Peter Simpson

Infant Media Exposure:
Accuracy in Current Methods of Measurement and
Effects on Sleep and the Early Language Environment

Abstract

Despite large amounts of research, and the development of full-day home audio-recording and analysis tools like the LENA Research Foundation's Language Environment Analysis module (LENA), the role of television and media exposure remains chronically under-examined in relation to the quality of the language environment and sleep habits of children under two years of age. These factors play an important role in shaping an infant's developmental trajectory (Hart & Risley, 1995). The American Academy of Pediatrics has issued recommendations that parents completely separate infants from television exposure during the first two years of life, while pointing out the lack of research concerning TV and related factors like sleep for this age group (American Academy of Pediatrics, 2011). This study focused on the analysis of parent questionnaires and LENA full-day home audio-recordings for a sample of four-month-old infants. Type and duration of media exposure was measured by parent report, and by both automated analysis and hand-coding of the full-day home audio-recordings. Additionally, television exposure was compared with parent-reported child sleep time. The results showed significant inaccuracies in the automatically generated LENA measure of TV exposure; a significant negative relationship between TV exposure and infant sleep time; as well as noteworthy discrepancies in parent reporting of infant TV exposure. Despite its failure to estimate overall media exposure, LENA was successful in differentiating between spoken word and television with respect to calculating adult word count. These findings have important implications for what is known about the negative impact of television on very young children, as well as the reliability of widely-used measures of media exposure in the early language environment.

Acknowledgements

My work would not have been possible without the generosity of Dr. Clancy Blair, Dr. C. Cybele Raver, Katherine Adams, Andrew Ribner, Lara Kyriako, Meriah DeJoseph, and everyone else at the New York University Steinhardt School Neuroscience & Education Lab. I am eternally grateful for the wealth of opportunities and kindness I've experienced during my time at NYU. I would also like to thank my research mentors at school, Guido Garbarino and Alejandro Victoria, who have provided me with encouragement and advice since I began this study.

Introduction

The quantity and quality of language that a child is exposed to in their first few years of life has repeatedly been shown to have serious consequences for a child's linguistic development and academic performance later in life (Cartmill 2016; Zauche, Thul, Mahoney, & Stapel-Wax, 2016; Weisleder & Fernald, 2013). Recording technology and analysis software created by the LENA Research Foundation is now widely used by researchers studying the early language environment, and has greatly streamlined the process of gathering data on the early language environment and made producing high-quality data significantly less time-consuming. However, one potential blind spot of the LENA recording technology is in quantifying exposure to media. Anecdotal evidence suggests that the software often mistakes language coming from a media source such as a television for actual human speech, despite the important difference between the two in terms of impact on the early language environment development (Christakis et al., 2009).

The American Academy of Pediatrics (AAP) has warned parents against exposing children under the age of two to television since 1999, due to the wealth of studies (typically focusing on older children) which show its detrimental effects on attention, sleep, and development (American Academy of Pediatrics, 2011; Dworak, Schierl, Bruns, & Struder, 2007). In a 2016 policy statement, "Media and Young Minds," the AAP guidelines recommended families "avoid digital media use (except video-chatting) in children younger than 18 to 24 months" (American Academy of Pediatrics, 2016). The AAP has repeatedly highlighted in its statements the lack of research examining the effect of television exposure on key health

and development variables, often studied in older child populations, for infants (American Academy of Pediatrics, 2011).

Sleep is one of the most likely mechanisms through which television exposure could impact an infant's language development, given its prominent role in infant development and television's negative association with child sleep, well-documented particularly in regards to older children (Scher, 2005). In a 2011 study of media use and sleep in children aged 3 to 5 years, Garrison et al. concluded "television viewing at bedtime, regardless of location, may result in increased autonomic activation due to hyperarousal or disrupted melatonin production via brightly lit screens" (Garrison, Liekweg , Christakis, 2011). The dearth of knowledge regarding how television exposure affects sleep in children under two years of age, often highlighted by the AAP, is alarming given the critical period that the first two years of life represents in language development, and the potentially significant adverse effects of television during this developmentally crucial time.

Statement of Purpose

This study was performed to explore the role of television in the early language environment and its effect on sleep, in addition to testing the accuracy of a widely used research technology in detecting media exposure and differentiating it from other stimuli present in the language environment.

Methods

Participants

Participants in this study were drawn from a larger study that included 129 cohabiting couples in heterosexual relationships expecting their first biological child. Families were recruited from New York City hospitals and classes when mothers were pregnant. At time of recruitment, mothers were, on average, 33.5 years of age (mean = 33.48 years; SD = 3.49) and fathers were 35 (mean = 35.34 years; SD = 4.90). All participants completed a home visit with a trained research assistant during their last month of pregnancy and when children were 4 months of age (mean = 4.12 months; SD = 0.52). Data for the present sample is from a subset of

participants (N = 41) who were given the opportunity to opt into data collection to record the language environment of their child for a full day when children were 4 months of age.

Data Collection - Completed Prior to Entry of Student Researcher

Parents were given one LENA recorder and were taught how to operate the module. The recorder was placed by parents in a specially designed bib worn by the child for the entirety of the day. Parents were additionally asked to complete a questionnaire detailing the amount of sleep their child received that day, their average sleep, the amount of child media exposure, the relative typicality of the child's environment that day, and sleeping and waking times. LENA software was then used to produce data pertaining to adult word count, television presence, and child vocalization during every five-minute segment of the recording. Adult word count has been established as a readily available and effective way to measure the "quality of the language environment" in relation to the theory that greater exposure to language increases lexical processing efficiency in children, which resultingly increases language acquisition (Weisleder & Fernald, 2013; Hart & Risley, 1995).

Measures. To assess infant sleep, parents completed the Brief Infant Sleep Questionnaire (BISQ; Sadeh, 2004). This measure has been used previously, and acceptable psychometric properties are reported elsewhere. In particular, I created a composite measure of sleep during a typical 24 hour period by combining measures that asked "How much time does your child spend asleep during the night? (between 7PM and 7AM)" and "How much time does your child spend asleep during the day? (between 7AM and 7PM)".

Daily television viewing was obtained from parent responses to a single item that asked parents to report, "Number of hours watching TV/DVD or looking at iPAD or Computer." This item did not specify platforms for viewing, but instead assessed time spent watching television and video programming on any device. This item captures a global measure of screen time, and has been used in previous investigations of the effects of television exposure (e.g., Ribner, Fitzpatrick, & Blair, 2017; Pagani, Fitzpatrick, & Barnett, 2013; Robertson, McAnally, & Hancox, 2013).

Data Cleaning - Completed After Entry of Student Researcher

Data was cleaned first for recording irregularities such as the recorder being detached from the child, and child sleep time was marked so as to exclude any language picked up by the recorder during child sleep. Language detected during infant sleep was excluded: it was assumed that children were not processing language (and that little language was being directed toward the child) while he or she was asleep. Data cleaning involved using the Praat software package to analyze waveforms and aurally scan through each five-minute segment of a subject's recording, and investigate further if media use or irregularities appeared during the exploration.

If media use was present, it was recorded in the media-presence variable for the five-minute segment. Media type (television or music) as evidenced by cues in the recording, was also marked in a text field. This formed the observationally-derived measure of media exposure, which is assumed to be the most accurate for the purposes of this paper. The components of this data marked under television form the observationally-derived measure of TV exposure. Additionally, a media-confusion variable was completed during cleaning for segments that contained media exposure if the LENA software had erroneously counted language coming from the media source in the adult word count. The media-confusion variable was given a positive value only if a majority of the LENA-reported adult word count for that five-minute segment was erroneously derived from media. Separate values were entered if a majority of reported adult words came from adults, or if there was an even or near-even split between media language and adult speech.

Analysis

Analysis was performed in IBM SPSS 24. To address our research questions, I first was interested in the amount of media to which infants were exposed, and the disparities in reporting of media exposure. To do this, I analyzed descriptive statistics and bivariate correlations among observational-, parent- and LENA-reported television exposure. To determine whether there were differences in the magnitude of length of television exposure as reported by parents, LENA, and observation, I performed within-family t-tests. Within-family t-tests were also performed comparing adult word count between the first and second rounds of cleaning. Additionally,

observed media exposure and parent-reported media exposure were compared in cross tabulation analysis as binary values (either the subject was exposed to any television, or not).

I next was interested in the association of media use with infant outcomes. Data was submitted to a linear regression controlling for other characteristics of the child and home environment that might be associated with infant sleep. I investigated whether exposure to screen-based media is negatively associated with infant sleep time during a typical day.

Results

Descriptive Statistics

Descriptive statistics for variables of interest are reported in Table 1. Cross tabulation results for parent-reported and observed media exposure are reported in Table 2. With regard to frequency within the analytic sample, 18 parents (50% of those who answered the questionnaire item) reported their child used any television; however, this report was at odds with observational reports derived from analysis of LENA data during cleaning. 38% of children whose parents reported that they were not exposed to television both during an average day and in the past day were found during analysis of recordings to have been exposed to television during the recorded period of their day.

56% of children were observed to be exposed to any television during their recording session. Children were, on average, exposed to 44 minutes (mean = 44.27; SD = 64.75) of television during LENA recording, which averaged 898 minutes (14.97 hours) (mean = 897.80; SD = 124.30) in length.

Bivariate Relations

Bivariate correlations among all study variables are reported in Table 3. Of particular note, the LENA-produced value for television (without cleaning) was correlated only with the amount of time the LENA device was on and in use ($r = 0.370$, $p = 0.017$) and was not correlated with either the observed television exposure variable or parent report of media use. This suggests that LENA-reported television may be strictly error, and that as LENA detects more sounds, it is more likely to code some of them as media use.

Observed television exposure was moderately correlated with parent-reported television exposure ($r = .46$, $p = .005$), and the two did not significantly differ (paired $t(19) = 1.79$, $p = 0.090$). This suggests that despite the discrepancies uncovered in cross tabulation analysis, parent-report is roughly accurate. Figure 4 shows the amount of observed TV, LENA-reported TV, and parent-reported TV for each subject in minutes.

Accuracy of LENA automated analysis

LENA automated analysis (not including sleep and irregular segments) reported that children had been exposed to an average of 15,676 words (mean = 15675.56; SD = 7063.79) and 32 minutes (mean = 32.09; SD = 60.90) of television during the full recording period. After removing segments in which LENA misattributed media noise as adult speech, the average number of words each child was exposed to was reported as 15,481 words (mean = 15480.90, SD = 7067.96). Adult word count that had only been cleaned for sleep and irregularities did not significantly differ from adult word count for segments which had been cleaned for LENA media confusion in addition to sleep and irregularities (paired $t(40) = 0.622$; $p = 0.537$). This suggests that LENA is relatively accurate in parsing adult speech from media, and thus is effective in its main functionality of evaluating adult word count.

Descriptive analysis of LENA-reported television exposure shows that LENA reported there to be no subject in the sample who was exposed to no television during the recording, with the maximum value at 267 minutes (min = 2.65; max = 267.00). This is contradictory to observed television exposure, where 54% of subjects were found to have received no television exposure. Observed TV exposure and LENA-reported TV exposure differed significantly (paired $t(21) = 2.217$, $p = 0.038$). This suggests that the LENA-reported measure of TV exposure has little grounding in reality, and supports the previously described correlative results which found LENA-reported TV exposure to be significantly correlated only with recording length.

Regression Analyses

Results of regression analyses are shown in Table 5. I investigated whether increased TV exposure was associated with sleep, over and above the effects of other characteristics of the

home and child. Controlling for child age and sex, and for total length of recording, a linear regression revealed no association between minutes of television exposure during the recording and sleep (Beta = -.23, p = .20). However, further analysis revealed that it may not be the amount of television exposure, per se, but rather, whether there is any television exposure that is associated with child sleep. A dichotomous variable representing whether any television exposure was observed during the recording was entered into a linear regression with child age and sex, as well as total length of recording. Indeed, participants who were exposed to any television slept less per night (Beta = -.385, p = .023), an association of over ⅓ of a standard deviation, or nearly 40 minutes less of sleep per night. There was no association of age, gender, or length of recording with sleep.

Discussion and Conclusion

It is critical that we continue to look deeper into the root causes of developmental inequality among children, particularly as the strength of the early language environment has been strongly associated with parental socioeconomic status (Hart & Risley, 1995). In order to develop meaningful interventions that can help to ensure equal opportunity for educational success and success in life, we must first understand all the factors that work in tandem to affect development, and ensure that research is conducted using accurate methods and instruments. This study examines both these aspects of the issue, and the findings should be worrisome for anyone working in this area to develop meaningful mechanisms to improve the developmental trajectory of children.

The findings regarding the accuracy of LENA-reported media exposure are particularly troubling given the widespread adoption of the technology. This study, among many others, confirms its ability to effectively parse and quantify adult speech, a key measure of strength for the early language environment. However, LENA detection and quantification of TV exposure appears to be an unreliable measure and should be treated with significant caution going forward. More research is definitely required to diagnose the shortcomings of the media detection algorithms and develop more effective means of detecting media in the language environment.

The findings regarding television exposure in relation to child sleep are also alarming, and reinforce the American Academy of Pediatrics' existing recommendations on parental abstention from infant TV exposure. Importantly, we find in the present analysis that it is not the amount of screen time to which children are exposed, but rather that children are exposed at all that seems to be associated with sleep. This is likely due to the accumulation of time exposed to screens, which has previously been shown to split attention and overwhelm young children with multisensory information. This is not to suggest that being exposed to screen-based media a single time, or even on occasion is detrimental to children's sleep. It is worth noting that directionality cannot be inferred: Children who sleep less may have parents who leave the TV on more to keep themselves entertained while trying to soothe a sleepless baby. However, given prior findings (e.g., Dworak et al, 2007; Paavonen, Pennonen, Roine, Valkonen, & Lahikainen, 2006), it is a distinct possibility that exposure to screen-based media has negative effects on children's sleep. Given the wealth of research connecting child sleep duration to diminished cognitive development and the lack of widespread public knowledge of the AAP's recommendations, these findings point the way for more effective interventions and publicity efforts in the future.

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Figures

TABLE 1: Descriptive statistics of variables of interest.

Variable (units)	N	Min	Max	Mean	SD
Total recording length (minutes)	41	585.00	975.00	897.80	124.30
Duration of all media exposure, determined by observation (minutes)	41	0.00	295.00	101.10	82.37
Duration of television exposure, determined by observation (minutes)	41	0.00	275.00	44.27	64.75
Duration of music exposure, determined by observation (minutes)	41	0.00	200.00	51.10	49.29
Duration of recording without media exposure, determined by observation (minutes)	41	85.00	545.00	387.93	93.47
Total uncleaned adult word count (words)	41	3896.00	42814.00	17855.24	7954.63
Total preliminarily cleaned (excludes sleep and irregular segments) adult word count (words)	41	3708.00	33379.00	15675.56	7063.79
Total cleaned (excludes sleep, irregular segments, and media misattributed as talk) word count (words)	41	3708.00	33379.00	15480.90	7067.96
Sum of AWC during segments with media in which media was not erroneously added to adult word count (words)	41	0.00	19038.00	2922.46	3696.73

Sum of AWC during segments with TV in which media was not erroneously added to adult word count (words)	41	0.00	18978.00	1203.34	3168.13
Sum of AWC during segments with music in which media was not erroneously added to adult word count (words)	41	0.00	4783.00	1148.27	1310.24
Sum of AWC during segments with no media (words)	41	1585.00	24698.00	12558.61	6122.16
Sum of TV exposure as reported by LENA raw (minutes)	41	2.65	267.00	55.32	55.93
Sum of minutes of TV exposure reported by LENA preliminarily cleaned (excludes sleep and irregular segments) (minutes)	41	1.15	110.45	32.41	32.96
Parent-reported infant television exposure during the previous day (minutes)	37	0.00	240.00	32.09	60.90
Parent-reported infant sleep time on an average day (hours)	36	8.50	15.50	12.85	1.59

TABLE 2: Cross tabulation analysis of parent-reported television presence and observed television presence as binary variables.

			TV Present? (observed)		Total
			No	Yes	
TV present? (parent-reported)	No	Count	11	7	18
		% of Total	30.6%	19.4%	50.0%
	Yes	Count	5	13	18
		% of Total	13.9%	36.1%	50.0%
Total		Count	16	20	36
		% of Total	44.4%	55.6%	100.0%

TABLE 3: Bivariate correlations between variables of interest. Columns represent variables as ordered in descending order on the rows. For each correlation, r = first row value, p = second row value.

	1	2	3	4	5	6	7	8
1 Duration of recording	-							
2 Duration of media exposure, determined by observation	0.129 0.422	-						
3 Duration of TV exposure, determined by observation	-0.073 0.649	.763** 0.000	-					
4 Duration of music exposure, determined by observation	0.258 0.103	.572** 0.000	-0.058 0.721	-				
5 Duration of recording without media, cleaned	0.138 0.391	-.452** 0.003	-.452** 0.003	-0.159 0.321	-			
6 Sum of minutes of TV exposure as reported by LENA, raw	.370* 0.017	0.036 0.823	-0.095 0.554	0.189 0.236	-0.092 0.569	-		
7 Sum of minutes of TV exposure as reported by LENA, cleaned	.314* 0.046	.361* 0.020	0.050 0.755	.507** 0.001	-0.017 0.917	.554** 0.000	-	
8 Parent-reported infant television exposure during the previous day	-.326* 0.049	0.223 0.185	.455** 0.005	-0.199 0.237	-.464** 0.004	-0.139 0.411	-0.142 0.401	-

9	Parent-reported infant sleep time on an average day	-0.178	-0.266	-0.135	-0.304	0.181	-0.260	-0.325	-0.127
		0.299	0.117	0.431	0.072	0.292	0.126	0.053	0.459

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

FIGURE 4: Minutes of television exposure reported by all relevant data sources. Each grouping of three bars represents one subject.

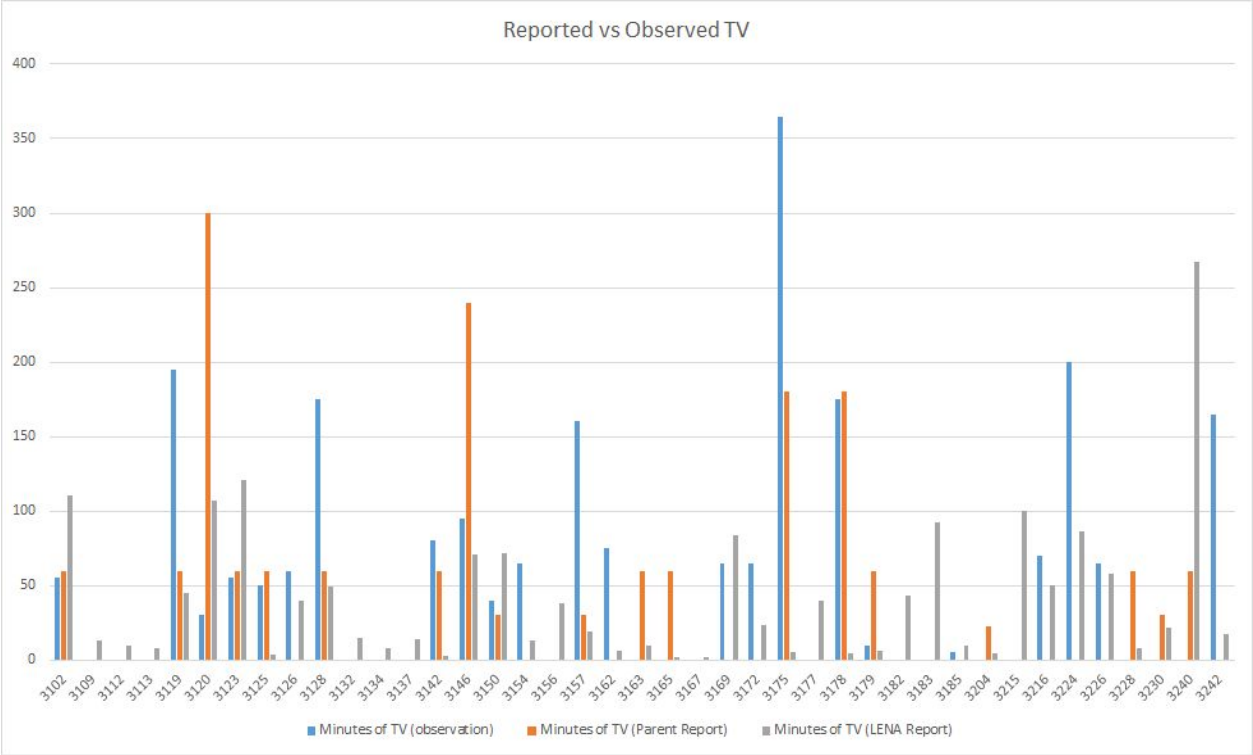

FIGURE 4: Sources are color-coded: observed television (BLUE), parent-reported television (ORANGE), LENA-reported television (GRAY).

TABLE 5: Results of regression analysis.

Model		Beta	Sig.
	Child age (months)	-0.074	0.647
	Child gender	0.246	0.136
	Was the child exposed to television during the recorded period? (Y/N)	-0.385	0.023
	Total recording length	-0.181	0.265

Dependent variable: Parent-reported infant sleep for a typical day