Linguistically deprived children: meta-analysis of published research indicates *mental synthesis disability* – implications for novel intervention strategies for children with language delay

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Introduction

• Most researchers believe that there is a strong association between early language acquisition and normal cognitive development (critical period hypothesis, Lenneberg, 1967); however, there is no consensus on the neurological mechanism of this association.
• We analyzed published reports of children who grew up without exposure to formal language, such as *feral children,* and *deaf linguistic isolates,* since these cases present a rare opportunity to study the effect of syntactic language on the developing brain.
• *Feral children* grow up in an isolated environment, with little or no exposure to human language (see the case of Genie and Victor of Aveyron).
• *Deaf linguistic isolates* grow up communicating to their families using homesign, a system of iconic gestures which is typical of families that live isolated from a sign language community, and which often develops spontaneously between deaf children and their hearing parents. This type of communication consists of simple commands but lacks much in the way of syntax.

Materials and Methods

• We analyzed all published reports of individuals not exposed to a syntactic language until puberty, who were subsequently tested as adults following several years of rehabilitation: two reports of feral children and eight reports of deaf linguistic isolates.
• All tests performed on these individuals were sorted by how much these tasks rely on the ability to create and inspect *novel* mental images.
• For example, tasks of vocabulary comprehension do not require creating any novel mental images. On the other hand, a subject's ability to follow the direction of "putting the bowl on top of the cup," hinges not only on their ability to recognize the words "bowl" and "cup" (simple task) but also to imagine the two objects in the correct and novel spatial configuration (complex task). Someone who cannot simulate the process mentally, would have no mental image of a bowl on top of a cup and would therefore just use trial-and-error and place the cup and bowl into a random (and likely incorrect) arrangement.
• We call the cognitive process of actively creating *novel* mental images - *mental synthesis*

Clinical outcome of syntactic language deprivation

• According to our analysis, feral children and deaf linguistic isolates performed poorly in all of the more complex tests that require mental synthesis.
• The consistent observation of *mental synthesis disability* within these individuals stands in stark contrast to their performance on memory as well as semantic tests: these individuals could easily remember hundreds of newly learned words and recall previously seen images from memory but had real difficulty in any tasks requiring them to mentally combine these images into novel configurations.
• **Conclusion: exposure to syntactic language (as opposed to homesign that lacks syntax) during the critical period is essential for development of *mental synthesis*.**

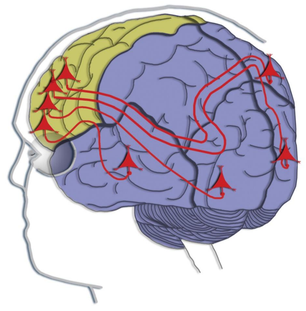
Reduced connectivity between brain areas

• Myelination and electrophysiological studies suggest that the likely problem of linguistically deprived children is the reduced connectivity between the PFC and the posterior cortex.
• The PFC-posterior cortex connection model indicates that syntactic language exercises in neurotypical children, which include pretend play, fantasizing, exposure to fictional stories and complex conversations, etc., provide the necessary input for fine-tuning those connections.
• The model predicts that *mental synthesis* relies on synchronous networks, whereby fiber conduction velocity is equilibrated by increased myelination of longer fibers (see Fig.).
• A lack of exposure to a syntactic language before the end of the critical period appears to result in reduced myelination and asynchronous connections between the PFC and the posterior cortex.
• Exposure to a syntactic language past the critical period can improve semantic content, but it has little effect on the cognitive problem of *mental synthesis disability*.
• Thus, it is very important to develop mental synthesis before the end of critical period.

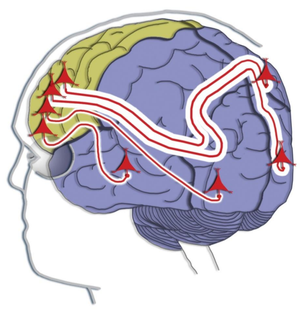
Tests require Less Mental Synthesis ↑ More Mental Synthesis ↓

	TESTS \ SUBJECTS	Genie (1970) (Curtiss S, 1977, 1981)	Victor of Aveyron (1797)	E.M. (Grimshaw GM, 1998)	Chelsea (Curtiss S, 1988)	Maria & Marcus (Morford J, 2003)	I.C. (Hyde DC, 2011)	Shawna, Cody and Carlos (Ramírez NF, 2012)
1	**Learning vocabulary, semantic acquisition, naming items, good memory of images and words**	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2	**Talking about nonpresent people and objects**	Yes	No data	No data	No data	Yes	No data	Yes
3	**Singular vs plural:** e.g. 'Show me the flowers.'	Yes	No data	Yes	No data	No data	No data	No data
4	**Comparative:** e.g. 'Which button is smaller?'	Yes	No data	Yes	No data	No data	No data	No data
5	**Copying stick and block structures**	Yes	No data	No data	Yes	No data	No data	No data
6	**Representational drawing**	Yes, at a 6- to 7-year level	No data	No data	"Yes. Though she manifested a small degree of left neglect in some of her drawings" (CS)	No data	No data	No data
7	**Picture arrangement into a story**	Yes	No data	Deficit	Deficit. "She didn't perform as well as Genie on such tasks, but she could put picture sequences into a logical sequence" (CS)	No data	No data	No data
8	**Understanding of simple negation:** e.g. a subjects was asked to indicate a picture in which the rabbit does not have a carrot	Yes	No data	No	No data	No data	No data	No data
9	**Integration of modifiers:** e.g. 'Point to the {big/little} + (yellow/red} + {circle/triangle/square}.'	Yes	No data	Inconsistent	No data	No data	No data	No data
10	**Superlative:** e.g. 'Which button is smallest out of five?'	Inconsistent	No data	Inconsistent	No data	No data	No data	No data
11	**Possessive pronouns: my, your, our, his/her, and theirs:** e.g. 'Show me your nose.'	Appeared to comprehend my and your, but had difficulty with all other possessives.	No data	Difficulty only with the plural pronouns our and their	No data	No data	No data	No data
12	**Pronouns:** e.g. 'Show me, she is feeding him.'	Inconsistent	No data	Inconsistent	No data	No data	No data	No data
13	**Understanding of spatial prepositions such as in, on, under, over, beside, in front of, behind, etc.**	No	No data	No	"No. She did not appear to comprehend (or use) such elements" (CS)	No data	No. IC was unable to use spatial signs (left/right, on top of/underneath) to describe the relationship between the objects.	No data
14	**Before/after word order:** e.g. 'Touch your nose after you touch your head.'	No data	No data	No	No data	No data	No data	No data
15	**Active vs. passive:** e.g. 'The boy is pulling the girls' VERSUS 'The girl is pulled by the boy'	No	No data	No data	No data	No data	No data	No data
16	**Understanding of complex syntax (verb tense, word order)**	No	No	No	No	Barely above chance level; performance improved when participants were allowed to review the topic sentence an unlimited number of times	No data	Despite their age, their utterances were neither long nor complex, never used lexical items indicating subordination or conditionals, and never used inflected verbs
17	**Exact arithmetic abilities:** mental two-digit addition / multiplication	No data	No data	No data	No data	No data	No	No data

Reduced myelination in linguistically deprived children



Linguistically deprived children end up with asynchronous connections



Neurotypical children use syntactic language to fine-tune their connections

Compiled from "On The Origin Of The Human Mind," 2nd edition. A free download of the complete book is available: www.mobilereference.com/mind

Clinical Solution: ImagiRation Puzzles

• One of the main challenges of working with any children exhibiting a significant language delay is finding a way to provide them with the necessary cognitive training outside the low-performing speech-domain.
• Developmental toys and puzzles that require mental synthesis may be helpful; however, physical puzzles are always limited in their range and adaptability.
• Visual puzzles presented on an iPad, on the contrary, have neither limitation: the number of puzzles can be practically limitless and it is therefore possible to adjust the difficulty of these puzzles to be just one small step away from the child's level (not too easy and not too difficult).
• Our hypothesis is that training the "visual syntax" with visual puzzles can assist the development of synchronous neural connections between the prefrontal cortex and the posterior cortex and thus establish the neurological framework necessary for the future acquisition of full syntactic language.