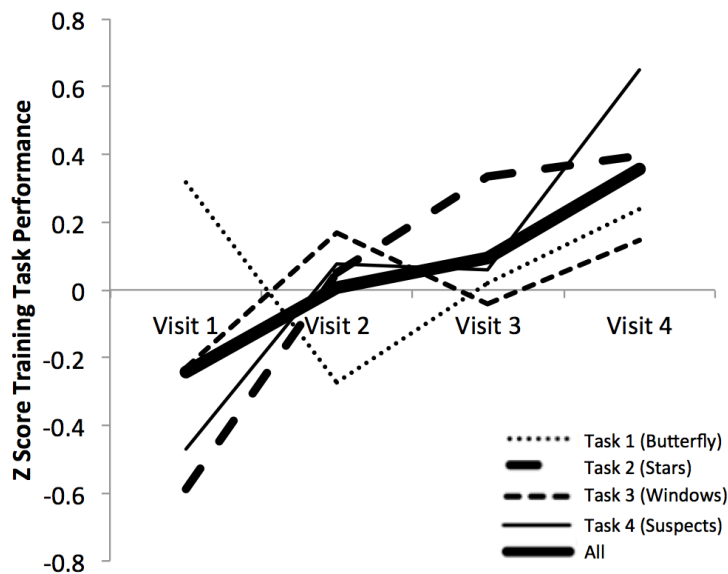


Scatterplot illustrating a further relationship observed between infants' Eye-Gaze following observed at 6/7 months and later language development

13. Training study - effectiveness of training tasks

Within-task improvements during the training phase

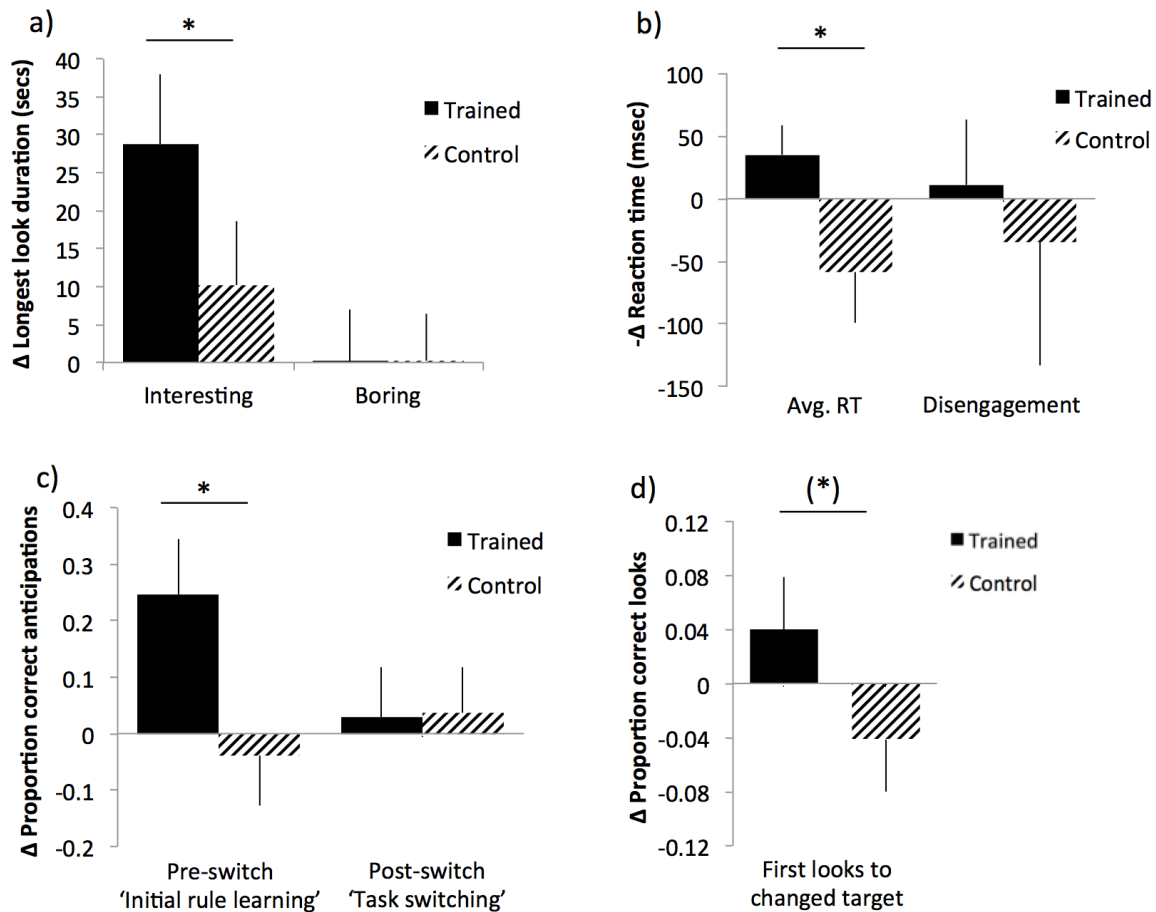
First, we assessed whether changes in performance on the training tasks were observed across the four training sessions conducted. The figure below demonstrates how training task performance changed across the four visits in the current study. In order to assess the significance of these changes, linear regression lines were calculated based on change in performance across the four training sessions. The gradients of these lines were positive for eight out of ten infants, suggesting that they improved across the training sessions. A t-test analysis suggested that this result differed significantly from chance ($t(9)=2.25$, $p=.025$, one-tailed). This change was consistent with that predicted, based on previous research (Wass, et al., 2011). This finding established a measurable effect of training, and suggests that infants' attention can be trained within the context of CC visits with infants from this demographic population.



Change in performance across the four training visits. The performance at each training task was compared to that individual's average performance across the entire training phase by calculating a z-score. In this way, we identified significant improvements in task performance across the four visits.

Impact of training on pre-and post-tests

In order to examine whether the training led to improvements in other aspects of attention control that had not been directly trained, a number of other assessments of infants' capacity for voluntary, self-directed control of attention were administered before and after the intervention phase to all participating infants (see section 9, above). The results of these assessments are presented below.



Bar charts show change (Δ) scores on pre-post assessments, calculated from the marginal means. a) Sustained attention. b) Gap-overlap task. (Because the valence of the predicted and observed change was negative, $-\Delta$ scores are presented for this measure, for ease of comparison.) c) Cognitive control task. d) Short-term memory task. Stars indicate the significance of the training effects observed. * - $p < .05$, (*) - $p < .10$.

We found that, after training, the trained group showed a significant increase relative to the control group in sustained attention to 'Interesting' targets (see Figure a), above). However, we observed no change after training in looking time to 'Boring' targets. This suggests that the effect of training was not simply an overall increase in looking time to the screen. Rather, it is

consistent with a model suggesting that training attention leads to increases in infants' capacity to exercise voluntary, selective control over the what they pay attention to.

We also found that average reaction time on the gap-overlap task was significantly improved following training (see Figure b), above). By contrast, no changes were found on disengaging visual attention. However, this may have been to do with the high rates of data drop-out on this task, due to low eye-tracking data quality. Of note, substantially longer reaction times were obtained on this task compared to lab-based versions of the same task, a pattern that is predicted by lower data quality (Leppänen, et al., 2014; Wass., et al., 2014).

We also observed improvements on a task assessing anticipatory saccades during rule-learning (see Figure c). Changes in performance were observed during the initial rule learning phase only; this was slightly unexpected, as previous findings (Wass et al., 2011) had suggested that training improvements would be observed on both phases of the task. Finally, we observed trend-level improvements on a task assessing short-term memory (see Figure d). This is in contrast to the previous study (Wass, 2011), which used a different assessment, in which no improvements were found. In separate investigations (Wass, 2011) we found test-retest reliability of the task that we previously used to be very low, and it may be that memory training effects can be detected when a more sensitive measurement paradigm is used.

In conclusion, these results are encouraging, and demonstrate that early attention can be trained in high-risk infants from low SES backgrounds, working with CC settings. The results obtained are encouragingly similar to those obtained in previous lab-based studies, suggesting the replicability of this work.

14. Conclusions

Using eye-tracking to screen infants in CC settings

Our key findings from the Screening study were as follows:

- CCs offer an effective context for recruiting and assessing large and highly diverse samples of infants from areas of high deprivation.
- CC staff are receptive to learning to use eye-tracking equipment and delivering assessments, but only if staffing levels and time are sufficient.
- Playing back a video of an infant's looking pattern is an effective way of engaging parents with the assessment of their infants, and of opening up a discussion about the importance of attention in infants' development.
- The sessions were effective in changing how parents reported what they understand and thought about their babies. This was most effective for parents with lower socio-economic occupations.
- The eye-tracking technique proved to be convenient and effective in collecting research data in CCs. We were able to collect data that is of reasonable quality and comparable to data obtained in laboratory settings.
- Our eye-tracking assessments provided some indicators that differences in infants' processing of visual and auditory information contingent on SES are already discernible by 6/7 months of age. However, the size of these differences was relatively small.
- In addition, we conducted a separate assessment, in which we followed up the infants assessed in the TALBY study when they were 2 years of age. Our analyses identified a number of significant associations between infants' performance on the eye-tracking tasks at 6/7 months and their language outcomes at 2 years. This suggests that the CC assessments that we administered can successfully predict children's subsequent language development outcomes.

As a result of these findings, we can conclude that eye-tracking offers a feasible and effective method for measuring early infant cognitive development within community settings. Eye-tracking research has considerable potential for use as an early screening tool to identify infants at elevated risk of subsequent atypical development. Particularly encouraging are the findings from our follow-up study which suggested that infants' performance on these early infant eye-tracking measures significantly predicted later language outcomes during early childhood.

From a policy perspective, early identification of infants who are developing atypically is considered vital, insofar as it allows for interventions to be administered at as early stage as possible. Early interventions are widely considered to be a more cost-effective way of remediating problems than interventions administered later in development (Heckman, 2006). Investigating in early screening and intervention may, therefore, offer a more cost-effective way of remediating problems than waiting until problems have developed greater severity later on, and attempting to remediate them then. Other research has also suggested that this type of early screening work should be concentrated on infants from low-SES backgrounds, for whom the risk of atypical development in terms both of academic and long-term mental health outcomes is most severe (Businelle, 2013).

Using eye-tracking to train infants' attention in CC settings

Our key findings from the Training study were as follows:

- Eye-tracking can be used to train infants' attention within CC settings, with infants from low-SES backgrounds.
- The training effects observed were consistent with those observed on previous, lab-based studies with high-SES infants.
- However, participant drop-out was a problem, with 10 of the 33 families recruited for the study failing to complete. Future work should investigate whether it is possible to make this intervention less onerous for participating parents, such as by conducting training sessions within participants' homes as a complement to CC visits.

Overall, our results provided promising evidence for the feasibility and efficacy of an early intervention that targets infants' capacity to exercise voluntary control over the focus of their attention. In future, this work offers a potential new early intervention tool to target infants identified as particularly high-risk via early screening. These two methods can be used to complement one another, to provide more sensitive and cost-effective means for understanding early development in infants from low-SES backgrounds, who are known to be at the most elevated risk of adverse long-term outcomes.

15. Publications and presentations from the study to date

- Ballieux, H., Tomalski, P., Kushnerenko, E., Karmiloff-Smith, A., Johnson, M.H., & Moore, D.G. (2013). Eye-tracking in the Community: Relations Between Infant Attention to Social Cues and their Socio-economic, Ethnic, and Language Background. Poster presented at the *Biennial meeting of the Society for Research in Child Development, Seattle, US*.
- Ballieux, H., Tomalski, P., Kushnerenko, E., Johnson, M. H., Karmiloff-Smith, A., and Moore, D. G. (2015), Feasibility of Undertaking Off-Site Infant Eye-Tracking Assessments of Neuro-Cognitive Functioning in Early-Intervention Centres. *Infant and Child Development* 25 (1), 95-113 doi: [10.1002/icd.1914](https://doi.org/10.1002/icd.1914).
- Ballieux, H., Wass, S. V., Tomalski, P., Kushnerenko, E., Karmiloff-Smith, A., Johnson, M. H., & Moore, D. G. (2016). Applying gaze-contingent training within community settings to infants from diverse SES backgrounds. *Journal of Applied Developmental Psychology*, 43, 8-17.
- Ballieux, H., Tomalski, P., Karmiloff-Smith, A., Johnson, M., Kushnerenko, E. & Moore, D.G. (manuscript prepared) Individual differences in 6-7 month-old infants' face preferences as potential predictors of emerging language and social communication outcomes at 2 years.
- Haiko Ballieux, Derek Moore, Annette Karmiloff-Smith, Mark Johnson, Deirdre Birtles, Elena Kushnerenko, Przemyslaw Tomalski (2014) Individual Differences in Social Orienting in 6-month-olds as a Longitudinal Predictor of Language and Social Communication Outcomes at Age Two, and Their Relationship to SES *International Conference on Infant Studies, Berlin*.
- Moore, D.G. Tomalski, P. Ballieux, H. Birtles, D. Johnson, M.H. Karmiloff-Smith, A. & Kushnerenko, E. (2014) Audio-visual Speech Integration at Six Months as a Predictor of Language Outcomes at Age Two in Infants from Families Varying in Income, Occupation, Ethnicity and Language. Paper presented at: *International Conference on Infant Studies, Berlin*.
- Moore D.G., Kushnerenko E., Ballieux H., Karmiloff-Smith A., Johnson M.H. & Tomalski P. (2015) *Adapting eye-tracking paradigms to assess SES-related individual differences in six-month-old infants*, Society for Research in Child Development Biennial Meeting. Philadelphia, USA.
- Tomalski, P., Moore, D. G., Ballieux, H., Kushnerenko, E. V., Johnson, M. H., & Karmiloff-Smith, A. (2016). Separating the effects of ethnicity and socio-economic status on sleep practices of 6- to 7-month-old infants. *Learning and Individual Differences* 46 (2016) 64–69
- Tomalski P., Ballieux H., Karmiloff-Smith A., Johnson M.H., Kushnerenko E., Moore D.G. (2015). *Early predictors of language development in infants from low-SES families: a multi-ethnic eye-tracking study in the community*. Society for Research in Child Development Biennial Meeting. Philadelphia, USA.

16. References

- Aldridge, H.; Bushe, S.; Kenway, P.; MacInnes, T.; Tinson, A. London's poverty profile. Published by Trust for London & New Policy Institute; 2013. ISBN: 978-1-901373-75-4. www.londonspovertyprofile.org.uk/LPP_2013_Report_Web.pdf
- Barnett, Vic, and Toby Lewis. *Outliers in statistical data*. Wiley, 1974.
- Bayer, J. K., Hiscock, H., Hampton, A., & Wake, M. (2007). Sleep problems in young infants and maternal mental and physical health. *Journal of Paediatrics and Child Health*, 43(1-2), 66–73. doi:10.1111/j.1440-1754.2007.01005.x
- Bedford, R., Elsabbagh, M., Gliga, T., Pickles, A., Senju, A., Charman, T., ... BASIS team. (2012). Precursors to social and communication difficulties in infants at-risk for autism: gaze following and attentional engagement. *Journal of Autism and Developmental Disorders*, 42(10), 2208–18. <http://doi.org/10.1007/s10803-012-1450-y>
- Businelle, M. S., Mills, B. A., Chartier, K. G., Kendzor, D. E., Reingle, J. M., & Shuval, K. (2013). Do stressful events account for the link between socioeconomic status and mental health? *Journal of Public Health*, 36(2), 205-212.
- Department for Communities and Local Government. English indices of deprivation. 2010. ISBN: 978-1-4098-2924-9. www.gov.uk/government/publications/english-indices-of-deprivation-2010
- Gervain, J., Mehler, J., Werker, J. F., Nelson, C. a, Csibra, G., Lloyd-Fox, S., ... Aslin, R. N. (2011). Near-infrared spectroscopy: a report from the McDonnell infant methodology consortium. *DCN*, 1(1), 22–46. <http://doi.org/10.1016/j.dcn.2010.07.004>
- Guiraud, J. a, Tomalski, P., Kushnerenko, E., Ribeiro, H., Davies, K., Charman, T., ... Johnson, M. H. (2012). Atypical audiovisual speech integration in infants at risk for autism. *PloS One*, 7(5), e36428. <http://doi.org/10.1371/journal.pone.0036428>
- Hackman, D. A., Farah, M. J., & Meaney, M. J. C.-P. (2010). Socioeconomic status and the brain: mechanistic insights from human and animal research. *Nat Rev Neurosci*, 11, 651–9 ST – Socioeconomic status and the brain: me. <http://doi.org/nrn2897> [pii] 10.1038/nrn2897
- Heckman, J. J. (2006). Skill formation and the economics of investing in disadvantaged children. *Science*, 312(5782), 1900-1902.
- Kushnerenko, E., Teinonen, T., Volein, A., & Csibra, G. (2008). Electrophysiological evidence of illusory audiovisual speech percept in human infants. *Proc Natl Acad Sci U S A*, 105(32), 11442–5. <http://doi.org/10.1073/pnas.0804275105>
- Kushnerenko, E., Tomalski, P., Ballieux, H., Potton, A., Birtles, D., Frostick, C., & Moore, D. G. (2013a). Brain responses and looking behavior during audiovisual speech integration in infants predict auditory speech comprehension in the second year of life. *Frontiers in Psychology*, 4, 10.3389/fpsyg.2013.00432. <http://doi.org/10.3389/fpsyg.2013.00432>
- Kushnerenko, E., Tomalski, P., Ballieux, H., Ribeiro, H., Potton, A., Axelsson, E. L., ... Moore, D. G. (2013b). Brain responses to audiovisual speech mismatch in infants are associated with individual differences in looking behaviour. *Eur J Neurosci*, doi:10.1111/ejn.12317. <http://doi.org/10.1111/ejn.12317>

- Lewkowicz, D. J., & Hansen-Tift, A. M. C.-P. (2012). Infants deploy selective attention to the mouth of a talking face when learning speech. *Proc Natl Acad Sci U S A*, 109(5), 1431–6. <http://doi.org/1114783109> [pii] 10.1073/pnas.1114783109
- Noble, K. G., McCandliss, B. D., & Farah, M. J. (2007). Socioeconomic gradients predict individual differences in neurocognitive abilities. *Dev Sci*, 10, 464–80 ST – Socioeconomic gradients predict indiv. <http://doi.org/DESC600> [pii] 10.1111/j.1467-7687.2007.00600.x
- Noble, K. G., Norman, M. F., & Farah, M. J. (2005). Neurocognitive correlates of socioeconomic status in kindergarten children. *Dev Sci*, 8, 74–87 ST – Neurocognitive correlates of socioecon. <http://doi.org/DESC394> [pii] 10.1111/j.1467-7687.2005.00394.x
- Mattock, K., Molnar, M., Polka, L., & Burnham, D. (2008). The developmental course of lexical tone perception in the first year of life. *Cognition*, 106(3), 1367–81. <http://doi.org/10.1016/j.cognition.2007.07.002>
- McGurk, H., & MacDonald, J. (1976). Hearing lips and seeing voices. *Nature*, 264, 746–748.
- Polka, L., Rvachew, S., & Molnar, M. (2008). Speech Perception by 6-to 8-Month-Olds in the Presence of Distracting Sounds. *Infancy*, 13(5), 421–439. <http://doi.org/10.1080/15250000802329297>
- Tomalski, P., Moore, D. G., Ribeiro, H., Axelsson, E. L., Murphy, E., Karmiloff-Smith, A., ... Kushnerenko, E. (2013a). Socio-economic status and functional brain development – associations in early infancy. *Dev Sci*, 16(5), 676–87. <http://doi.org/10.1111/desc.12079>
- Tomalski, P., Ribeiro, H., Ballieux, H., Axelsson, E. L., Murphy, E., Moore, D. G., & Kushnerenko, E. (2013b). Exploring early developmental changes in face scanning patterns during the perception of audiovisual mismatch of speech cues. *European Journal of Developmental Psychology*, 10(5). <http://doi.org/10.1080/17405629.2012.728076>
- Tomalski, P., Ribeiro, H., Ballieux, H., Axelsson, E. L., Murphy, E., Moore, D. G., & Kushnerenko, E. (2012). Exploring early developmental changes in face scanning patterns during the perception of audiovisual mismatch of speech cues. *Eur J Dev Psychol*, DOI:10.1080/17405629.2012.728076. <http://doi.org/10.1080/17405629.2012.728076>
- Tomalski, P., Moore, D. G., Ballieux, H., Kushnerenko, E. V., Johnson, M. H., & Karmiloff-Smith, A. (2016). Separating the effects of ethnicity and socio-economic status on sleep practices of 6-to 7-month-old infants. *Learning and Individual Differences* 46 (2016) 64–69
- Tomalski P., Ballieux H., Karmiloff-Smith A., Johnson M.H., Kushnerenko E., Moore D.G. (2015). *Early predictors of language development in infants from low-SES families: a multi-ethnic eye-tracking study in the community*. Society for Research in Child Development Biennial Meeting. Philadelphia, USA.
- UK Office for National Statistics. (2010). Standard Occupational Classification 2010. Volume3: The National Statistics Socio economic Classification User Manual .Basingstoke: Palgrave Macmillan.
- Wass, S., Porayska-Pomsta, K., & Johnson, M. H. (2011). Training attentional control in infancy. *Current Biology* : CB, 21(18), 1543–7. <http://doi.org/10.1016/j.cub.2011.08.004>
- Wass, S. V., & Smith, T. J. (2014). Individual differences in infant oculomotor behavior during the viewing of complex naturalistic scenes. *Infancy*, 19(4), 352-384.
- Zimmerman, I., Steiner, V., & Pond, R. (2002). *Preschool Language Scale* (4th ed.). San Antonio, TX: The Psychological Corporation.