The Gift of Language

"The limits of my language were the limits of my world" (expressions of a child with autism, 2012)

IT ALL STARTED HERE

Program for Cognitive Sciences
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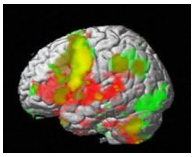
COLUMBIA UNIVERSITY

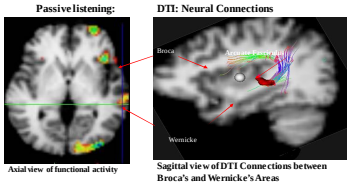
We used functional MRI to look into the autistic brain: what brain areas and connections are & are not working?



CHILD FOR FMRI PRIOR TO BRAIN SURGERY: ' 'PLEASE REMOVE MY TUMOR BUT LEAVE MY LANGUAGE ALONE'

Souweidane, M.M., Kim, K.H.S., McDowall, R., Ruge, M.I., Lis, E., Krol, G., Hirsch, J. Brain Mapping in Sedated Infants and Young Children with Passive-Functional Magnetic Resonance Imaging. Pediatric Neurosurgery 30, 86-91, 1999.

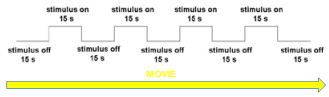
We also needed diffusion tensor imaging (DTI) to map the NEURAL CONNECTIONS:



DTI map of a typical language system.

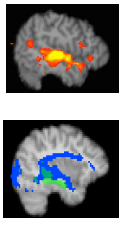
Language Imaging Procedure: Passive Listening

Neurotypical children listened to recordings of mom, dad and music while in the scanner.

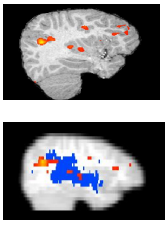


US Patent Pending: PCT/US09/61724

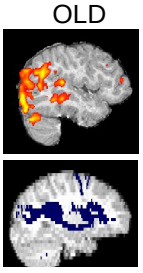
And after a lot of brains, we saw how a neurotypical child's brain functioned.



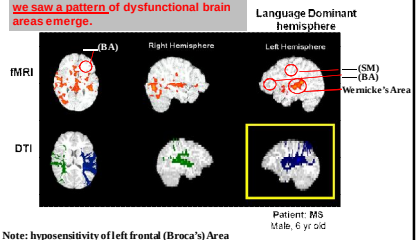
Then we scanned lots of autistic brains, like this 6 year old's.



AND THIS AUTISTIC 7 YEAR OLD



After scanning many 'autistic brains', we saw a pattern of dysfunctional brain areas emerge.



Note: hyposensitivity of left frontal (Broca's) Area

US Patent Pending: PCT/US09/61724

After years of investigational research, our study was accepted for publication!

- ***Functional MRI as a potential indicator of autism*. - to appear in *Radiology***

  It will be in print in August, 2011.
- As soon as I get the go ahead, I'll email the Journal specs to those interested.
- There may be a "press release" in July. (I hope it was the parents' idea that this long, hard, dedicated work was newsworthy!

Back to the scans. The parents had asked us afterwards what were we going to do for their kids? They wanted their kids to speak!

- **We said we had to give their kids basic grammar; they said they didn't really understand why grammar.**
- **We said we would use "TDCS" to *stimulate* parts of the brain to achieve *neural plasticity* which might help restore language**

We said (admitted) this was new research!
"If we knew exactly what we were going to do, we wouldn't call it research" (Einstein)

- .

We even asked them to use their imagination this slide: "neural plasticity"

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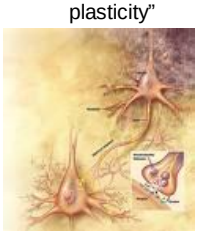


These were very courageous parents.

- We promised we wouldn't harm their kids.
- We said it would work or it wouldn't.
- They didn't fully understand about the grammar.
- They didn't know much about transcranila direct current stimulation (tDCS)

- **The game was afoot! (Sherlock Homes)**

WE BEGAN WITH FUNCTIONAL MRI AT COLUMBIA FOR DIAGNOSIS, BUT THE TREATMENT BEGAN AT:

THE CENTER FOR MEDICAL AND BRAIN SCIENCES, PLAINVIEW, NY
(yes, it's in Long Island)

DEBRA SCHNEIDER, ADMINISTRATOR, BOSS OF THE OFFICE

HARRY D. SCHNEIDER, ASSISTANT TO THE BOSS

INVESTIGAIONAL RESEARCH ABOUT TDCS WAS ALSO ACCEPTED FOR PUBLICATION.

- **"The use of the Bilingual Aphasia Test for assessment and transcranial direct current stimulation to modulate language acquisition in minimally verbal children with autism" (Schneider & Hopp, 2011)**

  i.e. using (TDCS) and implicit learning to promote language acquisition in LFA kids.

  This is the first paper in the world about successfully restoring grammar to minimally functioning children with classical autism !!

This was a Peer-Reviewed article (so what…)

- We had been doing pilot studies using tDCS to treat LFA kids for three years – with good outcomes.
- We sought validation from the scientific community to ensure that the ideas and methods behind our research were sound: we a scientific publication.
- **We wanted a pat on the back (Good Job)**

I personally needed something else …

- I needed to express the idea that good science is all about how to go from A to B.
- But I always felt that everything beyond going from A to B is all about the power of imagination.
- Imagination funneled correctly is a powerful tool! " If the facts don't fit the theory, change the facts" . (Einstein) –

This tDCS article

- Also happens to be scheduled to be in print in the same month as the functional MRI article.
- August, 2011.
- Journal of Clinical Linguistics and Phonetics: Volume 25, Issue 06/07.
- **One article about diagnosis and one about treatment**.

OK, SO LET'S TALK ABOUT HOW WE TALK.

- Why do we say: *park our car in the driveway* and *drive our car on the parkway.*
- And skating on *thin ice* gets you into *hot water*.
- Why do fat chance and slim chance mean the same thing?

And in human language, Why is grammar so important?

- "As you hear what I am saying, you and I are taking part in one of the wonders of the natural world. Simply by making noises with my mouth I can try to put ideas into your mind by manipulating words: **Manipulating words = grammar! (not "being manipulative" ☺)**
- This ability comes so naturally, that we often forget what a miracle it is.
- **The way neurotypical kids "learn" language is as far away from their minds as the rationale for laying eggs is from a chicken's!**

Grammar is a complex piece of biological machinery.

- A complex **skill** that develops **spontaneously**
  - but without conscious effort or formal training
  - and is essentially the same in all of us no matter what language we speak.

  SKIPPING is a skill, but different! ..I went skipping
- Typical children know how to talk "like a spider knows how to spin a web". LFA kids do NOT always instinctively know how to spin a web.
- Whether it's intentionally making sounds to put forth ideas (words) or unconsciously spinning a web (grammar) - **both make up language!**

Words + Grammar = Language

- It's said that when a ***dog bites a man***, that is not news - but when a ***man bites a dog***, that is news! (all we did was reverse the nouns)
- Language works because **it conveys news,** and grammar can make words **newsworthy**.
- Language is able to do this, because of these **two (2)** important features:

  words and **grammar**.

Language has 2 features:

- Words + grammar.
- Words + grammar
- Words + grammar
- Words + grammar
- Words + grammar
- Words + grammar
- Words + grammar.

What is a word?

- A **word** is just a bunch of sounds we make to describe something.
- For example, the word *duck* does not look like a duck, walk like a duck, or quack like a duck. We choose to use it to convey the concept of a duck.
- And..we all have CONSCIOUSLY learned – and decided to accept - the same connection between this particular sound and its meaning.
- **We all agree that a duck is something that quacks.**

The golden rule of language 1

We learn:

- **Words by memory**
- **Grammar by rote**.

The golden rule of language 2

- Words are **consciously** memorized.

The rules of grammar are three "i" s**: implicitly,inadvertently & inconsciously** not paying attention) 'picked up' on how to use these words.

The real golden rule of language:

- **Words by memory**
- **Grammar by rote.**

Now, what is Grammar?

- Typical children do not just learn individual words. They use **grammar to** combine them into larger words, phrases, and sentences.
- It is grammar, not words, that allows children to be able to speak a language fluently and productively.
- The principle behind grammar is: '**the infinite use of finite media**' (400 years).

What exactly does that mean: "Infinite use of finite media"?

Finite: We can CONSCIOUSLY memorize thousands of words: but there really is a **finite** limit to the number of words we can remember (20,000?). Is "OMG" and "LOL" in the dictionary?

- Infinite: We UN -CONSCIOUSLY (*implicitly)* pick up grammar, which allows us to speak an **infinite** number of sentences, each of which corresponds to a distinct thought.
- Infinite Use: We all know the rule **(Eng.)** that sentences must have a **subject** a **verb** and an **object,** in that order: e.g. *I ate the cookies.* As children get older , some show off: "*I wonder if Mommy knows that I know that she knows that I ate the cookies.*" ad infinitum…
- **The number of words we use may be finite, but the number of ways in which we combine them is virtually infinite!.**

REAL GRAMMAR IS INDEPENDENT FROM COGNITION – AND IT'S NOT ABOUT THE QUEEN'S ENGLISH!

Our grammar is so inherently good, we 'get it' even if the combination of words ain't correct: (ungrammatical): "You be down with that"?

- *The child seems sleeping.*
- *Is raining outside.*
- *Daddy poured the glass with water.*
- *This is not a complete. This either.*
- *This sentence no verb.*

HOW DID YOU LEARN YOUR (FIRST) LANGUAGE?

- No one really taught it to you!
- There were no verbs to conjugate.
- There were no behavioral interventions.

  You just looked, listened and one day you began speaking!
- From "ga ga goo goo" to "I don't wanna do my homework; I wanna watch TV".
- You can NOT memorize all of language!

Neurotypical children experience rapid language development

- Learning language is **probably innate**" : we may be born with a "grammar machine" in our brain.
- The infant is a '**naturalist**' ('FLOOTIME), passively observing the speech of other's, with its grammar machine on.

  The child **'osmoses"** grammar "implicitly" (**unconsciously**) – without teaching!
- Here's the math: If a child can speak (5000wd) or a 20-word sentence , then the child can deal with a hundred million trillion sentences. And.. A child would need a hundred trillion years to do this **without** the grammar machine!

More about the "grammar machine"

- Children unknowingly discover grammar from examples of well-formed sentences they hear**.**
- Infants and toddlers (UNCONSCIOUSLY) develop the rules of grammar - forming a *grammar template* - into which they manage to put categories of words (5000) in the correct order: i.e. the **subject, verb, and object of a sentence**.

Grammar template: use your imagination!

Grammar machine?

Why is this "grammar machine" important?

- **If children don't have implicit, un-scripted, un-memorized, un-taught grammar,**
- **Then they will never speak fluently .**

VERY IMPORTANT SLIDE!!

Humans have 2 *different* memory systems!

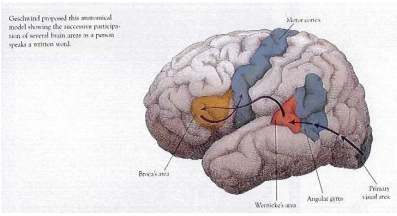
1) **The Explicit System** – also called the **"declarative"** or the "conscious" memory systems
2) **The Implicit System** – also called the "procedural" and unconscious system".

THESE 2 MEMORY SYSTEMS ARE THE KEY TO UNDERSTANDING AUTISM AND HOW WE INTRODUCE LANGUAGE with tDCS!

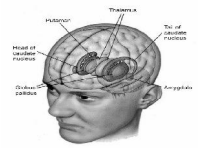
Explicit vs. Implicit Memory

- Explicit: is described as *knowing that* - ("I know that that Abe Lincoln was the 16th president").
- Implicit: is described as *knowing how* ("I can't explain it, I just know how to do it")
  Some people call it "muscle memory".
- N.B. The 2 learning/memory systems use 2 different brain areas that do not interact!

Declarative (Conscious) Language Areas are on the Cortex (surface of the Brain): e.g. sounds, words



Procedural areas ('**reptile brain**') are the infant's unconscious grammar machine and are connected to evolutionary newer surface areas of brain!



WE CAN'T EXPLAIN IT, WE JUST KNOW HOW TO DO IT!

Implicit memory to:

- tie their shoes,
- ride a bicycle
- talk without thinking
- develop intuitions about how other people will act

–all this without consciously thinking about these activities.

IMPLICIT LEARNING IS INVISIBLE!

- Implicit learning is outside of awareness, so people typically don't realize how important it is."
- Implicit learning happens when people are just going about their daily business, when they are focused on living - not on memorizing or on learning per se.
  And it's very useful
- We think implicit unconscious learning is much more important for adapting to new places and people than conscious forms of learning. (**"unstructured" may be more useful than "structured" for getting functional language in LFA kids!**)

A good example of implicit learning: How do you drive a car?

- Implicitly ? (automatic and unconscious)
- Explicitly? (do we think about what we learned in driving school)?
- Or both ways? e.g. "Did you ever drive home and not remember …?"

Here is a good example of implicit interaction!

.

Here is Spencer doing a puzzle, while listening to mom read a boring book.

Here is Spencer giving up his puzzle coz he heard mom read something better than his puzzle!

Explicit Learning does get you good grades in school!

- History test, neuroscience test, most tests
- In daily life, people rely on their explicit memory **declarative memory)**, to stores facts,

that can be consciously discussed: textbook learning; general knowledge; personal events.

Explicit learning is necessary, but not sufficient.

- Minimally-verbal children with classical autism are often explicitly taught some grammatical rules E.g., **I want juice, I have 2 pens.**
- But this this kind of sentence learning is NOT the same *as "acquiring" the implicit linguistic competence to consistently speak automatically, fluently, and correctly".*

LFA kids often:

- Say things that have no content or information.
- Repeat learned scripts. (I want the red book)
- Have limited interactive conversation, often without spontaneity and relevant conversational fluency.

Faulty procedural memory -> poor grammar machine

A child with ASD will have difficulty with:

- **prepositions**, adjectives, adverbs
- **pronouns**: I, you, he, she, my, your, etc.),
- **things** (this, that, these, those),
- **places** (here, there, above, below, etc.),
- **times** (sometimes, now, tomorrow, yesterday);
- **recognizing ungrammatical sentences**

Our Paper: Hypothesis

- Our theory was that facilitating grammar acquisition would help restore language in minimally verbal children.
- Our objective was to demonstrate acquisition of a basic "canonical" subject, verb, object (SVO) syntax construction in LFA kids that didn't have it yet. (I will show you later how we did that)
- We needed to measure **syntax** comprehension **before and after treatment with "online" tDCS.**
- NB: **Syntax acquisition** is such an important step in the development of functional language , it makes this a worthwhile endeavor on a global scale! (cont'd later)

FIRST: WHAT IS SYNTAX?

- **Correct placement of word order** to form a sentence. (Different languages may have different word order)
- It is the principles and rules for constructing this word order to **properly convey** orders of thoughts we want.

SYNTAX is one part of Grammar

1) **Syntax** is the first and most basic part: the system that combines words into phrases and sentences. *Dog bites man* and *Man bites dog*
2) **Constituency**: "*On tonight's program, Dr Phil will discuss sex with Mr. Frank N. Stein.*
3) **Argument**: *Man fears dog* and *Man frightens dog.*
4) **Transformation**: *The dog bites the man* vs. *The man is bitten by the dog.*

AND BY THE WAY…

- The neural representation and connectivity of this grammar rules is not fully known.
- What we call "grammatical rules" are actually very complicated neural circuits.

mathematical probability connections more like a supercomputer chip than a rule book.

Back to our Paper: Current Treatments for Language in Autism

- Neither Conventional nor Complementary and Alternative Medical CAM techniques have consistently demonstrated "external validity": i.e., others who use the same methods should get the same results.
- Holistic, homoeopathic, and biomedical interventions, such as nutritional supplements and vitamin therapies, all have benefits, but have they NOT been shown to significantly improve language acquisition in classical autism.

Knowledge + imaginative thinking suggested : Why not use TDCS?

- tDCS has been extensively studied for cognitive and language treatments for 15 years (Paulus, 2004):
- It improves post-stroke aphasia (Hummel & Cohen, 2006;
- It increases short-term memory (Marshall, 2004;
- It facilitates language acquisition (Fregni et al., 2005).
- It increases speech and sound production without side-effects in children ages 3 to 6 with developmental delays (Berezhnia, 2007).

And, if the implicit grammar system is not working well,

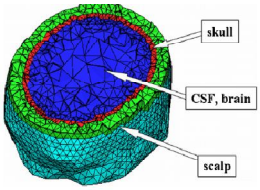
Neuromodulation with tDCS might help restore dysfunctional procedural circuits via neuroplasticity and speed up the process of (re)-acquisition of grammar .

Transcranial Direct Current Stimulation (tDCS)

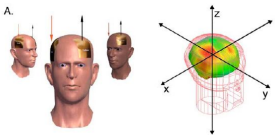
tDCS is SAFE !

- tDCS supplies a weak constant direct current to the scalp to depolarize neurons below.
- tDCS gives between 0.5 and 4 mA of direct current delivered through two sponge electrodes soaked in saline solution.
- The saline-soaked sponges keep current densities low and safe.
- Anodal (+) tDCS enhances excitability, whereas cathodal (-) tDCS reduces it.
- Forty years of use without serious side effects!

Current densities below 25 mA/cm2 do not induce brain tissue damage even by applying stimulation over several hours.
In our protocols, we use stimulation a thousand fold lower than this limit.



Careful measurements are made to ensure safety.



tDCS neural effects remain!

- tDCS has a long after-effect (AE), which depends on stimulus duration and stimulus intensity. (how long was it on) – often up to several days, hours and even months.
- We often get calls weeks later about new things kids said and did!
- Many kids often seem very relaxed after a productive TDCS session

BACK TO THE PAPER; WHO DID WE TEST? Children who are just about ready begin to pick up grammar.

- During the prelinguistic communication period, i.e., before syntax emerges, there are "intentional communication behaviors" that have been shown to be predictive of grammar readiness:
- **Increasing situational awareness (of surroundings**, etc).
- Improving attention following; increasing "joint attention",
- Improving eye contact.
- Trying to speak - without giving up too quickly.
- Vocalizations, a few words, and gestures having function or meaning
- Understanding simple commands.
- Behaviour self-regulation (fewer meltdowns and defiance)
- Good motor imitation ("if your happy & you know it, clap your hands") – and they clap!

.

How did we choose them?

- The children in this study were selected on the basis of having achieved the pre-linguistic milestones described above and a lexicon (vocabulary) greater than 20 words (the amount of words for this test).
- Choosing of 8 boys and 2 girls who ranged from 5 to 14 years of age (reflecting global 4/1 male/female ratio)
- Randomly selecting children from a larger group of similar, minimally-verbal children within the practice, who fulfilled the prelinguistic criteria - and who were already undergoing tDCS treatment at our center.

.

What did we test: Basic grammar ability to identify "who did what to whom"

E.g.: Show me the picture of **"the boy touches the girl"** (girl touches boy, girl touches girl, boy touches boy) – no speech necessary.

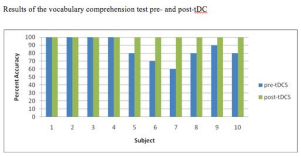
1. **word teaching then testing for all the words used on the test (teach "boy & girl) – using toys - was done first ("show me the boy")**
2. **syntax training then testing**. E.g., show me the picture of the boy AND the girl."

- **All testing was done both before and after tDCS** to show the effects of brain stimulation.
  Only children with a score of over 80% on vocabulary test progressed to the syntax test: to insure errors on the syntax test were not because they did not understand the words.

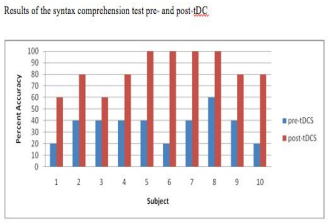
Paper, cont'd: Statistical Results

- Results of the one tailed paired t-test indicated that post-tDCS mean **syntax scores** (4.20 SD 0.79) were significantly higher than pre-tDCS mean syntax scores (1.70 SD 0.67), t (9) = -8.801. $p < 0.0005$.
- The results of the Wilcoxon signed ranks test were statistically significant, $Z = -2.809$, $p = 0.003$, confirming the results of the paired t-test.
- The effect size of the difference was large: $d = 2.78$.
- There was sufficient evidence to indicate a significantly higher post-tDCS mean syntax score than pre-tDCS mean score.
- **They got syntax AFTER we zapped them: it worked**

VOCABULARY TESTS: all kids scored 100% after tDCS



Syntax test



What do we see in the graphs?

- They relied to a great extent on conscious (explicit) memory and did better on vocabulary learning.
- They did NOT do well on syntax testing before stimulation. Children with autism have particularly weak procedural (implicit) memory system.

  In general, the better declarative memory is the more LFA kids rely on memorizing to solve all tasks - even trying to memorize grammar (for those who begin to speak a second language (L2) after the age of 6 or 7, it's the same thing. We try to memorize whole phrases, e.g. *"where is the bus stop"*?

We were curious about one unexpected test finding..

- How come 4 children got perfect scores on the vocabulary test before we stimulated them?
- And how did these 4 children do on the grammar test compared to those children who did not get good scores on the vocabulary test? (let's look at the charts)

BACK TO THE GOLDEN RULE: Words by memory; Grammar by rote.

- We compared syntax test scores (after using tDCS) of two subject groups : kids who had achieved vocabulary scores of 100% vs. kids with scores less than 100%).
- They were significantly different ($z = -2.282$, $p = 0.022$).
- The children who scored 100% both before and after tDCS on the vocabulary test had significantly lower syntax scores than did the children who did not score 100% .

Our paper demonstrated the known separation of the Declarative and Procedural systems - by accident.

- Four subjects who achieved 100% accuracy on both the pre- and post-tDCS vocabulary tests **performed worse on the following syntax test.**
- This is not interpreted to mean that high vocabulary scores predict low syntax scores. This finding demonstrates that in minimally verbal children with autism, **there is no correlation between vocabulary size and appropriation of syntax .**
- Words are learned in the conscious procedural system and grammar is unconsciously acquired in the procedural system - and these brain systems do not "talk" to each other!
- **Large vocabulary has nothing to do with grammar**

How best to use tDCS for our LFA kids? To repeat:

- **We can stimulate speech areas of robust activation** seen on individual child's functional MRI (e.g. Wernicke's Area) that are **not well connected** to other speech areas.
- **Stimulate areas of no activation**, but known to be important to speech: such as areas of speech motor planning/execution or areas of "executive control" of the brain.

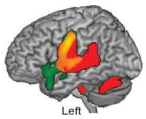
We can target:
- Wernicke's Area: to drive the connections to Broca's area
- Broca's Area or the supplementary motor area
- basal ganglia and cerebellum (via known pathways)
- frontolimbic system (areas that increase motivation)

New area of study: **What will help make an LFA kid more spontaneous? Use tDCS on brain areas of "intention to speak".**

The intention to speak!

- Speech production is predominantly a left-lateralized brain function.
- The sequence for speech is (1) temporal (Wernicke's) then (2) frontal (Broca's) cortex.
- Before speech production happens, *the brain prepares for the consequences of speaking in areas of the auditory cortex (Kell et al).*

New Research: Can we drive spontaneous speech production using tDCS in areas within the auditory cortex?



Bottom line: Use both implicit and explicit teaching for LFA kids!

- **Explicit** learning and memory (our ability to memorize facts and words) has received much more attention than implicit learning, among behavioral educators (ABA), speech pathologists (speech therapy) and those teaching developmental language delays.
- **Implicit learning** is a less obvious phenomenon, difficult to observe and measure. This style of learning is subtle, occurring without intention or conscious awareness that the learning is taking place. And It's anot easy to explain. We often can't fully articulate what we've learned implicitly, even though we may have absorbed and retained significant amounts of information. ("I can't quite explain all that I have learned today, but it's in here somewhere!")
- So let's all be aware that there are 2 very important methods of teaching!

HOW DO WE MEASURE IMPLICIT AND EXPLICIT LEARNING TOGETHER

- We might use interactive games on the computer with characters that children enjoy, e.g., 'Trying to find Elmo & Barney" on a touch screen). We can program when and where the characters appear on the screen!
- We can present these characters either in a **predictable** location or pattern (implicit learning) - or we can present them completely **randomly** (explicit learning). The children do not realize which games are which.
- NB: As they practice finding and "touching" Elmo and Barney, they should come to respond faster and more accurately to the pre-programmed events (implicit) than to the random ones (explicit) all the while unaware they are doing so.
- We can use the BAT to assess their learning trajectory with each form of learning and use it accordingly when teaching language.

Adding implicit learning for their language and social skills.

- The more rapid learning of a computer-generated predictable outcome of an "Elmo and Barney matching game' is similar to adapting to a regularity in an LFA kids' environment without knowing it.
- Typical people do this all the time in everyday life, enabling them to adapt to new people and situations at homes and in school and jobs.

Memory and ageing

- A major question for children with autism is how implicit vs. explicit learning decline as they grow up.
- Studies on neurotypical children and older adults already confirm that implicit memory will last longer.
- We have seem the same trend in LFA kids

Back to the future

- **During aging in gereral, declarative, conscious (explicit) memory declines, while implicit learning is spared.**
- Compare a young college student and an elderly person, both moving to a new home: The elderly person is likely to have a hard time memorizing her new phone number, while the college student can remember it easily. This is because the task of explicitly memorizing the phone number is often more difficult for the elderly.
- However , both the college student and the elderly person, after a few days of routine, would likely have little trouble going to the correct cabinet to get the Advil without giving it much thought.

Both forms of learning go hand in hand for life.

1) **For Language Skills**: Language is words + grammar **(the golden rule)**

2) **For Life Skills**: The long-range implications this research could lead to new methods of learning & teaching for LFA kids that will help them implicitly transition easier into a typical world.

Autism around the world!

- According to the United States Census 2000, about 10 million children in the US speak a language other than English at home (U.S. Census Bureau, 2010).
- Approximately 60 to 75% of the world (estimated at 7 billion) is bilingual and 22% of the world's bilingual population are children less than 15 years of age (that's >1 billion bilingual children).
- With the prevalence of autism estimated at about 1/150 globally, a gross estimate of the number of bilingual children with autism is at least **6 million**!

Help the children

- There is a general lack of knowledge about autism across the world and an inadequate understanding of the nature of its accompanying language difficulties.
- **We need to target the awareness of autism in different cultures and communities in an effort to improve and extend services, to increase research support, and to encourage improved social inclusion of children with autism.**

I ROBOT !! Kaspar is from England and helps kids with autism interact

Imagination is everything. It is the preview of life's coming attractions. (Einstein)