CHAPTER 6

Age of acquisition effects in language development

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The most accessible language for deaf children is generally a sign language, but few children have input in sign languages early in life. Late first-language acquisition of a sign language reveals age of acquisition effects that must be taken into consideration by linguistic theories of acquisition. When deaf children access spoken language through a cochlear implant, age of acquisition effects can again be seen, and the presence or absence of sign language is an important factor in language outcomes. Finally, the development of a sign language as a second language in unique contexts such as that of Christopher, a polyglot savant, can reveal more about the nature of language development and the theories of language structure that must be posited.

1. Introduction

Virtually every child with typical hearing receives accessible linguistic input from birth; indeed, some linguistic information is even available *in utero*, as evidenced from linguistic fine-tuning shown by neonates (e.g., Moon et al., 1993; Partanen et al., 2013). Thus, most research on first language acquisition keeps age-of-exposure as a constant. Nevertheless, researchers have been aware of the possibility of age of acquisition (AoA) effects since at least the 1960's, when Lenneberg (1967) proposed that language acquisition is subject to a *Critical Period.* On Lenneberg's proposal, learning a language after the critical period is over would be a significantly different process from acquisition before its closure.

Lenneberg suggested several types of evidence to support his proposed critical period, including adult second language (L2) learning, and young children's recovery of linguistic function following brain injury. But as for children experiencing variation in the age of first linguistic exposure, Lenneberg had to rely on extreme cases in which many other factors, such as social isolation, are relevant (such as the famous case of Genie; Curtiss et al., 1974).

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In the decades since, it has become apparent that the evidence regarding the critical period hypothesis is much more complex (Mayberry & Kluender, 2018). Studies with adults learning a second language have revealed similarities to first-language acquisition, alongside persistent difficulties which might be attributed to a sensitive period for optimal language development (among many others, see Flege et al., 1999; Johnson & Newport, 1989; Smith, 2002). It has become clear that AoA is but one factor that contributes to linguistic development.

Whether there is a critical period for language acquisition is important for numerous reasons. Some have taken its putative existence as an argument for the existence of an innate language-learning mechanism (e.g., Smith, 2005). However, AoA effects could be related to general neural development and not implicate a domain-specific language acquisition device. The proposal of an innate language learning mechanism does not in itself predict or depend on the existence of critical period effects. Either way, if language learning is substantially a different process at age one compared to age fourteen, theories of language development need to account for this. Practically speaking, knowing the cut-off for a critical period – or more likely, which aspects of language are learned differently at which times – could be an important justification for certain educational approaches, such as those encouraging early bilingualism, and could assist in the design of improved language teaching materials.

With these and other issues in mind, researchers have recently addressed a number of new questions related to possible effects of AoA: questions which are among the many topics that Bencie Woll's work has addressed. In this chapter, we summarize selected aspects of this research, drawing connections to her work and her influence, in acknowledgment of the great contribution that her studies have made. We start with relevant background on the critical period hypothesis and on modality effects in language acquisition in Section 2.

It is not possible to ask about potential effects of differences in the age of first linguistic exposure for hearing children, since input in at least one language is available from birth. However, many children who are born deaf are in exactly this situation: at birth, there is no accessible linguistic input presented to them, since they cannot readily access spoken language and the vast majority of children born deaf have hearing, non-signing parents (Mitchell & Karchmer, 2004 estimate that at most 5% of deaf children in the U.S. are born to signing parents). Even if children have extensive interactions with loving parents, it may take years before accessible input is available.

Given this general context, researchers have used variation in age of language access to address questions about possible effects of the AoA of a first language. We start with the cases in which this late first language is a natural sign language. For many deaf people, following a lack of success in learning a spoken language despite oral training, exposure to a natural sign language commences. How that language develops, where modality effects might be seen, and consequences of linguistic delay on both structure and processing will be the topic of the third section of this chapter.

Over the past few decades, the linguistic environment for deaf children has changed substantially, due to the increasing sophistication and availability of hearing technology, such as hearing aids and especially cochlear implants. Nevertheless, cochlear implants have not eliminated possible linguistic effects of deafness, since even very early-implanted infants experience some delay of linguistic input, and the result of implantation is not natural spoken language acquisition but requires extensive training. There is considerable variability in the linguistic outcomes of children who have received cochlear implants (Bruijnzeel et al., 2016; Niparko et al., 2010), some of which may be related to variation in the age of exposure following activation. Effects of AoA for spoken language development in deaf cochlear implant users will be summarized in the fourth section.

Finally, we look at the unique case of the acquisition of a sign language by a linguistic savant. Christopher shows that even in adulthood, there are aspects of language that he can learn easily. However, the linguistic domains of relative strength and weakness for him reveal potential age effects and effects of the linguistic modality. These factors can interact with age in a way that presents great difficulties for adult learners. These findings will be discussed in the fifth section. We will conclude with some implications and connections to Bencie Woll's influence.

2. Background

2.1 Language domains and critical period effects

The consensus of researchers is that talk of 'a critical period' is too simplistic: there is evidence for more than one critical period, as shown by some of Bencie Woll's work (e.g. Woll & Morgan, 2002, p. 292), where the issue is raised whether "the critical periods for native-like acquisition of signed and spoken languages" are identical; and by some of our own work (Berk & Lillo-Martin, 2012; Smith & Tsimpli, 1995; Smith et al., 2011). There are, moreover, partially overlapping critical periods for syntax and phonology and, we contend, a critical period for the acquisition of the core vocabulary of the lexicon (*near*, *go*, *table*, *moon*, *out*, *off*, etc. as opposed to *circumnavigate*, *economy*, *esoteric* and so on). If this claim is correct, it suggests that second language vocabulary is partly calqued on the first language's vocabulary, with the result that learners find it difficult to master subtle differences between 'equivalent' (or cognate) lexical items in their first and subsequent languages. For example, speakers of Hindi where the word for 'hand' ([ha:th]) includes the fore-arm and the word for 'foot' ([per]) includes the lower leg, may persist in giving the English translations the same extended meaning despite explicit teaching.

Nonetheless, the domain of the Critical Period is quintessentially syntax, which is also the primary locus of parametric variation (Baker, 2008).[1] However, parametric differences can regulate overarching or more detailed properties of language, referred to as macroparameters and microparameters respectively (Biberauer, 2008; Roberts & Holmberg, 2010). Each macroparameter is associated with a number of microparameters which allow for variation within the same macro-type. For example, the OV/VO distinction and the Verb-Second rule (V2) of Germanic languages are macroparameters associated with microparametric options distinguishing further among head-final, V2 languages (Haider, 2012) and are usually associated with morphological distinctions. From this perspective, macroparameters and their associated microparametric options determine the core components of each language.

In monolingual development, the phenomena which are acquired earliest belong to the core and are narrowly syntactic. In first language acquisition, macroparameters are acquired only slightly earlier than microparameters; in second language acquisition, the distinction between macro- and microparameters is more evident and could be associated with age or Critical Period effects (Tsimpli, 2014). Specifically, late bilinguals seem to have problems with the microparametric properties of the core system rather than the macroparametric ones (Kroffke & Rothweiler, 2006). This is mostly due to the *dissociation* between the development of syntax and morphology in second language grammars which has been argued for on theoretical and empirical grounds (Lardiere, 1998; Schwartz, 2009; Smith & Tsimpli, 1995). Thus, although morphology and syntax develop concurrently in L1 acquisition, adult L2 acquisition may show better syntactic than morphological abilities.

2.2 Modality effects and age effects

For the very small percentage of deaf children who acquire a sign language as a native language by exposure from their signing parents, the overall course of language development can be described as parallel to that observed for children acquiring a spoken language (for an overview see Chen Pichler et al., 2018). This population – like those children developing spoken languages – shows no variation

1. The conjecture limits syntactic variation to formal features of functional categories and would not include the kind of Hindi example we mentioned above.

in age of exposure, hence no age-of-acquisition effects. However, this is not to say that there are absolutely no differences between acquiring a sign language and acquiring a spoken language; there are significant differences in the modality of sign and spoken languages which can lead to *modality effects* in acquisition. As we discuss potential age of acquisition effects in this chapter, we will attempt to contrast them with potential modality effects, to better understand how these factors may interact.

The first, most apparent modality effect is that sign languages are produced using the hands, face, and body, and perceived through the eyes, while spoken languages are produced using the vocal tract and perceived primarily through the ears (though visual perception of spoken language is also important; see, e.g., Massaro & Simpson, 1987). Thus, signs are generally described by specifying (at least) their handshape, the location in which the sign is made, and the movement of the sign. In addition, certain facial expressions and head positions are associated with various types of linguistic information, including intonational marking of information/discourse structure, adverbials, and negation. This distinction between signed and spoken words, while a surface difference, is relevant to multiple aspects of native first-language acquisition, and potentially to age-of-acquisition effects.

For example, because the manual articulators develop more quickly than the vocal ones, it is possible for signing children to produce recognizable signs somewhat earlier than the first spoken words are produced. Exactly how much difference there is has been debated, but there is arguably at least a one-to two-month difference in the average age of first signs versus first words (Meier & Newport, 1990). In addition, the form of the early signs may differ from adult forms in ways that are determined by modality (Meier et al., 2008). Children's first signed or spoken words show effects of their still-developing phonology and the articulatory control needed. In spoken languages, this can be realized by replacement of certain (marked) phonemes by others (unmarked), change in the number of syllables produced, consonant cluster reduction, and the like. In sign languages, marked handshapes (such as ) may be replaced by unmarked ones (such as ); joints proximal to the body (shoulder, elbow) may be used when the target requires joints farther from the body (wrist, knuckles), resulting in signs appearing larger; and the child's production may contain a different number of syllables from the adult target. As these descriptions indicate, similar underlying processes can be implicated in a number of cases, but the differences in spoken and sign language development are still tied to differences in the modality of production.

When sign linguists list the modality-based differences between sign languages and spoken languages, they go beyond the surface fact of hands vs. mouth, because modality differences are indeed deeper (e.g., Meier et al., 2002). A compelling and still not fully understood modality difference has to do with the way that 'signing space' is used. While spoken words are uttered in a sequential stream and signs are also uttered in sequence, the signs add a spatial dimension. It has already been mentioned that a sign's location is part of its necessary description. However, when signs are produced in 'neutral space' in front of the signer, additional distinctions can be made, so that spatial differences correspond to verb argument structure, complex representations of motion or spatial descriptions, contrast, and numerous other functions. Because several of these spatially realized differences have been analysed as involving complex morphology, a number of studies of early and later language development have concentrated on them. We will expand on these areas of potential modality effects as we come to studies for which they are relevant in the following sub-sections.

How, then, can we take potential modality effects into consideration while we look at putative effects of age of acquisition? First, we can keep in mind that surface differences in the production of sign versus speech might be relevant. Second, we can look at phenomena that relate to modality differences, such as the use of space, and ask how learners with varied types of experiences do with these phenomena, in comparison (when possible) to other learners and other phenomena. While there are very few studies that can be used to compare effects of age of first-language acquisition of a sign language to a spoken language, as would be necessary to definitively attribute some effect to modality versus age, we will bring up the modality issue throughout this chapter to keep it in the forefront of our consideration.

3. Late L1 acquisition of sign languages

When a deaf child is born to hearing parents who do not sign, some time is needed for parents to adjust, decide how they want to communicate with their child, and begin to learn how to implement their decision (Young & Tattersall, 2007). If the parents choose to expose their child to a sign language and learn to sign themselves, it will take time for them to do this, and their early efforts will be quite limited; but once a child is exposed to a natural sign language that input will be immediately accessible. If the parents choose to use speech only (possibly with hearing technology for the child), the child will watch their parents' faces as they speak as infants generally do (Dodd, 1979), but the input they receive will be limited; speech training will begin at some point but there will inevitably be some delay, and in some cases, children will subsequently learn a sign language.

A few studies have looked at the course of sign language development by deaf children once they begin to have delayed exposure to a natural sign language. One such study looked at two unrelated deaf children (called Mei and Cal in the literature) who started attending a residential school for the Deaf in the United States around the age of 5–6 years, having had no accessible linguistic input prior to their enrolment (Berk, 2003). This study followed the children for four years, using repeated longitudinal collection of spontaneous production data, as they interacted with a Deaf native signer who provided their primary input in American Sign Language (ASL).

A number of findings about the course of delayed language development emerged from this study. One point was that the children both went through a two-word stage of the type that very young language learners typically do (Berk & Lillo-Martin, 2012); this observation implies that the two-word stage is a function of linguistic development rather than chronological age per se. A separate study of teenage late learners of ASL found the same thing (Ferjan Ramirez et al., 2013).

Within the domain of morphology, a very interesting contrast was observed in the study of Mei and Cal. Mei and Cal displayed a remarkable asymmetry in their use of signing space, not observed in native signers with input from birth. For some verbs, such as HELP,[2] GIVE, SHOW, and ASK, the way they move in space represents the referents involved in an event described by the verb. This use of space is called verb agreement or person marking in much of the sign language literature (see Lillo-Martin & Meier, 2011). Other verbs, known as spatial or locative agreeing verbs (Padden, 1983), including GO, COME, BRING, and MOVE, indicate not their arguments, but the location(s) of the events they denote.

The two uses of space for person agreement and locative agreement look very similar: both involve movement of a verb sign from one location to another. Both also require the locations in space to be associated with their person or locative referents – either because the referent is actually physically there, or through a linguistic association. However, they function differently in several grammatical ways. For Mei and Cal, the two types of space were learned in different ways: both children were able to use signing space correctly with spatial verbs, and both made many errors with person agreeing verbs. Their errors included some failures to use person agreement where it is required as well as some instances of using the wrong location – somewhat analogous to English-speaking children dropping required inflection ('he run') or supplying the incorrect form ('I runs'). They did not improve in their use of space with person agreeing verbs even over the four years of observation

Difficulties with the use of space have been reported in other studies of late learners as well, including those by Newport (1990) and Emmorey et al. (1995), though these studies did not distinguish between person-agreeing and spatial

2. As is common in sign linguistics, we use English glosses written in upper case to represent signs that have an overlapping range of meaning.

verbs. We will come back to this commonality after summarizing other findings from late learners.

Ferjan Ramirez et al. (2013) report on early stages of acquisition of ASL by three deaf late first-language learners (Shawna, Cody and Carlos) whose exposure began during adolescence (around age 14, tested after 12–24 months of exposure). They measured the learners' vocabulary using the ASL version of the MacArthur-Bates Communicative Development Inventory (Anderson & Reilly, 2002), and found that their vocabulary size was larger than the norms for typically-developing native ASL signing children with the same length of exposure. Interestingly, the learners showed evidence of discussing concepts that typical 2-year-old learners do not yet know, like computers, sports, and distant events, such as a volcano eruption they learned about at school. They also found that the mean length of utterance (MLU) of the learners was between 2 and 3, which is comparable to native signers between the ages of 1 and 2 years. In many ways these results are comparable to those found by Berk & Lillo-Martin (2012), indicating that at the early stages of acquisition at least, progression is similar whether the delay is relatively less (5–6 years) or more (14 years).

While the studies just summarized examined the first years following immersion in a sign language, a number of studies have looked at adults with decades of experience using a sign language as their primary language. These studies compare adults who had, long before, experienced their first accessible linguistic input at various ages. While many of them might have been in oral-language-based educational programs before they were exposed to a sign language, their development of spoken language was so limited that they are generally considered to be late learners of a first language.

One study (Newport, 1990) looked at performance on a number of ASL tasks by adults in three groups: native signers, whose exposure began from birth, 'early' signers, whose exposure began around the ages of 4–6 years (note that this is the age of exposure for Mei and Cal), and 'late' signers, whose exposure began only after the age of 12 years (the age of exposure for Shawna, Cody and Carlos). Among the assessments these participants took, one was a test of basic word order, which in ASL is Subject – Verb – Object. All three groups, native, early, and late-exposed participants, scored fairly high on this assessment. However, the groups differed in a series of other tests, with the native signers scoring highest, the early learners scoring significantly lower than the native signers, and the late learners scoring significantly lower than the early signers. These tests looked at various aspects of ASL morphology, including verb agreement, and verbs of motion and location, or classifiers. The contrast between performance on basic word order and complex morphology could be a parallel to the proposed Critical Period distinction between macroparameters and microparameters mentioned in

Section 2.1, although the contrast has not been discussed in these terms and more work would be needed to see whether these categories are appropriate for the sign language phenomena.

ASL classifiers are of some interest because of the persistent challenges they pose for learners. Although there is debate about how best to analyse these structures (see papers in Emmorey, 2003), a general, simplified description is as follows. The handshape, which in non-classifier signs is a meaningless component, is chosen to represent a class of referents, such as upright animate beings, vehicles, or long thin objects. This referent might be the subject, object, or instrument of an event which is conveyed through the movement through space of the hand. In order to use a classifier construction accurately, the signer must choose the appropriate handshape for the referent, and produce the movement in such a way as to convey the movement of an entity (possibly between a source and a goal) along with its path and manner. Native signing children begin to use classifiers at an early age (Slobin et al., 2003), but they do not perform at adult-like levels until they are much older (Schick, 1990, among others). Later learners seem to have particular difficulties with tests of their production or comprehension of classifiers. Both the 'early' group and the 'late' group of non-native signers performed much worse than native signers on such structures (Newport, 1990).

A study of two adolescent late learners by Morford (2003) also bears on this issue. She studied two learners, Maria and Marcus, who were 12–14 years old when they were first immersed in ASL. In their first few years of exposure to ASL, both learners began using classifier constructions, but they made errors in their choice of handshape and/or in the accuracy of the movement. When their comprehension was tested 7 years after exposure, both learners performed quite poorly (around chance) at normal processing levels. However, when the learners were allowed to view stimulus videos multiple times and at slow speeds, their performance increased dramatically. This indicates that at least some of the difficulty experienced by late learners might be related to phonological processing issues.

That phonological processing is a particular challenge for late learners is supported by a number of other studies. Mayberry (2010) and Mayberry and Kluender (2018) review a series of studies that were conducted with adults who had been late learners (generally with acquisition starting in adolescence). These participants are long-time users of ASL, but differences between them and native signers have been shown on tests including narrative shadowing and sentence recall. Strikingly, tests of late second-language learners of ASL (participants who became deaf and learned to sign after having learned a spoken language with normal hearing) show much better performance than late first-language learners, indicating that the possible critical period effects for language learning are much different for first-versus second-language learners. As might be expected, these late learners also showed particular problems with ASL morphology, including verb agreement and classifiers.

In one of the few studies that focus on syntactic knowledge as well as ASL morphology, Boudreault and Mayberry (2006) tested native signers, early learners, and delayed learners using a grammaticality judgment task with sentences of differing levels of complexity, including WH-questions and relative clauses, as well as sentences with verb agreement and classifiers. They found that late learners performed significantly worse than native signers overall. Interestingly, the pattern of responses across different types was similar for the three groups, with all groups performing worst on the relative clause sentences.

Cormier et al. (2012) raised a question about the results presented by Boudreault and Mayberry. Since the participants in their study had been involved in oral educational programs prior to their immersion in ASL, it might have been possible that they had learned some English as a first language, so that their ASL results actually reflect L2 learning. This possibility can be discounted for the studies that test the early stages of acquisition (e.g., Berk & Lillo-Martin, 2012; Morford, 2003; Ferjan Ramirez et al., 2013), since the level of learners' knowledge of a spoken/written language at the time of immersion is virtually nil. To address this possibility, Cormier et al. replicated the Boudreault & Mayberry study with signers of British Sign Language (BSL), but also assessed their English knowledge at the time of testing. In this way, they could factor out English reading level in their analyses of the participants' scores on the BSL grammaticality judgment task.

Cormier et al. (2012) found that their delayed learner group (reported immersion in BSL between 9 and 18 years of age) scored significantly higher on the reading test than the early learner group (BSL exposure beginning between 2 and 8). This suggests that the late learner group had some competence in English as an L1 and learned BSL as an L2. This might relate to the result that only the early learner group (not the late learners) showed a decrease in accuracy on the grammaticality judgment task as their age of first exposure to BSL increased.

The proposal by Cormier et al. (2012) that (at least some) participants who are classified as late L1 learners of a sign language might actually be L2 learners should be considered when evaluating suggestions that learners like Shawna, Cody and Carlos are more severely affected by their late exposure than learners who were in oral educational programs (Mayberry & Kluender, 2018). It is impossible to know without a decades-long longitudinal study, but the possibility remains that the majority of late learners in most research studies have a slight advantage, with at least some aspects of language accessed before their exposure to sign language. The widespread differences between such participants and native signers (or late known L2 signers) indicate, however, that whatever might have been gained before exposure to a sign language did not suffice to serve as equivalent to a full natural first-language, whether signed or spoken.

To sum up, a series of studies have indicated that delayed exposure to language for children born deaf will have profound consequences on language development which persist into adulthood. While the effects are widespread, they are not uniform; there is evidence that some areas of language are more severely affected than others. We have raised the possibility that the distinction between areas more and less severely affected would correspond to the distinction between macroparameters and microparameters that has been proposed to account for differences in L2 acquisition effects. In particular, the relative sparing of word order in simple sentences versus the greater difficulty with more complex syntax (such as ones with relative clauses) is potentially compatible with this division. It remains to be seen whether the distinction between spatial and person agreeing verbs observed by Berk (2003) is – if replicated – also amenable to such an explanation.

4. Deaf children with cochlear implants

The studies reviewed in the previous section demonstrated that delayed exposure to a sign language as a first language can have serious, long-lasting effects on linguistic development and processing. Many deaf children are likely to face such delay while parents learn to sign and/or the child's educational placement provides sign input. But in the past few decades, the options for deaf children have expanded with the introduction of paediatric cochlear implantation and universal new-born hearing screening leading to early identification and intervention (Yoshinaga-Itano, 2009). Does the introduction of a cochlear implant and subsequent spoken language development alleviate the challenges children face in delayed language acquisition?

Although cochlear implants are increasingly recommended at earlier ages, with many children receiving surgery even before 12 months, there is still a time-period during which deaf children cannot readily access spoken language before the implant is inserted and activated (Levine et al., 2016). Much research has observed that even when participants are chosen from those with the greatest likelihood of success with a cochlear implant, results are quite variable. Even for those who received their implants before 18 months of age, three years later the mean of their expressive and receptive language scores was equivalent to hearing children two years younger, with a large variation (Niparko et al., 2010). While it is clear that results are better for those implanted in the first few years, what accounts for the range of results even within the early-implant group?

Some researchers have argued that exposure to a visual language before implantation and/or during rehabilitation contributes to lower levels of success (e.g. Geers et al., 2017). There have been a number of studies that compare spoken language outcomes in deaf children who have received CIs and then been educated using oral only approaches vs. those who have had some amount of sign language and/or visual linguistic input (e.g., cued speech). The results are mixed; some show equivalent outcomes (e.g., Jiménez et al., 2009), others show an advantage for oral only (e.g., Peterson et al., 2010). However, these studies almost never measure the quality or quantity of the visual language input or the child's development of sign; they simply group together all children who have had any amount of visual input (Caselli et al., 2017). What are the findings if children's sign proficiency is also considered?

In a very few studies, the children's proficiency in sign language is measured or can be assumed. Hassanzadeh (2012) and Davidson et al. (2014) tested spoken language outcomes in deaf children from deaf, signing families, after the children had received cochlear implants. Both studies found that these participants showed much better spoken language development (in Persian, Hassanzadeh; or in English, Davidson et al.) in comparison to non-signing deaf CI users. Davidson et al. furthermore found that the native signers showed (chronological) age-appropriate scores on standardized tests, which were not distinct from the scores of hearing children of deaf parents.

Despite the suggestive results from native signers, some researchers have maintained that exposure to sign language is deleterious for spoken language development in cochlear-implanted children (e.g., Geers et al., 2017). They argue that visual linguistic input leads to take-over of auditory neural areas, which subsequent auditory input through the implant cannot override. Two papers from Woll and her colleagues review the evidence and make a strong case against this conclusion (Lyness et al., 2013; Campbell et al., 2014).

First, it is important to point out two observations about neural areas for language processing: (a) brain areas used for sign language largely overlap with those used for spoken language; (b) spoken language processing itself is multi-modal, with a significant role of vision. Neural areas for language are known to be multi-modal (or amodal) (see also Cardin et al., Chapter 9 of this volume). As for the primary auditory areas, Lyness et al. (2013) and Campbell et al. (2014) review studies that have purported to find dystrophic processing due to visual stimulation, and conclude that there is no convincing evidence for such an effect. Campbell et al. (2014, p. 8) conclude that disordered cortical circuitry which has been observed is "more likely to be associated with disordered language learning in the sensitive early years," since auditory deprivation and language deprivation are typically confounded. Lyness et al. (2013) suggest that when children do receive accessible visual language input in the early period, normal development of amodal brain areas for language will take place, and that this is crucial for brain readiness for spoken language after implantation.

The conclusion by Campbell et al. (2014) and Lyness et al. (2013) is that differences in how the brain processes language between deaf CI users and hearing non-signers are more likely to be due to delayed linguistic exposure in the former and not specifically their lack of auditory input or their exposure to visual language input. Since the age of implantation is now increasingly younger, such a result indicates that some critical period(s) close off at a very early age, even if some language development is still achieved by learners with exposure at early school age or even adolescence. What properties of language crucially require input in the first year of life?

The most likely conclusion is that the optimal period to begin language exposure is right after birth, because important perceptual processes for both spoken language and sign language develop during this time (e.g., Werker & Tees, 1984; Stone et al., 2017). As Morford and Mayberry (2000) have argued, phonological development typically takes place in this first year, and delays or disruptions in this development will have cascading effects in other linguistic domains. The longer accessible input is delayed, the more profound these effects are.

So far, we have seen clear evidence for effects of the age of acquisition of a sign language for those born deaf, for whom spoken language development cannot take place in the typical way. What kinds of effects might be found in those children or adults who are learning a sign language as a second language? While there is relatively less research in this area, one point that is clear is that modality effects must be taken into consideration, since most learners of a sign language as L2 are also learning a language in a new modality, or M2 (Chen Picher, 2012; Chen Pichler & Koulidobrova, 2015). To what extent do M2L2 learners transfer linguistic knowledge from their L1, as spoken language L2 learners frequently do? Do M2L2 learners show Critical Period effects such as those discussed in Section 2.1, distinguishing between macroparameters and microparameters? It is not possible to answer such questions for typical adult M2L2 learners here, but they can be addressed from the point of view of an atypical learner: Christopher, a linguistic savant who learned BSL.

5. Sign language acquisition in an atypical case: What Christopher can tell us

Christopher, born in January 1962, is an individual who has been institutionalized all his adult life because he is unable to look after himself. His case demonstrates an asymmetrical pattern between cognition and language with the latter spared in comparison with the former. On standardized measures of non-verbal cognition he scores between 40 and 75, while his verbal abilities are within the upper range of the scale (O'Connor & Hermelin, 1991; Smith & Tsimpli, 1995; and references therein).

Christopher's profile becomes unique when one turns to language. Apart from English, his native language, Christopher speaks and/or understands twenty other languages to different degrees. His language learning abilities exhibit an extremely fast and accurate pattern mostly for languages which have a written form, although his ability to learn signed languages lacking written feedback, while weaker overall, still reveals a special talent for language compared to non-verbal abilities (Smith et al., 2011).

An in-depth investigation of his linguistic abilities reveals further asymmetries *within* his languages. Starting with English, Christopher's mastery of morphology and vocabulary are intact, but his syntactic abilities show a diverse pattern. For instance, although subordination, in the form of relative and adverbial clauses, interrogatives and parasitic gaps, is clearly part of Christopher's native grammar, topicalisation and left-dislocation are not. He does not use these constructions himself and rejects examples of them produced by others as ungrammatical. Other aspects of his language performance are also affected in apparently different ways. For instance, Christopher's translations into English (from a variety of languages) occasionally fail to meet criteria of coherence and pragmatic plausibility; interpreting non-literal language can also be distressing. Smith et al. (2011) have interpreted these findings as reflecting a demarcation between structures which reflect higher and lower discourse-sensitivity. The contrast is then between the intact status of 'formal' aspects of Christopher's English on the one hand, and discourse-related structures which are affected for independent reasons, such as his communication deficit, on the other. Christopher's performance on comparable discourse-sensitive structures in his other L2s (e.g. Greek, French, Spanish) is also problematic, presumably for similar pragmatic reasons (Smith & Tsimpli, 1995).

BSL also fits this overall picture: Christopher's mastery of the formal side of BSL – the morphology and syntax – is superior to his use of BSL for communication. Christopher's performance on BSL becomes more impressive when one considers his severe apraxia, his limited visuo-spatial, kinaesthetic and social abilities. BSL was the first signed language he was exposed to, and as he was explicitly instructed in BSL (rather late considering the other languages he learned), it was clearly a 'foreign' language to him. Nevertheless, Christopher's learning of BSL was within the same range of achievement as that of a comparison group of university undergraduates given the same syllabus.

In order to address possible critical period effects in Christopher's acquisition of second languages we can exclude pragmatically-relevant syntactic structures, as these require the integration of macroparametric and microparametric properties with discourse-related information, external to the language core. We can thus directly compare Christopher's mastery of formal properties of his L1 with those of his L2s, signed and spoken. As both BSL and all of his 'second' spoken languages were taught either in adolescence or in adulthood they qualify as 'late' L2s, i.e. languages acquired post-critical period. Apart from L1 vs. L2 syntax, we can also focus on similarities and differences in morphology and the lexicon of Christopher's BSL and spoken languages to identify candidate areas for critical period effects.

The evidence: Christopher's signed and spoken languages

A dissociation between syntax and morphology has been attested in second language grammars. Christopher's language learning in general also shows such a dissociation, although his profile goes the opposite way: he excels at morphology (however complex – e.g. he coped easily and enthusiastically with the morphology of Berber), and at the lexicon (his vocabulary in 20 languages is remarkable) while his L2 syntax rapidly reaches a plateau beyond which he is unable to progress. In all, Christopher's spoken L2s diverge from the average L2 learner who, with exposure, is expected to perceive, accept and eventually produce structures that do not exist in the L1. Christopher's L2 syntax was different from his English L1 mostly in cases when L2 morphology – which was easily mastered – allowed him to infer syntactic properties. In this respect, we can suggest that critical period effects are responsible for blocking some aspects of L2 syntactic development which in the typical L2 learner may be circumvented by employing compensatory linguistic or cognitive mechanisms (Smith & Tsimpli, 1995; Hawkins & Hattori, 2006; Tsimpli & Dimitrakopoulou, 2007).

The situation becomes more complex when we turn to the signed modality. Despite his (mild) autism and consequent reluctance to make eye contact, Christopher learned BSL to a standard comparable with a comparison group of talented second language learners in comprehension tasks (comprehension is the appropriate measure since production was compromised by his severe apraxia). Apart from being taught and tested on the lexicon of BSL, Christopher and the comparison group were exposed to negative and interrogative sentences, subject and object agreement verbs and classifiers encoding spatial relations.

The main asymmetry observed in Christopher's performance was between classifier predicates, a structure in which most of the comparison group performed very well, and the other syntactic structures in which he was similar to the other participants, albeit at the lower end of the range. Notably, Christopher showed minimal transfer effects from English on BSL sign order in interrogative, declarative and negative sentences, a remarkable difference from all of his other spoken languages for which English word order is his preferred choice. Despite the fact that his BSL production was very limited, Christopher exhibited good progress in developing knowledge of the BSL syntax of negation, less so in verbs encoding subject and object agreement such as GIVE, ASK, LOOK, HELP, TEACH, etc., and most poorly in classifier predicates encoding spatial relations. His inability to process and judge spatial information with classifier predicates stands in contrast with the performance of deaf late language learners and of the hearing learners of BSL included in the comparison group of the study.

We have proposed that the gradual decline in Christopher's performance in the three structures (negation, agreement, classifiers) could be explained by comparing the contribution of spatial processing to linguistic processing in each case (Smith et al., 2011, p. 167). Given Christopher's deficit in visuo-spatial processing, it is inevitable that higher demands on linguistic processing would accrue in classifier structures encoding spatial relations followed by subject-and-object agreement predicates. If our analysis is correct, then the signed modality affected Christopher's development of BSL morpho-syntax in specific structures, something that we had not observed in his spoken languages even when the linguistic representation encoded spatial relations. The lack of a written form of BSL input also deprived him of the opportunity to detect morphological information and develop the same level of morphological awareness he appears to have in his spoken L2s. Modality effects were also found in Christopher's performance on the BSL lexicon where iconicity did not seem to facilitate his recognition of signs as it did in many participants of the comparison group (Smith et al., 2011, p. 186).

Overall, Christopher's learning of BSL revealed three areas where modality seemed to affect performance positively or negatively. Positive effects of the signed modality were found in the absence of negative transfer effects from English on the sign order in his BSL sentences. While it is not clear what it is about the modality of sign languages that should lead to such an effect, the fact that this pattern was distinct from his performance on all spoken languages leads us to consider it a modality effect. An unexpected absence of modality effects was attested in the acquisition of the sign lexicon where iconicity did not seem to improve his performance, unlike what we found in every member of the comparison group. Finally, negative effects of the signed modality were found in the acquisition of classifier predicates where Christopher clearly struggled, unlike the other BSL learners, but like the late L1 learners of ASL discussed in Section 3.

Christopher is not like a typical L2 learner either in his spoken or signed languages. His profile is better than the average L2 learner's in the very fast and accurate development of the L2 lexicon and morphology and worse in that core syntactic structures seem to stagnate. The overpowering influence of his English L1 on his spoken languages indicates that not just complex syntax but also main parametric properties of the macro- and micro-type are problematic for Christopher. Whether this is an indication of a selective critical period effect on L2 acquisition remains an open question.

6. Conclusions and implications

We have reported several domains in which effects of the age of acquisition of a language can be observed, and a hypothesis about how critical periods for language dissociate different linguistic components. Further work is needed to test the hypothesized distinctions more thoroughly, particularly in the context of sign language acquisition (as late L1 or M2L2). In particular, late L1 learners may have a broader range of effects, which are more pronounced the longer the period of language deprivation extends. Which properties can still be learned for late L1 learners (core vocabulary, simple syntax?), and how they relate to common difficulties for L2 and M2L2 learners will be a persistent area of research (cf. Mayberry & Kluender, 2018). Furthermore, the observation that difficulties in spatial aspects of BSL might be related to more general visual-spatial problems for Christopher leads to the possibility that similar difficulties in late L1 learners call for testing of general visual-spatial abilities.

Special circumstances of language learning allow for extensive testing of theoretical proposals about critical periods, something that continues to be of great interest. We see Bencie Woll's contributions to critical period research as promoting such theoretical questions, but more importantly, she also stressed the practical issue of language access for deaf children. In this domain, we fully agree with the conclusions that Campbell et al. (2014, p. 8) come to:

> good first language acquisition within the early years, however that may be achieved, may be the best predictor of successful language outcome for the child born deaf.

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