Understanding Infants' Language Development in Relation to Levels of Consciousness: An Approach in Building up an Agent-based Model

Helena Hong Gao
Bilingual Development Lab, School of Humanities and Social Sciences and Complexity Institute,
Nanyang Technological University
Singapore
helenagao@ntu.edu.sg

Can Guo
Bilingual Development Lab, School of Humanities and Social Sciences,
Nanyang Technological University
Singapore
kfcankf@gmail.com

Abstract

Language development in infants is a dynamic process that involves the emergence and increase of consciousness, with which built-in learning mechanisms make infants' imitation and interaction with their surroundings become socially meaningful. Taking Gao & Holland's (2008, 2013) statements of levels of consciousness for language development as the theoretical guideline, this study proposes a *rule-based*, *signal-processing* agent-based model to explore the dynamics of language development in early infants. In this model, we assume that an infant's rule-based learning behaviors can be featured by different levels of consciousness and that its adaptation processes can be explained in relation to levels of consciousness. In this paper we will discuss properties of consciousness at different levels and identify the influencing factors for reaching them. Our ultimate goal in building up the model is to understand the processes of language development with an approach that can better reflect reality.

1 Introduction

Understanding how language is acquired by infants has remained to be a challenging task. Previous attempts, such as the behavioral approach (e.g. Skinner, 1957; Roediger, 2004; Ramscar & Yarlett, 2007), relational frame theory (e.g. Hayes et al., 2001), nativist theories (Chomsky, 1967, 1975), social interactionist theories (Bruner, 1983; Carpenter et al., 1998; Tomasello, 2003), etc. all have achieved remarkable results that have shed light on future directions in research in child language acquisition.

More recent views emphasize that child language emerges through imitation and social interaction with the support of built-in learning mechanisms (Tomasello & Bates, 2001; Tomasello, 2003; Snow, 1999; MacWhinney, 2004; Bates & Goodman, 1999). For example, emergentist theories, represented by MacWhinney's competition model (1986), argue that language acquisition emerges from the interaction of biological pressures and the environment through a cognitive process. These theories emphasize that nature and nurture need to be jointly involved to trigger the language learning process.

In psychology, Jean Piaget's experimental studies on cognitive development revealed stage-development in children. Children's speech was discussed in terms of thought and reasoning (Piaget, 1926). Following Piaget, psychologists and linguists (e.g. Bowerman, 1990, 2004; Bates, 1975, 1999; Bates & Goodman, 1997, 1999; Mandler, 2004, 1998) made data-based assumptions that there could be many learning processes involved in language acquisition. Evolutionarily, some wired-in help supplied by a long evolutionary history is assumed to exist in supporting this task. For example, infants can imitate facial gestures between 12 and 21 days of age, an age much earlier than predicted by stage development theory (e.g. Piaget). Such imitation implies that human neonates equate their own behaviors with gestures they see others perform (Gopnik & Meltzoff, 1997; Meltzoff & Borton, 1979; Meltzoff & Moore, 1977). But how

29th Pacific Asia Conference on Language, Information and Computation pages 359 - 368
Shanghai, China, October 30 - November 1, 2015

does the newborn go on from there to make sense of the torrent of novel input? In particular, how does the newborn travel the long distance from very limited initial abilities to full language acquisition? Although we have large collections of relevant data, we have little theory of the dynamics of this process. These questions remain to be answered (Gao & Holland, 2013).

Our objective of this study is to apply the agent-based model (Holland, 1995) to explore language development in early infants. Our approach has substantial differences from the previous attempts. We will take Gao & Holland's (2008, 2013) statements of levels of consciousness (LoC) for language development as the theoretical guideline to build up a model that can reveal the dynamics of language development in early infants. By incorporate development observations into a theoretical framework, we will illustrate the mechanisms underlying LoC transitions and introduce an interdisciplinary approach to new experiments.

2 Level of Consciousness

Consciousness is often implicitly discussed as thought expressed in language (Carruthers, 1996, 2000). Even further back, in Plato's time, there was a general agreement that one can only speak of what one is consciously aware of. Therefore, it is reasonable to view infant language acquisition process from the perspective of consciousness. However, linguistic theories rarely touch upon consciousness.

Personal Construct theory (Kelly, 1955/1991) defines human consciousness as undergoing both conscious and unconscious processes. It postulates that human cognition starts from unconscious processes, or "low levels of cognitive awareness". According to Zelazo (2004), children's development of consciousness undergoes several dissociable levels before they reach full cognitive capability. His Viewing developmental and information-processing as the key features, Zelazo (2004) developed a hierarchically arranged LoCs and provided a metric for measuring the level at which consciousness is operating in specific situations. This is very different from models that are mainly based on adult data that distinguish between consciousness and a meta-level of consciousness (e.g., Moscovitch, 1989; Schacter, 1989; Schooler, 2002).

Based on Zelazo (2004) and Zelazo et al (2008)' work on the development of consciousness in children, Gao & Holland (2008, 2013) assumed that language development in a newborn depends upon expanding consciousness and that levels of consciousness can also be identified. Following Gao & Holland, we attempt to examine mechanisms (behavioral traits) that generate the behaviors at different levels of consciousness and their relations to well-known transitions as the newborn develops. In our model, infant's behavior is regarded not only simply as the output of the interaction between the infant and its surroundings, but also as the product of infant's understanding which is confined to age-related levels of consciousness.

In this paper, our focus is on the preverbal period (0-12 months). Although children during this period cannot express themselves by formal language that we can fully understand, they are obviously able to show their understanding and desires by non-verbal means together with simple but repeated trials of articulation of pre-linguistic sounds. To take a detailed look at these features, we follow Gao & Holland's (2008, 2013) definitions of the "level of consciousness" and make further divisions of these levels into more detailed sub-stages. Table 1 shows the "level of consciousness" sub-stages and their corresponding features in language development during a child's first year of life.

Level of Consciousnes s	**LoC Stage**	**Features relating to age**
LoC 0 Unconscious	**Stage 0** Reflective	Reflexive crying 0; Throaty noises 0
LoC 1 Minimal consciousness	**Stage 1.1** Intentionality	Sound localization 0; Distinguish consonant 1; Distinguish vowel 3
	Stage 1.2 Voluntary Action	Voluntary crying 2; Coos & laugh 2
	Stage 1.3 Repeated Action	Babbling & vocal play 4; Canonical babbling 6;
LoC 2 Recursive consciousness	**Stage 2.1** Differential Labels	Respond to name 5; Respond to "No" 6; Native preference 7; Segment speech 7;
	Stage 2.2	Patterned speech 10;

	Aware of Relationships	Adept to speech perception 11
	Stage 2.3 Functional Reactions	First words 12

Table 1: The "Level of Consciousness" Stages and main language development features within a child's first year of life

From birth to the end of the first year, an infant goes through three levels of consciousness (See Table 1). The first level of consciousness development is LoC 0 – Unconscious, at which babies can only respond to stimuli unconsciously, without awareness of even their own actions. The main character of infant's behaviours at this stage is reflective. Take "throaty noises" for example, they are the earliest vocalizations produced by infants, such as breathing, coughing, burping, sucking or sneezing. Babies make these sounds involuntarily. They are mainly physiological reactions that are partly characters of a living being in general.

LoC 1 starts with the feature of growth that is labeled as the "Intentionality stage", which is the first stage (stage 1.1) of LoC 2. At this stage, babies begin to respond to environmental stimulations. As the examples shown in Table 1, infants are gradually aware of what they hear, where the sounds come from (sound localization) and what are the differences between them (consonant and vowel distinctions). "Voluntary action stage" is the second stage, at which infants initiate to direct their actions according to their desire. Therefore, the crying (voluntary crying) and cooing sound (coos & laugh) at this stage may be more related to infants' desires and emotions. That is, they start to use their abilities as communication tools to communicate with their caregivers. At the third stage – "Repeated action stage", babies begin to show their preference of repetition. This is seen as the fact that upon their responses to their caregivers the feedback that babies receive from the caregivers generates pleasure. This is possibly why we see 4-month-old babies play with vocalizations (babbling & vocal play) and produce repetitive syllables.

However, all the actions under LoC 1 are restricted to present intero- and exteroreceptor stimulation (Now), which are only triggered by present stimuli.

When babies start to be able to relate certain signals to a certain kind of meanings, they arrive at LoC 2 – "Recursive consciousness". At the "Differential Labels" stage they are able to maintain the previous consciousness level and recall what they have acquired before. A typical observation is a baby's reaction when she hears a certain syllable or a voice pattern. For example, when a 5-month-old baby hears someone calls her name, which she must have heard for many times before, she will look toward the sound source (response to name), though she does not know yet that it is her name. When a baby begins to be aware of relationships, she is at stage 2.2. A 10-month-old infant's use of protowords (patterned speech) and an 11-month-old infant's understanding of others' expressions (adept at speech perception) are typical developmental features at this stage. When a baby is around 1 year old, she can use words comparatively accurately alike adults (first words). This is the feature named as "Functional Reactions" shown at stage 2.3, the last stage of LoC 2.

3 Agent-based Model of LoC

The theoretical framework of *agent-based model* (ABM) proposed by Holland (1995) creates a flexible abstraction of the real world and provides an approach in the general study of complex adaptive systems (*cas*).

ABMs consist of basic computer algorithm units, so-called agents, which are the central modeling focus points. Agents are modular or self-contained. An agent is an identifiable, discrete individual with a set of characteristics or attributes, behaviors, and decision-making capability. Figure 1 shows the structure of an individual agent in our model. We name it "baby-agent". First, we will give our modeling assumptions with the four typical elements of ABMs: environment, interactions, behavior rules, and adaptation. Then, in the next section, we will describe the model in detail.

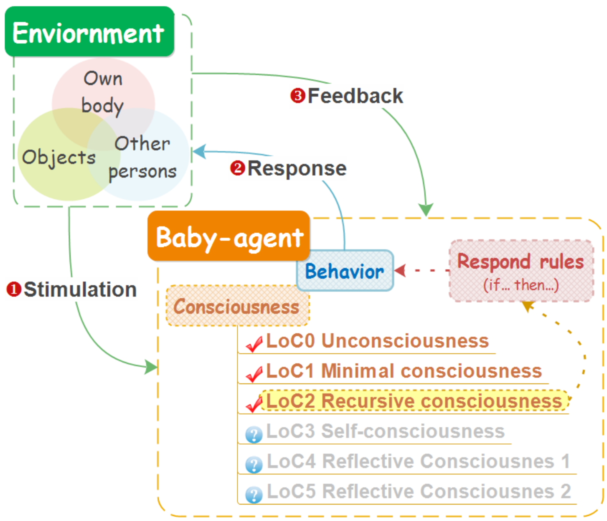

Figure 1: The structure of an individual baby-agent interacting with its environment confined to its LoC.

a) Environment

For a newborn, all the things including its own body are unfamiliar. Trevarthen and Aitken (2001) distinguished three type of engagement of a human subject with his body and the outside world: in his own body, to objects, and to other persons. These three aspects comprise a baby-agent's personal growth environment within which a baby-agent experiences three dimensional consciousness developments. The consequent accumulated consciousness forms a baby-agent's thought of the world and serves as fodder that muses for language expression.

b) Interactions

Baby-agents continuously interact with their environment as well as with other agents. A baby-agent is situated, or situationally dependent, in the sense that its behavior is based on the current state of its interactions with other agents and with its environment.

"Other agents" is a special part of the baby-agents' environment. Along with the increase of LoC, the interaction and relationship between a baby-agent and other agents will be greatly changed. For a baby-agent with the lowest LoC, it has no distinctive features from other agents within the entire environment. It can only receive and respond to signals, with no awareness of their existence and attributes. However, a baby-agent with a higher LoC can realize that some agents or signals are special for it. As a result, it will become conscious of other agents' identities as well as its personal connections with them, and thus begins to build up new protocols or mechanisms that channel its interactions with other agents.

c) Behavior rules

During the interaction and building up the relationship, a baby-agent is autonomous and self-directed. It can function independently in its environment and in its interactions with other agents. It seems as if its individual behavior processes are controlled by a combination of heuristic and stochastic rules. In our model, we define the behavior rules by a set of IF/THEN rules that respond to external and internal signals. A baby-agent interacts with its environment and other agents through an exchange of the signals. It should be noted that, baby-agent's behavior rules cannot be separated from its underlying level of consciousness. Providing the same scenario, baby-agents at different levels of consciousness are expected to show different behavior rules. The term "level" immediately suggests a progression from one level to another and a type of corresponding dynamics. The adaptation is the power that makes these progressions happens.

d) Adaptation

Being adaptive is the most important character of the agents. That is, the agents in the model can learn from their environment and dynamically change their behaviors in response to their experience. Casti (1997) argues that agents should contain both base-level rules for behavior as well as a higher-level set of "rules to change the rules." The base-level rules provide responses to the environment, while the "rules to change the rules" provide adaptation. A baby-agent has the ability to learn and adapt its behaviors based on its experience, which requires not only memory, but also feedback and recirculation. Suitable feedback is very important in the adaptation process, which points out the right direction for the cultivation of a new behavior pattern.

The behavior principle of the baby-agents with the lowest level of consciousness is quite simple. If a certain behavior pattern can make them feel happy directly, they will persevere in it and vice versa. This is the basis of the discovery of new rules and the modification of extant rules. However, as they reach a higher level of consciousness, they may consider more about the rules. Therefore, for different levels of consciousness, we may have different behavior principles according to the characters of each level. In addition, the kinds of signals processed determine the level of performance under a certain rule, and thus certain kinds of rule conditions can be typically associated with the LoC involved.

4 Model Description

4.1 IF/THEN rules and feature database

In our model, we will use *rule-based*, *signal-processing* agents (Holland et al., 1986), with rules of the form

IF (signal x is present)
THEN (send signal y).

Signals x and y could be utterances, gestures, or visual input.

In the following examples, T ("teacher", e.g. the mother) stands for a competent adult that regularly interacts with the infant L ("learner"). For example, a simple rule for L might be,

IF (T lifts a milk bottle)
THEN (L says "milk").

Signals can also serve to coordinate internal process, in which case they have no intrinsic meaning, serving much like the un-interpreted bit strings that coordinate instructions in a computer program. Each agent has many rules and, indeed, many rules can be active simultaneously (Gao & Holland, 2013). This simultaneous activity is roughly the counterpart of the simultaneous firing of assemblies of neurons in the central nervous system (Hebb, 1949).

By collecting data from literatures in the fields of linguistics, cognitive science, neuroscience, and psychology, we have built up an age-related development feature database. Beside the features of language development, we have identified other features. We believe that language acquisition is a complex process. Supports from various capabilities' development are needed (Gesell, 1928). The features arranged in different categories reflect the multiple dimensions of their interactions while the capacities of the baby-agent are being developed. Figure 2 shows main development features of the infants' first year of life and their associations with each other.

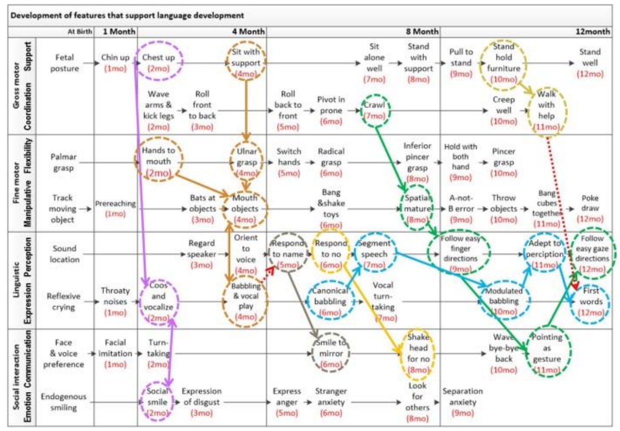

Figure 2: An illustration of some developmental features and their associations during infants' first year of life

To focus on the growth of the baby-agent, our model pays more attention to children's behavior transitions by applying IF/THEN rules referring to the development feature database. Based on the development features, we are able to determine a set of IF/THEN rules. The following are some examples:

[In the rules that follow, <action> denotes an overt action caused by a particular signal.]

Typical rule at LoC 0 [Unconscious activities].
At LoC 0, baby just has inherited ('wired in') cognitive abilities.

Stage 0 [Reflective – *action without awareness*]**:**
IF (T makes a tongue protrusion)
THEN (<L imitates the tongue protrusion >)

Typical rule at LoC 1 [Minimal consciousness].
At LoC 1, baby gradually shows innate reinforcement of repeatable activities.

Stage 1.1 [Intentionality – *begin to have some consciousness to environmental stimulations*]:
IF (T makes a sound)
THEN (<L turns his head towards the sound>)

Stage 1.2 [Voluntary action – *direct actions according to one's willing]*:

IF (L wants to be hugged by caregiver)
THEN (<L cries voluntarily>)

Stage 1.3 [Repeated action – *action repetitively and feel happy when doing it*]:

IF (a hand is in a vision cone)
THEN (<L waves his hand repetitively >)

Typical rule at LoC 2 [Recursive consciousness]. *At LoC 2, baby begins to awareness of the connections between object and its label.*

Stage 2.1 [Differential labels – *begin to aware that some signals have special means*]:

IF (T calls L's name)
THEN (<L pays attention to T>)

Stage 2.2 [Aware of relationships – *be conscious of the links between signals and objects]*:

IF (T say "milk")
THEN (<L looks to the milk bottle>)

Stage 2.3 [Action functionally – *be able to use related signals to indicate some objects*]:

IF (a milk bottle is present)
THEN (<L utters "milk">)

4.2 Learning Processes and Meta-Rules for Learning

According to Gao & Holland (2013), to *learn* in this rule-based context, the agent must have the ability to modify its signal-processing rules. Such rule-modifying, learning abilities are innate capacities supplied by evolution. Learning abilities can also be expressed as rules, functioning in a similar way as Hebb's (1949) learning rule in neuro-psychology. Therefore, these meta-rules for learning are clearly distinguished from the signal-processing rules. In agent-based models, the meta-rules are unchanging and common to all agents.

Our agent-based models described here are based on meta-rules that are demonstrably available to pre-primates. There are two general learning tasks that a baby-agent must be able to carry out:

a) Credit-assignment

As an agent interacts with other agents within a certain environment, it must be aware of the existence of rules and also able to decide which of the rules are helpful and which are detrimental. A mature agent must even be able to determine which early-acting, stage-setting rules make possible later beneficial outcomes. (As an example given by Holland (1998), consider the sacrifice of a piece in a game like checkers in order to make a triple jump later.) The credit-assignment learning process assigns strengths to the rules. A rule's strength reflects its usefulness to the system, useful rules having high strengths. Rules then compete to control the agent. The stronger rules have a better chance of winning the competition. In effect, the rules in this system are treated as hypotheses to be progressively confirmed or disconfirmed. (See Holland, 1998, chapter 4).

Obviously, during the credit-assignment procedure, recirculation and feedback are indispensable. The random variation and imitation provide a random sampling that helps uncover the most primitive behavior rules. When a behavior rule is repeatedly associated with rewarding feedback, such as food or a mother's smile, it becomes a sampled regularity that is associated with valuable experience. From the sampling point of view, the behavior rule's reliability is continually tested under the credit assignment procedure.

b) Rule discovery

Once rules have been rated by credit-assignment, it makes sense to replace rules that have little or no strength by generating new rules (hypotheses). Random generation of new rules is not an option here; that would be like trying to improve a computer program by inserting random instructions. Instead, newly generated rules must somehow be plausible hypotheses in terms of experience already accumulated. (See Holland, 1995, chapter 2).

For the baby-agent with a higher level of consciousness, random variation of rules from the very beginning is not the best way to get the beneficial behavior rules. A mature baby-agent may have the abilities to discover new rules by combining *building blocks* (Holland, 1995, chapter 1 ff) which are extracted from rules already established. An important advantage of building blocks is that they occur as repeated patterns in the ever-changing torrent of sensory input, which provide repeatable experiences in a perpetually novel environment.

4.3 Building blocks

According to Holland (1998), building blocks (*generators* in mathematics) have a familiar role in the sciences, best exemplified by the building block hierarchy of the physical sciences – the quark / nucleon / atom / molecule / membrane /… hierarchy. Selected combinations of building blocks at one level form the building blocks of the next level. For a spoken language there is a similar phoneme / word / sentence hierarchy. A grammar specifies the laws that determine how words can be combined to yield sentences. Actually, in viewing the levels of consciousness, we find a similar hierarchy. Higher levels of consciousness in the LoC theory are brought about by the iterative reprocessing of the contents of lower levels of consciousness. (Zelazo et al., 2007)

After a period of development process, a baby-agent has acquired a certain number of behavior rules, which can be seen as the building blocks for discovering new rules. Plausible new conditions and rules can be generated by *recombining* these building blocks that already confirmed. A confirmed building block becomes a plausible hypothesis when combined with other similarly distilled building blocks. The procedure is much like the crossbreeding of good plants (or animals) to get better plants. There is a substantial literature, centering on *genetic algorithms* (Holland, 1995), that discuss the production of new rules in agent-based models via the crossing of extant rules. There is not space here to discuss genetic algorithms in detail, but it is a well-established procedure.

The building blocks amount to hypotheses at different levels of precision, with the rules being confirmed (or disconfirmed) as the agent gains experience. These different levels of precision may be related to the levels of consciousness.

According to Gao & Holland (2013), the meta-rules for credit assignment and rule discovery allow the neonate to achieve a gradual increase in control, corresponding to increasing LoC. The process begins with the acquisition of repeatable sound and gestures. Sounds and gestures reinforced by T become the building blocks that can be used when the baby-agent is mature. For example, producing various combinations of utterances at LoC 1 can be simply a kind of play, while they are the necessary building block to form meaningful utterances at LoC 2. Connecting optional utterances with specific meanings greatly reduce behavior's ambiguity. In mathematical terms we refine a broad equivalence class into a set of smaller, more informative sub-classes.

In this way, selected combinations of building blocks at one LoC become the building blocks for the next level. Building blocks offer combinatoric possibilities: a large variety of useful or meaningful structures can be constructed from a small number of building blocks. Moving up the LoC hierarchy thus becomes a much more efficient process than trying to "establish" a monolithic rule for each possibility at the highest LoC.

4.4 A Baby-agent's consciousness properties

By now, almost every part of the agent-based model has been introduced, and we come to the final topic of this section – the properties of consciousness. Actually, there are three concepts of consciousness involved in our model: the level of consciousness, the consciousness capabilities, and consciousness status.

The level of consciousness and its impact on a baby-agent's behavior rules have already been emphasized. However, consciousness development is a continuous process, and the increase in LoC is a quantum leap from the accumulation of drip growth. Therefore, before determining at which level of consciousness a baby-agent is situated, we must know the factors that influence the development of a baby's *consciousness capability*. As an example, we focus on illustrating two main factors: time and training. Hereby, we give the measurement of *consciousness capability* as follows:

$$Consciousness_t = f(t) + h(N)$$

Where, $Consciousness_t$ is the measurement of a baby's *consciousness capability* at time $\boldsymbol{t}$ when a baby-agent has been consciously trained for N times; $f(t)$ and $h(N)$ are the consciousness increments gained from the time factor and the training factor separately.

There is no doubt that the increase of consciousness needs time. Ever since a baby was born, the internal and external environments provide it abundant stimulations, which promote the increase of its consciousness naturally. For convenience, we regard the natural increase rate (*rate*) of consciousness in our model as being constant, and thus the consciousness increment gained from the time factor can be defined as follows:

$$f(t) = rate \times t$$

As for the training factor, it should be much more complex. By denoting Δ as the consciousness increment of the *i*-th training, the consciousness increment gained from the training factor can be expressed as follows:

$$h(N) = \sum_{i=1}^{N} \Delta(feedback_i, status_i)$$

Where, *i* stands for the *i*-th training; *N* is the total training times by time *t*; $feedback_i$ and $status_i$ respectively indicate the feedback that the baby-agent receives and the *consciousness status* that baby-agent is situated in the *i*-th training.

The impact of the feedback on the learning process has been described. We now come to take a look at the *consciousness status*. It should be noted that, for a baby-agent whose consciousness capability can reach LoC 3, it doesn't mean that it remains situated at LoC 3. Actually, it will normally stay at a lower level of consciousness, and will elevate its own consciousness status to deal with specific requirement when needed. Just as we will achieve different scores if we bear different attitudes in exams, a baby-agent with a different consciousness status will have different amount of consciousness increase as well.

Given different parameters, we can model various development paths of baby-agents. By calibrating age-related development features according to the consciousness capabilities' increased integrally in a baby-agent, we can determine the consciousness condition of each behavior rule. This kind of treatment makes sense. Gao & Holland's (2013) framework makes it possible to observe an infant's language development in relation to the increase of levels of consciousness in specific situations. In principle, this approach takes the development of language as well as the growth of consciousness capabilities in an infant as being supported by diversified factors in reasonable environments.

5 Summary

This study proposes a *rule-based*, *signal-processing* agent-based model to reveal the dynamics of language development in early infants. This model shows how a newborn discovers behavior rules and improves its autonomy. With the establishment of such a model, we are able to explore the mechanisms that support language development and understand how language is acquired, used, and changes over time.

By building up the model, we are able to see that the influence of consciousness on language development is manifold. During the learning processes, it is very important to identify a role for interaction, without which it will be impossible for infants to develop a sense of learning. However, the impact of interaction on language development is limited by levels of consciousness. Infants cannot acquire the contents beyond the limit of LoC at a given age. That is, when consciousness does not exist or does not reach a certain level, a learning process cannot be activated in an infant. In addition, different learning procedures occur at different levels of consciousness. What infants acquire at a lower LoC will become the building blocks for a higher LoC, which is the reason why an infant at a higher LoC can acquire more complex rules for learning more quickly.

What is presented in this paper is only the description of a step toward building up experimentally executable versions of models. The present model setting described is seemingly simple. In the future work, such models will be further established to allow multiple agents to interact with each other at different levels of consciousness, suggesting that each agent will develop its own idiolect and that the agents that interact regularly with each other will have many common constructions in their idiolects.

Acknowledgements:

Academic Research Fund (AcRF) Tier 1 Complexity Seed Funding awarded to Helena Gao by the Ministry of Education of Singapore and Nanyang Technological University, Singapore. Experiment trials conducted by Can Guo.

Reference

Bates, E. (1975). Peer relations and the acquisition of language. *Friendship and peer relations*, 259-292.

Bates, E. (1999). Nativism versus development: comments on Baillargeon and Smith, MA, USA: Wiley-Blackwell.

Bates, E., & Goodman, J. C. (1997). On the inseparability of grammar and the lexicon: Evidence from acquisition, aphasia and real-time processing. *Language and cognitive Processes, 12*(5-6), 507-584.

Bates, E., & Goodman, J. C. (1999). On the emergence of grammar from the lexicon. *The emergence of language*, 29.

Bruner, J. (1983). *Child's talk: Learning to use language*. Oxford: Oxford University Press.

Bowerman, M. (1990). Mapping thematic roles onto syntactic functions: Are children helped by innate linking rules? *Linguistics, 28*(6), 1253-1290.

Bowerman, M. (2004). From universal to language-specific in early grammatical development [Reprint] *The child language reader* (pp. 131-146): Routledge.

Carpenter, M., Nagell, K., Tomasello, M., Butterworth, G., & Moore, C. (1998). Social cognition, joint attention, and communicative competence from 9 to 15 months of age. *Monographs of the Society for Research in Child Development, 63*(4), i+iii+v-vi+1-174.

Carruthers, P. (1996). *Language, Thought, and Consciousness: An Essay in Philosophical Psychology*: Cambridge University Press.

Carruthers, P. (2000). *Phenomenal Consciousness: A Naturalistic Theory*: Cambridge University Press.

Casti, J. L. (1997). *Would-be worlds: How simulation is changing the frontiers of science*. New York, NY: John Wiley and Sons.

Chomsky, N. (1967). Review of Skinner's Verbal Behavior. In L. A. Jakobovits & M. S. Miron (Eds.), *Readings in the Psychology of Language*: Prentice-Hall.

Chomsky, N. (1975). The logical structure of linguistic theory.

Gao, H. H., & Holland, J. H. (2008). *Agent-based Models of Levels of Consciousness*. SFI Working Papers. doi: SFI-WP 08-12-048. Santa Fe Institute. U.S. A.

Gao, H. H., & Holland, J. H. (2013). The Language Niche. *Eastward Flows the Great River: Festschrift in Honor of Professor William SY. WANG on his 80th Birthday*, 141.

Gesell, A. (1928). *Infancy and human growth*. New York: The Macmillan Company.

Gopnik, A., & Meltzoff, A. N. (1997). *Words, thoughts, and theories* (Vol. 1): Mit Press Cambridge, MA.

Hayes, S. C., Barnes-Holmes, D., & Roche, B. (2001). *Relational frame theory: A post-Skinnerian account of human language and cognition*: Springer Science & Business Media.

Hebb, D. O. (1949). *The organization of behavior: A neuropsychological approach*: John Wiley & Sons.

Holland, J. H. (1995). *Hidden Order: How Adaptation Builds Complexity*: Perseus Books.

Holland, J. H. (1998). *Emergence: From chaos to order*. Redwood City, California: AddisonWesley.

Holland, J. H., Holyoak, K. J., Nisbett, R. E., & Thagard, P. R. (1986). *Induction: Processes of inference, learning, and discovery*. Cambridge, MA: Bradford Books/ MIT Press.

Kelly, G. A. (1955/1991). *The psychology of personal constructs. Volume 1: A theory of personality*. New York, US: Norton. 2nd printing: 1991, London, New York: Routledge.

MacWhinney, B. (1986). *Toward a psycholinguistically plausible parser.* Paper presented at the Proceedings of the Eastern States Conference on Linguistics (ESCOL 1986), Columbus, OH.

MacWhinney, B. (2004). A multiple process solution to the logical problem of language acquisition. *J Child Lang, 31*(04), 883-914.

Mandler, J. M. (1998). Babies think before they speak. *Human Development, 41*(2), 116-126.

Mandler, J. M. (2004). *The foundations of mind: Origins of conceptual thought*: Oxford University Press.

Meltzoff, A. N., & Borton, R. W. (1979). Intermodal matching by human neonates.

Meltzoff, A. N., & Moore, M. K. (1977). Imitation of facial and manual gestures by human neonates. *Science, 198*(4312), 75-78.

Moscovitch, M. (1989). Confabulation and the Frontal Systems: Strategic versus Associative retrieval in Neuropsychological Theories of Memory. *Varieties of Memory and Consciousness: Essays in Honour of Endel Tulving*, 133.

Piaget, J. (1926). *The Language and Thought of the Child*. London: Routledge & Kegan Paul.

Piaget, J. (1959). *The Language and Thought of the Child*. London: Routledge & Kegan Paul.

Piaget, J. (2013). *The construction of reality in the child* (Vol. 82): Routledge.

Ramscar, M., & Yarlett, D. (2007). Linguistic Self-Correction in the Absence of Feedback: A New Approach to the Logical Problem of Language Acquisition. *Cogn Sci*, *31*(6), 927-960.

Roediger, R. (2004). What happened to behaviorism. *APS Observer*.

Schacter, D. L. (1989). On the relation between memory and consciousness: Dissociable interactions and conscious experience. In H. L. I. Roediger & F. I. M. Craik (Eds.), *Varieties of Memory and Consciousness*.

Schooler, J. W. (2002). Re-representing consciousness: Dissociations between experience and meta-consciousness. *Trends in cognitive sciences, 6*(8), 339-344.

Skinner, B. F. (1957). *Verbal Behavior*. Acton, MA: Copley Publishing Group.

Snow, C. E. (1999). Social perspectives on the emergence of language. *The emergence of language*, 257-276.

Tomasello, M. (2003). Constructing a language: A usage-based theory of language acquisition.

Tomasello, M., & Bates, E. (2001). *Language development: The essential readings*, Blackwell.

Trevarthen, C., & Aitken, K. J. (2001). Infant intersubjectivity: Research, theory, and clinical applications. *Journal of Child Psychology and Psychiatry*, *42*(1), 3-48.

Zelazo, P. D. (2004). The development of conscious control in childhood. *Trends in cognitive sciences*, *8*(1), 12-17.

Zelazo, P. D., Gao, H. H., & Todd, R. (2007). The Development of Consciousness. In P. D. Zelazo, M. Moscovitch, & E. Thompson (Eds.), *The Cambridge Handbook of Consciousness* (pp. 405-432).