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From “Communication Mode” to “Language Access Profile” in Research with DHH
Children

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Abstract

For d/Deaf and hard of hearing (DHH) children, “communication mode” is often included as a predictor of performance across a wide range of developmental outcomes; however, the operationalization of communication mode is highly variable and often falls short of what would be ideal. Here, I argue that DHH children, their families and service providers, and the field as a whole would benefit from replacing the concept of “communication mode” with that of “language access profile”: a term that reflects the child’s cumulative experience with various types of communicative input, beginning at birth. Language access profiles are intended to capture the multidimensional and dynamic nature of DHH children’s early experiences with diverse types of communicative input. I present data from a study that presents a new method of estimating individual language access profiles. I also use hierarchical cluster analysis to organize individuals with similar profiles into coherent, data-driven groups. Results suggest that this is a promising approach with strong potential for use in diverse contexts, including education, clinical care, and research.

Communication mode is a construct that plays a central role in research on the development of d/Deaf and hard of hearing (DHH) children, including studies that examine outcomes in speech, language (spoken or signed), cognitive, social-emotional, and academic domains. Communication mode is commonly understood as a broad construct that encompasses the wide range of communicative systems that DHH children might encounter, including various spoken languages, various sign languages, and various invented systems that are typically derived from a given spoken language, often emphasizing a particular level of linguistic organization. For example, sign-supported speech typically foregrounds content words over function words or morphology, cued speech emphasizes phonological/articulatory structure, and systems like Signing Exact English emphasize morphosyntax. Total Communication is a term whose meaning has shifted somewhat over time: while originally intended to refer to a philosophy where all options were valued and available, it is frequently used to describe what is here termed sign-supported speech (sometimes also called Simultaneous Communication, or SimCom).

Despite the centrality of communication mode as a construct to much theoretical and applied work with DHH children, seemingly little attention has been paid to how it is operationalized, and to the ways that a given operationalization can impact the types of conclusions that can be drawn from a given study. The goal of this paper is not to advocate for or against any particular operational definition, but rather to argue that communication mode as a construct is less useful than what I will refer to as a child's "language access profile".

Current methods of defining communication mode are diverse. Many –perhaps most– studies use binary groupings (e.g. oral vs. oral+manual/TC/SC; e.g. Belzner & Seal,

2009; Fitzpatrick et al., 2016;). Others use a tripartite split between oral-only communication, sign-supported speech, and bilingual-bicultural (e.g. Dettman et al., 2013, Yanbay et al., 2014). Still others use an ordinal scale that varies along a single dimension from exclusively visual to exclusively auditory (e.g. McConkey-Robbins, 2001; Neault, 2010 Nussbaum et al., 2004). Another approach also uses an ordinal scale, but one that ranges from sign emphasis, equal sign-speech emphasis, speech emphasis, cued speech, auditory-oral and auditory-verbal (e.g. Geers et al., 2011). Other studies may bin these categories even more coarsely (e.g. Geers et al., 2017). Despite their diversity, all of these approaches share a number of critical problems.

First, they all make the (implicit or explicit) assumption that each child can be cleanly assigned to exactly one group. In fact, many children experience multiple different types of communication, but that reality is not reflected in any of these definitions. In other words, current approaches fail to capture the fact that DHH children's experience with communicative input is often *multidimensional*.

Second, they typically categorize children based on the type of communication they use (or prefer) at time of test. This is deeply problematic for any cross-sectional or retrospective study that wants to explore possible causal relationships between communication mode and some other outcome of interest. The heart of the problem is that many DHH children's experience with linguistic input changes over time, for a variety of reasons. Thus, two children who happen to use the same type of communication at time of test may have radically different histories that are not captured using current approaches. In other words, DHH children's experiences with linguistic input is *dynamic*. By looking only at the endpoint, we lose the ability to understand the developmental trajectory of

communication mode: for example, do children in oral-only programs do well because oral-only habilitation causes better performance? Or do children who are not performing as well self-select out of oral programs and enter programs that include manual communication?

In view of this problem, some studies exclude children whose experiences change over time (e.g. Dettman et al., 2013), but this is not a satisfactory solution: on the contrary, it introduces the potential for bias, for similar reasons. To illustrate the problem, imagine that early access to a natural sign language combined with early cochlear implantation reliably leads to better spoken-language outcomes than early cochlear implantation with oral-only communication. In this hypothetical world, 5-year-old children who grew up signing from birth to 3 will mostly be proficient speakers and an appreciable number of them may have ceased using a sign language, whereas many children who grew up with only oral communication would not be proficient speakers, and an appreciable number of them will likely have turned to sign language. If researchers studying these 5-year-olds only included children whose communication modalities had not changed over time, they would not be working with a random or representative sample. Indeed, they would likely find that there was no effect of communication mode, or might even find the opposite (if in fact only the worst speakers were still using sign, and only the best speakers had not begun to sign). Again, my point is not to assert that this is the true state of affairs in the world: only that current methods cannot distinguish one theory of interest from its polar opposite.

A third problem with relying on communication mode as a construct is that most current approaches do not distinguish between natural sign languages and other forms of manual communication, such as cued speech, sign-supported speech, and manual codes for

English. These systems cannot justifiably be arranged along any one-dimensional continuum: instead, the differences between them must be recognized. Natural sign languages (e.g. ASL) have their own grammar whereas the others are all based on the grammar of English. Even this is not the only relevant distinction: cued speech is based on grammatical structure at a phonological/articulatory level, whereas sign-supported speech typically supplies content words in English word order, while manual codes for English strictly follow English morphosyntax, including content word, function words, and both inflectional and derivational morphology. The fact that they are all perceived by eye (at least in part) is secondary to the fact that they are fundamentally different types of semiotic systems.

Fourth, by focusing only on categorical labels, current methods obscure vital information about the *extent* of a child's access to different types of communication. We can be confident that a child who receives 10% of her input in, say, ASL is less likely to develop proficiency in ASL than a child who receives 90% of her input in ASL. Research on spoken language bilingualism has begun to reveal that although the relationship between amount of exposure and degree of proficiency is monotonic, it does not appear to be linear. Instead, current estimates suggest a sigmoidal function, with inflection points somewhere around 30-40% and 60-70% (Cattani et al., 2013; De Cat & Serratrice, 2017; Thordardottir, 2011). In other words, with less than 30-40% exposure to a given language, developing native-like proficiency is unlikely, and variation between 0% and 30-40% only weakly predict outcomes. Conversely, given 60-70% exposure to a language in early childhood, developing native-like proficiency is nearly inevitable (in hearing children), and variation between 60-70% and 100% does not strongly predict outcomes. Although the range of

these numerical estimates depends on many factors (e.g. linguistic construct under study, languages involved, child's age, dominant language of the community, etc.), there is broad consensus about the general concept.

These findings provide helpful but imperfect context for evaluating language access in deaf children. They are helpful because they remind us that if a child fails to master a language that constitutes less than 30% of her input, that should not be taken as evidence that this type of input is inherently difficult for the child to learn; there may simply have been insufficient opportunity. Conversely, if a given child fails to master a given language despite it constituting 70% or more of her input, that should be viewed as highly problematic, and not attributable to a lack of opportunity. More concretely, the likelihood of developing proficiency in English among DHH children who have access only to the grammar of English is much lower than it ought to be, considering that all of their input is in English: for instance, Geers et al. (2017) report that even in the best-performing group of young CI users in their sample, 49% scored below the average range for hearing children on a standardized assessment of English proficiency. In a normal distribution, only 16% would be expected to score in this range: these results therefore reveal a statistically significant threefold increase in risk. Similar patterns are evident wherever the full distribution of spoken language outcomes is reported (e.g. Ching et al., 2013; Geers et al., 2016; Niparko et al., 2010). Meanwhile, the likelihood of developing proficiency in ASL among DHH children who have partial access to ASL is virtually unknown, due in part to the fact that few studies distinguish natural sign languages from other forms of manual communication, and that even those few that make this distinction do not assess proficiency in the relevant sign language (e.g. Percy-Smith et al., 2010; Dettman et al., 2013;

Yanbay et al., 2014). These crucial gaps can only be filled by distinguishing sign languages from other forms of manual communication, by directly assessing proficiency in sign languages as well as spoken languages, and by quantifying access as a continuous variable, rather than a categorical one, as research in spoken language bilingualism is now doing.

Having said that, the insights from research on spoken language bilingualism are also imperfect, because they are largely predicated on the assumption that there are only two relevant categories of language exposure (language A and language B); thus, a hearing bilingual's language access profile has exactly 1 degree of freedom and the whole profile can therefore be represented by a single value on a single axis. In contrast, as argued above, a DHH child's language access profile can involve as many as 8 different categories, meaning that each child's profile may have multiple degrees of freedom. This prevents us from characterizing the relationship between degree of access and degree of proficiency with bivariate measures, because two children with the same degree of access to one type of communication (e.g. English) may diverge completely along other dimensions of exposure, and the variation in these other dimensions may account for (or at least contribute to) the observed outcomes. It is therefore essential to have a method that takes all relevant dimensions into account, and captures the *extent* of access, rather than merely the *fact* of access.

The fifth problem with current reliance on communication mode as a construct is that none of the extant approaches capture what may turn out to be a crucial dimension of DHH children's early experience with language: the extent to which they may have *lacked* direct access to a linguistic signal. Consider a handful of five-year-old DHH children who have not been exposed to any language other than oral English. The first child has a

unilateral loss and therefore never lacked direct access to language. The second child was born profoundly deaf in both ears and received a cochlear implant at 18 months; although she was surrounded by people talking during those first 18 months, she had only *visual* access to the auditory signal (i.e. speechreading) prior to implantation. We refer to this as *indirect access*. The third child was also born with profound deafness bilaterally, but was raised in an orphanage abroad with only indirect access to the spoken language there and received no hearing technology until adoption at age 4. The fourth child received bilateral implants at 12 months, but due to a combination of family circumstances and child temperament, the implants are only on and functional for about 3 hours a day. By most current methods, all four of these children would be considered to have the same “communication mode”, despite their heterogeneous experiences with access to spoken English.

One might argue that it is possible to capture these additional dimensions of variability by measuring other variables (e.g. age of implantation, degree of compliance, SES, etc.). I acknowledge that this is a possibility, and one that is used by some researchers. Still, I argue that it would be preferable to have a way of representing all of these dimensions and their change over time in a single measure. This is the motivation for the concept of a language access profile, which is itself an extension of a construct from spoken language bilingualism: *cumulative* language exposure.

Researchers who study the development of hearing children raised in multilingual environments have long recognized that to best predict a child’s performance on a given task (be it linguistic, cognitive, academic, etc.), it is generally preferable to measure their cumulative exposure to the languages in question rather than their current exposure

(Gutiérrez-Clellen & Kreiter, 2003; Unsworth, 2013). The most common method of doing so is by retrospective parent report (Byers-Heinlein, 2015), with structured interviews by a skilled researcher preferable to asking the parent to complete a form in isolation (Hoff & Luz Rumiche, 2012).

The method presented here is a straightforward extension of these concepts to DHH children. The shift in terminology from “exposure” to “access” reflects the fact that many DHH children are *exposed* to input to which they do not have direct *access* (e.g. speechreading); from a psychological perspective, measuring the signals that are *received* by the child (i.e. language access) is more likely to be useful for understanding development in DHH children than measuring the signals that are *sent to* the child (i.e. language exposure).

As currently conceived, a language access profile is a numeric estimate of the proportion of a child’s input that belongs to each of 8 categories: Indirect Access, English without signs, ASL, Sign-Supported Speech, Manual Codes for English, Cued Speech, Other Spoken Language, and Other/Unknown (see Appendix for definitions). In this way, it succeeds in capturing the *multidimensional* nature of DHH children’s access to language. The inclusion of the Indirect Access category mitigates what could otherwise be a serious problem in using a proportional measure with DHH children: the fact that there are often enormous discrepancies in the overall amount of input they receive. Consider two three-year-old children who have both had access to no other type of communication than spoken English: one child has had auditory access to English from birth, while the other gained auditory access after cochlear implantation at 12 months. Without accounting for the time spent without auditory access to English, both children would be described as

having 100% English input, which overlooks the critical difference in their access. By including the Indirect Access category, the first child's profile remains 100% English, while the second child's profile reflects 33% Indirect Access and 67% English. The Indirect Access category can also capture cases where a child's visual system does not provide direct access to manual communication, as well as additional instances of indirect access (e.g. exposure to spoken language when hearing technology is poorly-fitted or the child doesn't wear it, or interactions with people who persistently speak to a child who uses only ASL).

The estimate is based on parent report for a finite period of time: in the present study, the focus was birth to 3, but there is no inherent limit to this approach. The time interval can also be divided into any desired sub-intervals; in this way, it captures the *dynamic* nature of DHH children's access to language. With a large enough sample, future work could analyze whether the temporal dynamics of language access impact other outcomes; the present analyses average across time intervals. I argue that this is still preferable to the prevailing practice of sampling only communication mode at time of test, thereby ignoring all that has happened prior to that point.

A single child's language access profile is therefore represented by a single point in an 8-dimensional space. An important benefit of this approach is that it yields a highly individualized result that parents, educators, and clinicians could use to establish and track goals for a given child over time. For example, based on findings from spoken language research, a family that values bilingualism might want to ensure that their child has at least 30-40% access to ASL and at least 30-40% access to English. A teacher designing an IEP for a new student would benefit from knowing that a student who is performing at age level in

spoken language assessment spent the first two years of his life without direct access to communicative input, and may therefore be a candidate for a gifted program despite his average test scores. A clinician who finds that a child is scoring at the 75th percentile both in English and in ASL would be able to interpret these scores more accurately and make better prospective recommendations if she knew that the child's input was characterized by 70% access to English and 30% access to ASL.

On the other hand, researchers who are more interested in tracking broad tendencies over groups of children may initially balk at this concept, because it is unlikely that many children will occupy exactly the same point in this 8-dimensional space. If this method were unable to provide values that could be used as grouping or predictor variables, it might not be of much use in research contexts. Fortunately, it is perfectly feasible to derive grouping and/or predictor variables on the basis of language access profiles, via hierarchical cluster analysis. In a nutshell, hierarchical cluster analysis uses a series of algorithms to identify which points in an n -dimensional space are closest to one another. After iterating over all of the points in a dataset, the result is a scree plot and dendrogram (e.g. Figure 4A & 4C respectively) in which each point is successively joined into larger and larger clusters, while the distance between each cluster is measured by the y-axis on the scree plot, and the x-axis on the dendrogram. An optimal number of clusters is determined by identifying an inflection point on the scree plot. Past this point to the left, adding more clusters results in little information gain; past this point to the right, decreasing the number of clusters leads to increases in the heterogeneity within a cluster. The end result is that each child in the dataset is assigned to a cluster, which then serves as a categorical grouping variable or predictor, just as communication mode would have.

Unlike communication mode, the clusters based on language access profiles take into account the child's cumulative experience with multiple different types of communicative input, and how that may have changed over time.

The study reported below was conducted primarily to demonstrate proof-of-concept for the general approach proposed above, by conducting structured interviews with the parents of DHH children. Parents are familiarized with the eight categories of input described above, and are then asked to divide their child's experience across these 8 categories such that the result sums to 100%. We addressed the following questions:

1. How confident do parents report feeling when asked to make these retrospective estimates, and does their confidence change as a function of how far back in time they need to think?
2. Is hierarchical cluster analysis a viable technique for discovering groups of children whose language access profiles are similar?
3. Does asking parents to estimate language access for the entire 0-3 window yield different results than asking parents to provide three year-by-year estimates and then averaging them?
4. Does parents' level of concern about their child's current language proficiency vary as a function of their language access cluster from birth to 3?

Method

Participants.

To ensure that this method would be applicable to a wide array of DHH children, inclusion criteria were intentionally broad: the study included parents whose children (a) were currently age 12 or younger, and (b) had a hearing loss of any type, degree, etiology,

or laterality, known or suspected to have begun before age 3. Parents were also required to have access to the internet during the interview, and to be conversant in either English or ASL¹. We recruited via existing databases of participants and from social media (twitter, facebook), with a particular focus on facebook groups for parents of DHH children. Importantly, we recruited across groups that varied in their preference for language access, including those that advocated for listening and spoken language, ASL, total communication, cued speech, and manual codes for English. We also recruited via flyers at events for DHH children and their families in southern New England, including events sponsored by Gallaudet's northeast regional center, local chapters of AG Bell, and others. Our aim was to include participants with as many different types of communication backgrounds as possible. General demographics about the participants are given in Table 1.

We received responses from the parents of 56 DHH children (some of whom were siblings): of these, 1 did not meet the inclusion criteria, 8 did not schedule a session within the timeframe of the study, and data files for 1 were lost due to a technical error. This leaves data from the parents of 46 children. Of the 46 DHH children, 16 had at least one parent who knew ASL prior to the birth of their child (Deaf, $n = 14$; hearing, $n = 2$); the remaining 30 had hearing parents. We did not exclude any participants on the basis of national origin, home language(s), or additional diagnoses, because the goal of the present study was simply to describe the input to which the child had access, not the child's degree of language proficiency.

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¹ In future work, we aim to include parents who are only conversant in languages other than English and ASL. Note that this does not exclude multilingual parents in general- only those who are not also conversant in English or ASL.

Design & Procedure.

The first author interviewed all participants via telephone, videophone, or web-based videochat, depending on their preferred language (English or ASL) and internet speed. Informed consent was obtained via a web-based consent form with content in both written English and ASL, which was sent to the participants no less than 24 hours prior to their scheduled session. The session began with the researcher reviewing this form with the participant and answering any questions. Upon completion of the consent process, the website directed the participant to a webpage that was the basis for the rest of the study. Participants stated their responses verbally to the researcher and also entered them on the webpage; the researcher also filled in a second copy running on a local server. A data monitoring process was established in which a research assistant checked the two copies and flag any disparities, which were resolved by consulting a recording of the interview, if available.

The researcher explained that the interview would focus only on the birth to 3 period. The next step was to describe to the participant the 8 different language access² categories, using the descriptions given in the Appendix. The website also included video examples that parents could view if they were unsure after the description was provided. (Very few parents availed themselves of this option; those that did typically viewed examples of Signing Exact English and Cued Speech.) At this stage, the participant was asked to identify the categories that did not apply to their child during the birth to 3 period, by choosing “0%” from a drop-down menu. This process of elimination then revealed the

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² During the initial wave of data collection, the term “exposure” was used instead of “access”. This created ambiguity for some participants, which led the researcher to explain the distinction verbally. However, the written descriptions were not changed.

categories to which the child did have some degree of access during the birth to three window; the researcher then asked the parent to estimate what percent of the child's input belonged to each of these categories. The researcher instructed the parents to consider all of the child's interlocutors, including immediate family, daycare environments, early interventionists, etc. The response options were binned as 1-10%, 11-20%, ... , 91-100%; the website prevented page submission unless the values summed to 100%. The final question on this first page asked participants to indicate their level of confidence in their responses on a scale from 1 (not at all confident) to 5 (very confident).

Having obtained this overall estimate for the birth to 3 period, the website directed participants to three similarly-structured pages, each focusing on a single 12-month period (i.e., 0-12m, 12-24m, 24-36m). This allowed the researcher to capture change over time as a result of factors like gaining auditory access to spoken language via hearing technology, receiving early intervention from professionals who used ASL, the arrival of a relative who used a different language at home, etc.

After obtaining these three year-by-year estimates, the researcher administered a different assessment, still under development, whose goal is the same but whose design is different (involving more explicit hour-by-hour estimation of who was communicating with the child and how). Because the methods used during that assessment were still under development and changed somewhat over the course of the study, the analyses here focus on the first approach. Finally, the study concluded with a variety of demographic questions, including one single-item question that asked the parents to report their "level of concern regarding your child's language development (in sign language or spoken

language), relative to peers to the same age”³. This question was included primarily as a proof-of-concept; thus, the results below should not be considered definitive, especially since factors such as hearing level and additional diagnoses were not taken into account.

All study procedures were approved by the IRB at the University of Connecticut. In acknowledgement of their time, participants received an electronic gift card to Target, at a rate of \$10/hr, pro-rated by half-hour. Interviews were typically one hour long in total; the information analyzed here can be collected within ~15 minutes; the remaining time was spent on the other assessment, still under development.

Results

Confidence.

Our study focused on the birth to 3 period, but the participants included parents whose children were as old as 12.5 years, or as young as 8 months⁴. We therefore wanted to know whether parents’ self-reported confidence varied as a function of their child’s current age, which is a proxy for how many years back in time they were asked to retrospect. We predicted that there would be a negative and monotonic relationship between child’s current age and parent-reported confidence, although we did not have a prediction about the shape of the function. This prediction was only partially supported; to our surprise, confidence was high across the board, with only 3 of 46 participants reporting less than “pretty confident”. The children of these participants were all 96 months of age or

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³ When appropriate, it was clarified that “peers” referred to children who were similar to the child in every way except for hearing level; thus, a parent whose deaf child had autism would be comparing her child to a hearing child with autism.

⁴ There was no lower bound on eligibility. For children less than 3 years old, the overall estimate was based on cumulative exposure to date. Year by year averages were computed for children who were at least 24 months old; below that, there was no meaningful difference between the 0-3 estimate and the 0-1 estimate.

Figure 1. Parents' self-reported confidence in their ratings was typically high, even when thinking back 10 years or more.

older. Figure 1 displays the individual ratings and the density distribution; because the dependent measure is an ordinal scale, we computed Spearman's rho. The result was not significant ($\rho = .23, p = .13$), indicating that the child's current age does not predict the rank order of parents' confidence in their ratings. In other words, parents who had to think farther back in time were not systematically less confident in their responses than parents for whom their child's birth to 3 window was more recent.

Individual profiles.

Each panel in Figure 2 displays an individual participant's language access profile from birth to 3, selected to illustrate one child from each cluster (see next section for details about clustering). The values along each radial axis indicate the percentage of input belonging to each category. Summing the values along the edges of each polygon yields 100%. (The shape and area of the polygon itself are incidental, reflecting the ordering of the axes.) The children in panels A and B are different in nearly every dimension. The children in panels C and D have similar levels of access to ASL, but differ in whether the

remainder of their input is in English without signs or in sign-supported speech. The children in panels E and F are distinguished mainly by the fact that the child in panel E experienced a significant period of indirect access, whereas the child in panel F did not. The balance is reflected in the extent of their access to sign-supported speech.

Clustering and agreement of estimation methods.

The parental estimates for each child were submitted to hierarchical cluster analysis using Ward's method, which attempts to minimize the distance within clusters while maximizing the distance between clusters. Because each of the 8 axes uses the same

scale, the data were not standardized prior to clustering. These analyses were performed with JMP Pro 12 software.

The interview procedure yields two separate estimates of the child's language access profile from birth to three: one based on the parents' overall estimates of their child's language access during the entire 0-3 window, and a second used the average of the three year-by-year estimates (0-1, 1-2, 2-3). To measure the concordance rate between these two methods of estimation, we first conducted a single cluster analysis that included all data points as if they were independent, even though each participant was in fact represented by two data points (one from the overall estimate and one from the average of the year-by-year estimate). Both data points for a given child were assigned to the same cluster in 85% of cases: in other words, a concordance rate of .85. To interpret the statistical significance of this value, we used Monte Carlo simulations to calculate the concordance rate that would be expected by chance. We randomly shuffled the cluster assignments 1000 times, and found that 0/1000 cases returned concordance rates of .85 or higher (i.e., $p < .001$). The concordance rate expected by chance is .23 with a standard deviation of .05, which means that the observed concordance rate of .85 was 12.4 standard deviations higher than expected by chance.

As a second measure of agreement between the two estimation methods, we computed Cohen's kappa (κ), which is another method of measuring the extent to which observed agreement exceeds chance agreement, holding the overall prevalence of observations constant. By the standards of Fleiss (1981), our observed value of $\kappa = .81$ is considered "excellent" – the highest rating provided. By the more stringent standards of Landis and Koch (1977), $\kappa = .81$ is the lower bound of "almost perfect" agreement: again,

the highest rating provided. Given the robust agreement between the two estimation methods, the analyses below are based solely on the parents' overall estimate.

Figure 3 displays the average profile at the center of each language access cluster. Children assigned to this cluster will not all have this exact profile; however, they will be closer to it than to the center of any other cluster, making it the best available estimate. The current data yield 6 clusters, which we have labeled with Roman numerals in clockwise order based on their mode. Cluster I consists of children who lacked direct access to input for most of the birth to 3 period; this could be due to delayed diagnosis of deafness, international adoption, ineffective hearing technology, etc. Cluster II consists of children with access to English from birth, and essentially no use of manual communication; these children may have mild, unilateral, progressive, or fluctuating hearing losses. They may also have been fitted with effective hearing technology at such a young age that their time without direct access was minimal. Cluster III also has a mode at English without sign, but differs from Cluster II in two important ways: children in this cluster tend to report some time without direct access to language, and some degree of access to various forms of manual communication, of which sign-supported speech is the most common. Cluster IV has a mode at ASL; many of the children in this cluster have Deaf parents, but not all. In addition, not all children with Deaf parents were sorted into Cluster IV. Cluster V also has a mode at ASL, followed by English without signs and then sign-supported speech. This includes several children from both Deaf and hearing families who also received cochlear implants. Cluster VI has mode at sign-supported speech (a.k.a. SimCom), together with less frequent access to English without signs and ASL. In other studies, children in Cluster VI might be grouped with children in Clusters IV or V; however,

the distribution of access to these types of communication is strikingly different, suggesting that to collapse these groups together would be to overlook important differences.

Figure 3. Average language exposure profiles at the center of each of 6 clusters, labeled I – VI.

We note the absence of clusters with modes at Cued Speech, MCE systems, other spoken languages, and other/unknown. We will return to this in the general discussion; for now, we will remind the reader that children with access to these types of communication were included; however, there were not sufficient numbers of children with extensive access to these systems for them to form a coherent cluster.

Figure 4A displays the scree plot, with the number of clusters *decreasing* along the x-axis and intra-cluster distance (in arbitrary units) on the y-axis. At the left edge, there are 46 “clusters”, each containing a single child. At the right edge, there is 1 cluster, containing 46 children. The vertical line at 6 lies on the inflection point, indicating that 6 clusters achieves an successful balance of minimizing within-cluster distance and maximizing between-cluster distance. Figure 4B (constellation plot) and 4C (dendrogram) are equivalent ways of visualizing the end results of the clustering (best viewed in color).

The proximity of nodes in the constellation plot and the length of the horizontal lines in the dendrogram illustrate the distances between cases and groups of cases.

Figure 4. Panel A: scree plot indicating distance bridged by combining individual cases into larger (and therefore less numerous) clusters. Panel B: constellation plot illustrating the relationships of cases within clusters, and the relationships among clusters. Panel C: dendrogram showing the distances bridged by joining pairs of cases/clusters.

Language access clusters and parental concern about language proficiency.

As mentioned above, we asked parents to rate their level of concern about their child's language ability (in sign or speech), relative to peers of the same age. We deliberately avoided asking about their proficiency in a specific language (e.g. English, ASL) because not all parents place the same value on these languages, and therefore their level of concern would not be a good proxy for the child's degree of proficiency. By framing the question in a manner that is agnostic to the language(s) in question, we aimed to assess parental concern about their child's language ability in a way that would be comparable across all types of communication. Nevertheless, we recognize that this is merely a proxy, and include the analysis below primarily as proof-of-concept. The same general approach

can easily be used to analyze outcomes from formal assessments of language proficiency or other developmental domains (e.g. cognitive, social-emotional, academic, etc.).

Figure 5. Parent-reported level of concern about their child’s current degree of language ability (in sign or spoken language), relative to peers with full access to language from birth.

As shown in Figure 5, parental concern varied widely as a function of the cluster a child was assigned to based on their language access profile.

General Discussion

The primary goal of this paper has been to argue that researchers and other stakeholders who are interested in the development of DHH children would be better served by moving away from reliance on communication mode as a construct, and instead moving toward an alternate approach that (a) captures both the *multidimensional* and *dynamic* nature of DHH children’s experience with communicative input, (b) documents a child’s *cumulative* experience with language access, (c) distinguishes *natural* sign languages

from *invented* forms of manual communication (preferably also distinguishing among these various invented forms as well), (d) measures the *extent* of a child's access to various types of input, (e) reflects the extent to which a child has *lacked* direct access to any sort of linguistic input, and (f) still allows children whose experiences are similar to be organized into *coherent, data-driven groups*. I argue that such an approach is especially necessary to understand the development of deaf children born to hearing parents, about whom current approaches have perpetuated much confusion.

The secondary goal of this paper has been to present a first glimpse at what such an approach might look like. There is still work to do before a method like that presented here is ready to be deployed on a large scale; however, these initial results provide reason to believe that continuing along this path is likely to prove fruitful. For example, this general method can be used to evaluate the relationship between language access from birth to 3 and language proficiency at later ages. Although still fundamentally correlational in nature, such an approach at least avoids the problem of reverse causality that is inherent to studies that rely on communication mode, where it is never clear whether use of a particular type of communication is a cause or a consequence of attaining a particular degree of proficiency. In the approach proposed here, it is at least clear that proficiency at later ages did not cause the child to have a particular language access profile at earlier ages. Thus, although the present information is collected *retrospectively*, it can have a *prospective* function in modeling DHH children's development in various domains.

To illustrate the potential utility of these methods, the following paragraphs discuss the observed relationship between language access clusters and degree of parental concern about the child's level of language ability in more detail. It is critical to remember that this

analysis did not consider essential factors (e.g. child's age, parental hearing status, degree or etiology of hearing loss, type or extent of hearing technology, family SES, etc.); therefore, I make no claim that the findings below represent *actual* discoveries and I urge readers to not interpret them as such. Instead, I ask readers to engage in a thought experiment, considering the kinds of conclusions that would be possible if the analysis had controlled for these additional factors.

For instance, the preliminary findings here reveal important insights that other approaches might miss. Consider the children sorted into Clusters II and III. The most common type of language access for both clusters is spoken English without signs, and yet Cluster II elicits the second least concern from parents, while Cluster III elicits the most concern. Of the many possible explanations for this pattern, an obvious and familiar one is that the children in Cluster III simply do not have enough experience with oral English; from this perspective, the fact that roughly 37% of their input involves some type of manual communication could be interpreted to mean that the time spent using manual communication would be more profitably spent using listening and spoken language. However, that interpretation would be challenged by the results of Cluster V, which involves even less access to spoken English than Cluster III, and yet boasts the same low level of parental concern as Cluster II. But if time spent using manual communication cannot explain why parents are more concerned about children in Cluster III than Cluster II, what can? The present data support two possible answers.

One is that not all forms of manual communication are created equal. (In fact, not all forms of manual communication are *created* at all: some *evolved naturally*.) Cluster III averages about 7% access to ASL and 31% access to various invented systems created to

represent the structure of English on the hands: sign-supported speech (21%), manual codes for English (2%), and cued speech (7%). The fact that natural sign languages are structured differently than spoken languages is universally acknowledged; it is therefore puzzling that so many studies continue to group them together into a single category, or arrange them along an ordinal scale as if they represented different degrees of the same thing. Even the various invented systems differ enormously, with sign-supported speech consisting mainly of content words, manual codes for English including morphosyntactic marking, and cued speech based on phonological/articulatory information. There is no reason to treat these systems as if they were interchangeable simply because the eyes are involved in perceiving some or all of the signal. There are, however, reasons to suspect that naturally-evolved languages are inherently more learnable than invented codes, when controlling for degree of access (Hyde & Power, 1991; Marmor & Pettito, 1979; Maxwell, 1990; Strong & Charlson, 1987; Supalla, 1991; Tevenal & Villanueva, 2009; Wilbur & Peterson 1998). Thus, one reason that the children in Cluster III might lag behind those in Cluster II is that more of their access comes from invented codes rather than natural languages.

The second possible explanation for the difference in parental concern between Cluster II and Cluster III relates to a third way that the two clusters differ: the children in Cluster III experienced a greater degree of indirect access to language than those in Cluster II. It is entirely possible that this is the operative dimension, rather than either decreased access to listening and spoken language or increased use of sign-supported speech. Such an interpretation is consistent with all of the data, including the finding that parents also expressed higher levels of concern about children in Cluster I, who also experienced

significant periods of limited/indirect access to any linguistic input. Again, I do not claim that the present data constitute definitive proof that this third interpretation is the correct one. My main point is simply that without using an approach such as the one presented here, we would be likely to overlook the possibility that for Cluster III, the use of manual communication co-varied (and is therefore confounded) with the extent of indirect access. Identifying such patterns is a necessary first step toward testing the causal pathways involved. Continuing to rely on the notion of communication mode, under any of its present operational definitions, would never reveal this type of pattern, and would therefore continue to prevent progress in understanding the relationships between DHH children's access to various types of communicative input and their development in other domains.

Finally, I would be remiss to not also discuss the two clusters where parental concern is the lowest: Cluster IV (almost entirely ASL) and Cluster II (almost entirely English without signs). One important commonality between these two clusters is that they had the lowest average levels of indirect access (0% and 1%, respectively). For the children in Cluster IV, this was because at least one parent (whether Deaf or hearing) knew ASL prior to the birth of their child. For the children in Cluster II, this was because the nature of the hearing loss and/or the early use of effective hearing technology minimized the period during which they lacked meaningful auditory access to spoken language. These patterns raise important questions about the generalizability of the present findings. First, will the favorable findings from children with near-exclusive access to ASL generalize to children whose parents begin to learn ASL after birth? The answer to this question has remained difficult to document empirically, in part because so few families pursue (or are

guided toward) this path. Note that this question *cannot* be answered by studying outcomes in children with so little access to ASL that they would never be expected to become proficient, based on what we know about language development in hearing bilinguals. We must be careful to not allow the current absence of such evidence to be used to argue that such an approach would be ineffective.

Second, will the favorable findings from children with near-exclusive access to English without signs generalize to children who do not have direct access to communicative input for substantial amounts of the birth to 3 period? Because extant studies do not typically conceptualize the child's experience in this way, it is impossible to know how much of the current variability in observed outcomes might be attributable to the extent to which a child lacked direct access to communicative input in early childhood. Although age of implantation is sometimes conceived of as a proxy of the onset of direct access to input, this is far from accurate: for instance, it is not a valid proxy for children who have had auditory access to language prior to implantation (e.g. unilateral/asymmetric, progressive, or fluctuating hearing loss), or for children who have had visual access to manual communication. Age at implantation also fails to capture variability in access due to patterns of device use (or non-use). By describing participants in terms of their language access profile, future studies will be able to test whether favorable outcomes associated with near-exclusive access to English without signs ultimately generalize to children with congenital, severe/profound, bilateral hearing loss who do not have direct access to language until cochlear implantation.

Limitations.

There are, of course, a number of important limitations to this study, both conceptual and practical. On the conceptual side, the methods proposed here do not yet take into account the *quality* of the input to which children have access, which has been shown to be a significant predictor of some types of outcomes (Hirsh-Pasek et al., 2015). In addition, because the present approach uses proportions, it is not sensitive to baseline differences in the overall number of words/sentences that a child receives in early childhood. Such differences, often linked to SES, have been reported to have a strong impact on long-term outcomes in hearing children (Hart & Risley, 1995; Rowe, 2012); recent work by Suskind et al. (2016) has applied the same general logic to DHH children who are acquiring spoken language via hearing technology. Adapting the present methods to account for differences in *quality* of input is not especially challenging; there are existing ways to measure (or estimate) quality of input, by parent report or direct observation. These can then be modeled as moderators of the relationship between language access profiles and subsequent language proficiency. Being able to measure subtle differences in the baseline *quantity* of input is a much greater challenge; much of the work quantifying spoken language input relies on automated recording and annotation devices (e.g. LENA) that are not available for sign language or other forms of manual communication, and do not appear to be anywhere near the horizon. As long as such technologies remain unavailable, I argue that explicitly including the extent to which a child has lacked direct access to communication still represents a long-overdue advance relative to current approaches.

There are also numerous practical limitations of the present study, some of which are already being addressed in follow-up work. For example, the descriptions of the

various categories (Appendix) are being reworked in consultation with experts in the various systems. Recruiting a representative sample of participants is a goal whose attainment is difficult to measure, since the characteristics of the population from which the sample is drawn remains unknown. The present strategy has been to recruit from a wide range of organizations and networks, including those that state no preference for or against particular types of communication as well as those that specifically advocate for some approaches over others. However, in all such research, there exists the potential for response rates to be greater from some communities than others, leading to potentially skewed samples. The absence of clusters with high degrees of Cued Speech and Manual Codes for English could reflect failure to sample appropriately from these segments of the population; alternatively, it could be that these methods are currently uncommon for DHH children in the birth to three window. These explanations might also account for the absence of clusters with high degrees of access to spoken languages other than English: it could be that we failed to recruit from them (due, perhaps, to the requirement that parents be comfortable using either English or ASL), or that multilingual families with DHH children choose to focus more on English during the birth to 3 window. Several of the multilingual participants in the present study reported this explicitly, although it is difficult to know whether that would generalize to children whose parents are less proficient in English.

The present approach also relies on retrospective parent report as the main indicator of language access profile. Although this is not at all unusual, analogous approaches with hearing bilinguals are typically validated by measuring the reported degree of exposure against the observed degree of proficiency in participants, since the

underlying function is assumed to be nearly invariant in typically-developing children. No such assumption can be made for DHH children; in fact, that very question constitutes one of the central gaps in current knowledge that this method might one day address.

Therefore, the reliability and validity of the current approach must be measured in other ways, such as inter-rater reliability and test-retest reliability. We intend to begin collecting this information shortly. Prospective field studies that relate reported access to observed access would be another useful, if daunting, method of establishing the validity of the methods.

Parents may also be inaccurate in estimating the balance of direct vs. indirect access to spoken language, since many parents do not have a thorough grasp of the inner-workings of hearing technology and how various configurations of the same device can change the child's ability to access spoken language. For research purposes, this is not a major barrier, as long as parental (in)accuracy is roughly constant across individuals. For clinical purposes, it may be useful to ensure that the interview is conducted by someone who understands the child's history with hearing technology and can help the parent derive the most accurate estimate for their child.

There are also limitations in the analytical methods, particularly with respect to determining how many clusters are justified by the data. There can often be multiple candidates for good numbers of clusters (e.g. 6 vs. 7 vs. 4); the analyst's choice could potentially influence the subsequent findings. The strategy thus far has been to examine the data several ways (e.g. overall estimate vs. average of the year-by-year estimate, as well as the estimate generated by the other method under development), and to then select a number of clusters that lies on the inflection point in the scree plot for all estimation

methods (see Figure 4A). As the number of data points in the sample increases, the range of optimal clusters is expected to narrow, such that eventually there is a large enough data bank of profiles that the clusters remain relatively stable. Fortunately, when determining the number of clusters for a given dataset, the analyst has no way to know which particular data points will be assigned to which clusters, or how the clusters themselves will relate to subsequent outcomes. This mitigates the potential for outright bias.

Finally, there are also important limitations in the interpretation of the relationship between language access cluster and degree of parental concern about child language ability. As acknowledged above, the present study made no attempt to control for covariates such as the child's age, parental hearing status, socio-economic status, etiology of deafness, additional diagnoses, factors related to hearing technology, etc. Any or all of these factors are likely to influence this relationship. Therefore, the data presented in Figure 5 should not be strongly interpreted; rather, these data should encourage us to consider the value of conceptualizing the relationship between language access profiles and other developmental outcomes in a new way.

Future Directions

Although it is difficult to anticipate exactly where this line of inquiry will lead, there are at least four interrelated paths that seem worth pursuing: building a larger data bank of profiles, extending the age range beyond the birth to three window, developing a more thorough interview to elicit a higher-resolution picture of a child's language access profile, and measuring the validity and reliability of the methods. The end result will hopefully be a method of describing any DHH child's cumulative access to communicative input that will prove useful for families, educators, clinicians, and researchers alike.

Conclusions

Parents of DHH children still receive mixed messages about what types of communicative input are most likely to maximize their child's developmental potential. One reason for the continued uncertainty is that most of the empirical research that has been used to address this question has generally relied on the construct of communication mode. Unfortunately, this construct –both despite and because of its multiple operationalizations– fails to satisfactorily address this question. It cannot be used to infer causality, not only for the standard reasons inherent to all observational research, but also because it fails to capture the multidimensional and dynamic nature of DHH children's cumulative experience with communicative input, including the extent to which they had or lacked direct access to various types of input, and the distinctions between natural sign languages and other forms of manual communication. The alternative proposed here may or may not ultimately prove to be a satisfactory solution to these shortcomings; at the very least, it may spur the development of an even better solution.

DHH children, their families, and the professionals who serve them deserve to have a stronger foundation of research evidence than what is currently available – much of which is limited by the shortcomings just described, or by attempts at making generalizations based on findings from children born into culturally-Deaf families. Crucial questions on all sides will continue to remain unanswered unless we improve the methods we use to answer them. The theory and preliminary data presented here are offered as first step in what I hope will be a fruitful direction in the continued search for ways to maximize DHH children's developmental potential.

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Table 1. Participant demographics.

Information about parents	
Number of unique parents	39
Relationship to child	
Biological parent and primary caregiver	41
Not biological parent but primary caregiver	5
Primary caregiver's highest education level	
Less than high school	0
High school or equivalent	1
Some college or associate's degree	7
College degree	13
Graduate degree	25
Participating parent's hearing status	
Hearing	34
Deaf	12
Did at least 1 parent know a sign language before child's birth?	
No	30
Yes	16
Information about children	
Number of unique children	46
Child's age (years;months)	
mean (SD)	7;6 (3;11)
min - max	0;8 - 12;6
Level of hearing loss (better ear, unaided)	
none (i.e. unilateral loss)	1
mild	6
moderate	3
severe	8
profound	24
progressive or fluctuating	4
Use of hearing aids	
None	5
Former	24
Current, without CI	9
Current, with CI	4
Other	4
Use of cochlear implants	
None	21
Former	0
Current, unilateral	6
Current, bilateral	19

Degree of language concern	
Not concerned	23
Mildly concerned	8
Somewhat concerned	8
Fairly concerned	4
Very concerned	3

Appendix

Working descriptions of input categories used in this study. These descriptions are currently being revised in consultation with experts in the various categories.

1. **No Input**⁵: Many deaf children experience a period of time when they don't have access to any linguistic input. This period ends when the child is first exposed to a sign language or gains access to a spoken language via effective hearing technology.
2. **English without signs**: This means using spoken English without supportive signs, except the gestures that hearing people use naturally. Terms like "auditory-verbal", "auditory-oral", and "listening & spoken language" all refer to this category.
3. **ASL**: American Sign Language, or ASL, is one of at least 200 sign languages that have evolved naturally around the world. It has all the features that linguists expect languages to have, is not based on English, and is usually used without speech.
4. **Sign-supported speech**: Also known as simultaneous communication, or SimCom for short, this means speaking well-formed English sentences while also producing manual signs. These manual signs tend to appear with "content words" more than with "function words". For example, the spoken sentence "The baby is sleeping" might be accompanied by the signs BABY and SLEEP, but not signs for "the" or "-ing". You may have heard the term Total Communication: strictly speaking, that refers to a philosophy where no method is off-limits. In practice, it often looks like what we're calling sign-supported speech.
5. **Manually-coded English**: This category includes systems like Signed Exact English, Seeing Essential English, and other ways of producing signs (usually along with

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⁵ This category is described in the main text and in subsequent work as "Indirect Access".

speech) that don't just include content words, but really make an effort to include function words like "the" and "is", as well as grammatical markings on content words, like "-ing", "-s", and "-ed".

6. **Cued Speech:** Cued speech is another way of representing spoken language on the hands, but instead of representing whole words or grammatical units, it represents different combinations of speech sounds, like syllables. Because many speech sounds look alike to a person who's trying to lipread, Cued Speech uses different handshapes and locations to help the user tell the difference between those similar-looking sounds.
7. **Other Spoken Language:** Many children are exposed to spoken languages other than English, like Spanish, Mandarin, Arabic, and many others.
8. **Other/Unknown:** Finally, many deaf children have complex histories that might not be captured well in the above categories. For example, if children have been adopted or have spent time in foster care, parents may not have any information about their language input during that time. Or maybe they were exposed to an informal gesture system that's used just within the family.