REINFORCING INFANT VOCALISATIONS THROUGH SELF-INITIATED FEEDBACK: A TOOL FOR BASIC RESEARCH AND FOR CLINICAL INTERVENTIONS

Tamar Keren-Portnoy[1], Helena Daffern[2], Rory A. DePaolis[3], Christopher M. M. Cox[1,4], Kenneth I. Brown[2], Florence A. R. Oxley[5], & Mona Kanaan[6]

Affiliations:
[1]Department of Language and Linguistic Science, University of York
[2]School of Physics, Engineering and Technology, University of York
[3]Department of Communication Sciences and Disorders, James Madison University
[4]Interacting Minds Centre, Aarhus University
[5]Department of Education, University of York
[6]Department of Health Sciences, University of York

Email addresses for correspondence: tamar.keren-portnoy@york.ac.uk

ABSTRACT

We introduce a method for reinforcing vocalisations in prelinguistic infants (ages 6-7 months) without recourse to social feedback, through a self-reinforcing app. Study 1 presents findings that show that infants (N = 60; n= 30 in the experimental group) respond to the app's reinforcement by increasing their vocalisations. Study 2 is a randomised clinical trial (data collection ongoing). Infants from low socioeconomic-status families were recruited (N = 96, n = 48 in the intervention group). Families in the intervention group use the app over 3 weeks. Infants' are followed over 9 months until age 16 months. Demographic data for the two groups will be presented. We predict that infants in the intervention group will be more linguistically, but not motorically, advanced than those in the control group by the end of the study. We discuss potential uses of this method for basic as well as clinical research and intervention.

Keywords: Vocalisation, babble, reinforcement, low SES, language development

1. INTRODUCTION

Babble is understood to equip infants with the 'toolkit' required to approach word production [1]. This paper describes a study in which we aimed to encourage babble in infants, to see if that might affect later lexical development. This approach will quantify the relative importance of babbling for typical development and highlight effective clinical interventions for infants at risk for language delay.

The claim that babble is a tool for language learning is based on two types of evidence. The first are findings showing that children's first words share many structural characteristics with their babble ([2], [3]), indicating the continuity between the two behaviours. The second are findings showing that age at consonant mastery (through babble) correlates with the age at first words: children who master consonants in their babble earlier tend to start producing words earlier ([1], [4]). As infants master consonant production through continued practice, these consonants become easily accessible, sounds that the child can target at will and produce relatively effortlessly. These sounds also become especially salient when heard in the input, as produced by others ([5], [6]). As a result, the infant notices and begins to recognise word forms which contain the sounds they are particularly adept at producing, and thus the infant can direct their attention to the meaning or social context associated with those word forms. That leads the infant to be able to produce their first words, with scaffolding of the consonantal sounds they have mastered through babble.

However, to date, the association between age at consonant mastery and at first word production has always been correlational. We have not yet been able to show that the relationship between age at consonant mastery and at the transition to word production is causal. This project aimed to find a way to show such a causal relationship. Our method was to randomly assign infants to groups, one of which will be encouraged to babble more and as a result may master consonants earlier, and the other whose babble will develop at its natural pace, with no special interference. However, it is crucial that the intervention only affects the frequency of babble, without affecting a change in the infant's social world or in the rate of interaction the infant experiences.

To achieve this, we developed an app that responds to infants' vocalisations with moving colourful shapes

that appear on an iPad screen, and remain on it for the duration of the vocalisation [7]. We reasoned that if infants could learn that their vocalisations are causing the shapes to appear, they would vocalise more in order to see more such shapes.

We now describe two studies that utilise this approach. The first (Study 1; [8]) was intended to test whether young infants can learn to use the app. The second (Study 2), which is still ongoing, is intended to test whether infants who use the app over several weeks begin to produce words earlier than those who have not used it.

2. STUDY 1

2.1 Method

Participants were 60 6.5-month-old infants. The infants in the experimental group (n = 30, 19 females, mean age 198 days) received the app described above. Each infant in the control group (n = 30, 12 females, mean age 197 days) was yoked to an infant from the experimental group, and was shown the 'film' created by the sequence of moving shapes that resulted from the experimental group infant's vocalisations.

The infants first played with a non-responsive toy for 5 minutes (non-responsive trial) while the app recorded them without being seen by them, and tallied their vocalisations. Following that, the experimental group played with the app for 5 minutes and the control group watched the videos for 5 minutes (app trial).

We predicted that the infants in the experimental group would increase their vocalisations more when interacting with the app than would the infants in the control group who interacted with a non-responsive film.

2.2 Results

No evidence of a difference was observed between the groups in terms of the number of vocalisations during the app trial, after controlling for each child's baseline level of vocalisations (from the non-responsive trial).

In a second analysis we divided the app session into two halves, each 2.5 minutes long, and calculated the proportion of vocalisations produced in the second half out of the entire 5-minute period. Proportions over 0.5 indicate that the child vocalised more during the second than during the first half. Proportions under 0.5 indicate a reduction in the frequency of vocalising from the first to the second half. In the experimental group 25 out of 30 infants (83%) increased their frequency of vocalising from the first to the second half of the session (see Figure 1). In the control group only 14 out of 29 infants (47%) increased the frequency of vocalising from the first to the second half of the session. We compared the mean proportion of vocalisations in the second half out of the entire 5 minutes in each group to 0.5, the expected proportion under chance. The mean proportion in the control group (M = 0.48) was not significantly different from 0.5 ($t(28) = .0.528$, $p = .6$). However, the mean proportion in the experimental group (M = 0.64) differed significantly from 0.5 ($t(29) = 4.779$, $p < .001$); see Figure 1.

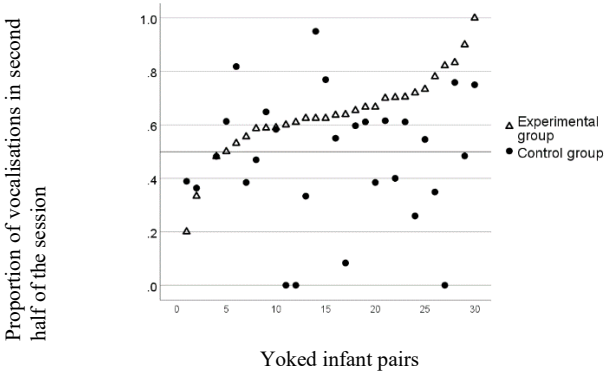

Figure 1: Proportion of vocalisations in the second half of the session in each yoked pair of infants.

In terms of the pairs, in 21 pairs out of 29, the proportion of vocalisations in the second half out of the 5 minutes was higher in the experimental group infant than in the control group infant (see Figure 1: Only in a minority of cases are the filled circles, indicating the member of the yoked pair who was in the control group, higher than the empty triangle, which indicates the experimental member of the yoked pair). A paired t-test showed this difference in proportions to be significant: M(difference) = .16, $t(28) = 3.195$, $p = .003$.

2.3 Discussion of Study 1

The results of Study 1 indicate that the 6.5-month-old infants in the experimental group learned that their vocalisations led to the visual response, and they increased their vocalising while interacting with the responsive app in order to see more visual responses. The fact that the control group didn't increase their vocalisations in the same way indicates that this increase in the experimental group was not in response to seeing the shapes after they appeared, but as a result of the infants, at some level, understanding that their vocalisations cause the shapes to appear (note that for 83% of infants in the control group, more shapes appeared on the screen in the second half of the session than in the first half, but those same infants did not systematically increase the frequency of their vocalisations in response to the rise in the frequency of the shapes). This difference between the

groups was also seen when looking at the yoked pairs, since in the majority of pairs, the infant with the responsive app increased their vocalising more than the infant with the non-responsive app.

We take this result to show that the app can be used to reinforce vocalising in infants, where the incentive to vocalise more is child-generated, and the learning of the relationship between the vocalisations and their external result (the visual scenes on the screen) is done by the infants, with no adult intervention, adult feedback, or social feedback.

This app allows researchers to manipulate the amount of vocalising practice a child experiences. We see this as a novel way of investigating self-generated rewards as part of infant learning. More specifically, we see the use of the app as a novel method that will allow further investigation of the causal relationship between a child's own production experience and practice and their later language development.

But if we can manipulate the amount of vocalising practice that a child experiences, might that not also be harnessed to encourage more vocalising in children who tend not to vocalise much, as a way of improving their future language/lexical prospects?

Study 2 was designed to combine these two aims: to test the causal relationship between vocalising (or babbling) practice and later lexicon development and to do it with a population who we thought would benefit from an intervention delivered through the app: infants from families of low socioeconomic status (SES). Infants from low SES typically vocalise less than those from middle SES homes [9], and typically have smaller lexicons than infants of a similar age from middle or high SES ([10], [11]). Study 2 was run as a clinical trial and was pre-registered (https://www.socialscienceregistry.org/trials/5552).

3. STUDY 2

We recruited 96 families of low SES (49 females, 46 males; one unknown), living in the UK. Ten families out of the 96 have withdrawn. The eligibility criteria for being considered low SES were any one of the following: (1) being considered 'at risk' or vulnerable by the council's children's services, or (2) financial criteria – eligibility for Universal Credit, the government scheme for help with living costs for people with low income, or (3) educational criteria – a requirement that neither parent/carer (in families with more than one carer) would be educated beyond Level 3 on the UK government qualification skills scale (e.g., A-levels), equivalent to 13 years of education, which are currently the number of compulsory years of education in the UK. Eligibility was determined based on families' reports, and no evidence for either financial situation or educational achievements were requested. Families who were recruited to the study were randomly assigned to either the intervention group or the control group. The assignment to groups was done by people not involved in delivering the iPads to families. The intervention group received the app described above. The control group received a reaching app, designed specifically for this study. The aim was for the control group to receive a similar non-language experience to that of the intervention group: both apps allowed the infants to learn to control an external apparatus (the app), an empowering experience for such young infants who have very little control over their own bodies, let alone over external objects. Both involved the child playing with an app with no adult 'teacher' to supply feedback or responses. And both were deemed to be potentially beneficial for skill development – practising vocalising in the one case, and practising reaching for moving objects in the other. The reaching app presented colourful moving shapes on an iPad screen (similar to those used in the vocalising app). When touched, the shapes changed from colour to black and white, grew bigger and then disappeared. The screen would then be black until a new shape appeared. Shapes that were not touched disappeared from the screen after 4-10 seconds. The reaching app, like the vocalising app, recorded the infant's vocalisations and tallied them. In addition, it counted the number of times the infants managed to touch the shapes.

This is a longitudinal study, with infants being followed from age 7-8 months until age 16 months.

3.1 Method

Families were given an iPad with one of the two apps on it, and asked to play with their child with the app twice a day for 5 minutes at a time for 3 weeks, or, if that wasn't possible, then as much as they could handle.

Before starting to play with either app and following the 3 weeks with the app, the families are followed with monthly motoric [12] and language [13] questionnaires, from age 7 or 8 months until age 12 months, and then once more at 16 months. At the start and at the end the families also fill in a questionnaire about their beliefs regarding the importance for infants of being spoken to [14].

3.2 Expected results

To date, all the families who have not withdrawn completed the app stage of the study. Forty-eight infants were randomly assigned to each group (although, due to technical problems and experimenter error, 3 families who were supposed to

receive the reaching app, received the vocalising app instead). By the date of the presentation we will have results from the app stage and from the questionnaires from the early ages. We do not present preliminary results at this stage because we have not planned for an interim analysis. Such analyses would require appropriate advanced adjustments to the statistical methodology utilised including sample size calculations. Therefore, we will only provide analyses comparing the two groups after the data collection is completed.

4. GENERAL DISCUSSION

This paper describes two studies that have made use of a new app intended to encourage vocalising in infants. In Study 1 we have shown that infants increase their vocalisations while they are interacting with the app. In Study 2 we are testing whether interacting with the app repeatedly over several weeks leads to a consistent rise in vocalisations, again – during the interactions with the app. Future studies will be needed to determine whether playing with the app over a period of time will lead to increased vocalisations outside of the interactions with the app, such that infants who play with the app often also vocalise more overall than those who haven't played with the app. However, even if we find this is not the case, as long as infants tend to be particularly vocal while interacting with the app, new avenues for both research and intervention become possible. Researchers will be able to use the app to study the effects of vocal practice in both typically and atypically developing populations, using a true experimental design, with random assignment to groups. Clinicians will be able to make use of the app to encourage more vocalising in infant (or child) populations that tend to vocalise little.

5. ACKOWLEDGMENTS

This work was supported by a C2D2 grant part funded by the Wellcome trust, a University of York Early Commercialisation Fund and an EPSRC Impact Accelerator Award (Study 1), and by a British Academy Grant and a University of York Research Priming Fund (Study 2).

5. REFERENCES

[1] McCune, L., Vihman, M. M. 2001. Early phonetic and lexical development: A productivity approach. *J. of Speech, Language, and Hearing Research, 44,* 670–684.

[2] Oller, D. K., Wieman, L. A., Doyle, W. J., Ross, C. 1976. Infant babbling and speech. *J. of Child Language, 3,* 1-11.

[3] Vihman, M. M., Mcaken, M. A., Miller, R., Simmons, H., Miller, J. 1985. From babbling to speech: A reassessment of the continuity issue. *Language, 61,* 395-443.

[4] McGillion, M. L., Herbert, J. S., Pine, J. M., Vihman, M. M. DePaolis, R. A., Keren-Portnoy, T., Matthews, D. E. 2017. What Paves the Way to Conventional Language? The Predictive Value of Babble, Pointing, and Socioeconomic Status. *Child Development, 88*(1),156-166.

[5] DePaolis, R. A., Vihman, M. M., Keren-Portnoy, T. 2011. Do production patterns influence the processing of speech in prelinguistic infants? *Infant Behaviour and Development, 34,* 590-601.

[6] Majorano, M., Vihman, M. M., DePaolis, R. A. 2014. The Relationship Between Infants' Production Experience and Their Processing of Speech. *Language Learning and Development*, *10*(2), 179–204.

[7] Daffern, H., Keren-Portnoy, T., DePaolis, R. A., Brown, K. I. (2020). BabblePlay: An app for infants, controlled by infants, to improve early language outcomes. *Applied Acoustics, 162,* 107183.

[8] Keren-Portnoy, T., Daffern, H., DePaolis, R. A., Cox, C. M. M., Brown, K. I., Oxley, F. A. R., Kanaan, M. (2021). "Did I just do that?"—Six-month-olds learn the contingency between their vocalizations and a visual reward in 5 minutes. *Infancy, 26*(6), 1057-1075. https://doi.org/10.1111/infa.12433

[9] Oller, D. K., Eilers, R. E., Steffens, M. L., Lynch, M. P., Urbano, R. 1994. Speech-like vocalizations in infancy: an evaluation of potential risk factors. *J. of Child Language*, *21*(1), 33–58.

[10] Furey, J. E. 2011. Production and maternal report of 16- and 18-month-olds' vocabulary in low- and middle-income families. *American J. of Speech-Language Pathology / American Speech-Language-Hearing Association*, *20*(1), 38–46.

[11] Hoff, E. 2003. The specificity of environmental influence: socioeconomic status affects early vocabulary development via maternal speech. *Child Development*, *74*(5), 1368–1378.

[12] Sparrow, S. S., Cicchetti, D., Balla, D. A. 2005. Vineland Adaptive Behavior Scales, Second Edition (Vineland-II) [Database record]. APA PsycTests. https://doi.org/10.1037/t15164-000

[13] Alcock, K. J., Meints, K., Rowland, C. F. 2017. *UK-CDI Words and Gestures - Preliminary norms and manual.* Retrieved from http://lucid.ac.uk/ukcdi

[14] Kennison, S. M., Byrd-Craven, J. 2015. Gender Differences in Beliefs about Infant-Directed Speech: The Role of Family Dynamics. *Child Development Research*, *2015*. https://doi.org/10.1155/2015/871759