The Role of the Interconnection between Global and Domain-Specific Processes and Universally Available Experience in Children's Cognitive Development

Asia Pacific Journal of Academic Research in Social Sciences
Vol. 4, 62-68
November 2019
ISSN 2545-904X (Print)
ISSN 2704-4157 (Online)
www.apjarss.org

Malathie P. Dissanayake
Faculty of Health Sciences, The Open University of Sri Lanka, Sri Lanka
malathie.dissanayake@gmail.com

Date Received: August 8, 2019; Date Revised: November 23, 2019

Abstract *– Cognitive development, a major aspect of child development, includes memory, perception, language, information processing, and thinking. Both brain development and the social world play significant roles in cognitive development. The child needs to adapt to the environment in which he lives in order to continue his life. Although brain at birth is already somewhat adapted to the environment, additional experience enhances adaptation to specific circumstances. The purpose of this paper is to discuss two questions related to cognitive development in children; one is, does cognitive development include global and domain-specific processes, and the other is whether universally available experience is sufficient for cognitive development?Understanding the interconnection between global and domain-specific processes and the impact of social environment in cognitive development can help parents and teachers to encourage children to improve different aspects of cognition and to guide them to achieve learning gains.*

Keywords –*childhood, cognitive development, the importance of experience, social environment*.

INTRODUCTION

One of the major issues in the field of child development was the "either-or" aspect of genes and environment. This has influenced many researchers to focus only on one aspect of development. Later, they introduced a new approach that linked two processes: nature and nurture, to understand the process of child development. Instead of the "either-or" distinction, they have given more attention to the interaction between the two [1]. Global processes facilitate various domains in cognitive development while domain-specific processes are considered modules of cognitive development [1].

The Role of the Interconnection between Global and Domain-Specific Processes

The classical example for global processes is Jean Piaget's (1896-1980) theory of cognitive development. Compared to nativist and empiricist theories, Piaget's approach has been considered as a more constructive approach that explains an individual's cognitive development through four main stages that range from birth to adulthood [2]. In contrast, modern theories have emphasized modules of cognitive development that comprise three major characteristics. First, they have well-connected biological systems and they do not need more experience for development. Second, they have developed gradually to face certain challenges of early humans. Third, they are sensitive to certain types of inputs and therefore, they react to those inputs involuntarily and quickly [1]. Noam Chomsky's explanation of children's language acquisition is an example of domain-specific processes [2]. According to Chomsky, children possess innate language-specific abilities or unique set of rules that are beneficial for language learning. These rules are not related to other domains of cognitive development. Similar to Chomsky, other theorists [3] [4] have also suggested modules for theory of mind, perception of faces, and visual analysis of objects and space [1]. They have attempted to strengthen the domain-specific idea by providing evidence through brain damages or impairment of certain skills. For example, impaired right medial prefrontal cortex causes impaired activities related to theory of mind [5], and damage to the fusiform gyrus causes loss of face recognition [3].

Research has introduced a new perspective that links global processes and modules in understanding cognitive development [1]. Global processes such as processing speed, working memory, and executive functioning require functioning with modules in performing tasks. Research has suggested that processing speed facilitates other cognitive tasks (e.g., perceptual tasks) and it increases gradually from childhood to adolescence [6]. Performing working memory tasks also requires other cognitive functions. Similar to processing speed, working memory also increases from childhood through adolescence [7]. In addition, executive functioning requires modules such as planning and inhibition for its cognitive task performance [6].

Kail and Hall [8] found that arithmetic knowledge explains some additional variability in word-problem performance beyond global cognitive skills. Hecht and colleagues [9] also indicated that working memory (global process) and children's conceptual understanding of fractions (modules) explain the variance of children's accuracy in grouping problems that require fractions [1]. Furthermore, several studies provided evidence for the interplay of global processes and modules. For example, processing speed and children's ability to choose good landmarks (e.g., places that may help avoid getting lost) predicted the accuracy wherewith 5-9 year-old children ordered scenes from a walk through an unknown area [10]. Reading-specific skills such as phonological awareness, visual-orthographic processing and global cognitive constructs have influenced reading comprehension in children [11]. Domain-specific knowledge in understanding the distinction between reality and appearance, and ability to inhibit irrelevant responses has explained developing theory of mind functions in 3 and 4 year-olds [12].

Case and Okamoto [13] revealed that the progress in conceptual structures such as social cognition, number, and spatial relations, increases the capacity of working memory in childhood. Accordingly, children's numerical understanding develops through four stages from age 4 to 10 with experiences they receive from social environment (e.g., instructions from teachers). Though there was criticism about lack of explicit rules for different tasks in different levels, their findings have supported the interplay of global processes and modules.

Siegler and Shrager's [14] distribution of associations model provides more evidence for global and domain-specific linkage. According to this model, children's arithmetic knowledge is a network that includes long-term memory of arithmetic knowledge, and procedures to retrieve that knowledge, to assess the credibility of it, and to decide other options (e.g., for wrong answers). This model has been used for other domains such as memory, spelling, and telling time [15]-[17]. Unlike Case's theory, the distribution of associations model links both global and modules in real time [1].

Findings of the effects of mothers' reminiscing styles on children's autobiographical memory can also be related to the link between global processes and modules [18]. Reminiscing is a language based function that facilitates children's strategic memory development, understanding of self, others, and world, and language and literacy skills. Following the Vygostsky's theory, some researchers have stated that mothers' narratives help children promote their encoding, retrieving, and recognizing information [19]-[21]. Many researchers have suggested that autobiographical recall includes how and when the event occurred, and what it means for the child [22]-[24]. "Autobiographical narratives are linguistically structured cultural constructs of what is appropriate to recall about one's self, and how to report it [18]." Children have to perform high cognitive and linguistic skills for their tasks in reminiscing as they are cognitively distant from the event. The above statement illustrates that autobiographical narratives link many domains such as memory (both event and deliberate memory, strategies like rehearsal and organizing), retrieving, language, and literacy skills.

Attention is another cognitive process that links with other domains [25]-[28]. It relates to other domain-specific processes such as altering, orienting, and executive control that are important elements of attention [26] [27]. For example, orienting function (selective attention) includes ability to disconnect the center of attention, shift attention, and reengage attention [29]. This illustrates how different domain-specific processes participate in attention (global process).

Cognitive Development in Adolescence

Cognitive development in adolescence is another evidence for the link between global processes and modules. Longitudinal findings have revealed that a human brain continues to develop even in adolescence with major neurological changes in both gray and white matter [30] with influences on cognitive development. For example, the effectiveness of information processing improves as a result of brain development in adolescence. This improvement can be identified through improved speed, improved capacity, and improved inhibition. There is evidence for improving processing speed from early childhood through mid-adolescence [6] [31] [32]. Also, inhibition skills (both abilities to resist to interfering stimuli and inhibitory control of one's own reactions) improve from childhood through adolescence [32]-[34].

Improved executive control is another major aspect of cognitive development in adolescence. Late adolescents and young adults exhibit enhanced skills in monitoring and managing their learning and knowledge acquisition, compared with early adolescents [35]. The

ISSN 2545-904X (Print) | ISSN 2704-4157 (Online)

decision making process also changes from childhood to adolescence and to adulthood. Klaczynski's [36] [37] dual process approach of the development of decision making skills ~~s~~ is another example for global and domain-specific linkage [35]. According to him, decision making skills develop through coordination of two systems: experiential and analytic systems. This dual process model is also important in increasing deductive and inductive inference skills that involve in inhibiting responses and bracketing.

The prefrontal cortex (PFC) is also important the link between global and domain-specific processes. The functions of the prefrontal cortex relate to use of rules [38]. It plays a significant role in processing information about person's goals and motivations, his/her current context, and retrieving rules to control current behaviour. PFC includes four subregions: orbitofrontal, ventrolateral, dorsolateral, and rostrolateral cortex. Neuropsychological findings suggest that these subregions connect with different parts of the brain and different kinds of cognitive performances. Also, these regions mature in a hierarchical manner. The age-related development of rule use of children is based on the improvements of hierarchical complexity of rules that can be described by them. Children's ability to describe these hierarchical rule sets is determined by the growth of the hierarchical network of different regions in PFC. This illustrates the complexity of interconnection between global and domain-specific processes in cognitive development.

In sum, it is clear that both global and domain-specific processes are interconnected in cognitive development. Research evidence of cognitive functions such as processing speed, working memory, executive functioning, word-problem performance, attention, and autobiographical memory have illustrated the importance of both global and domain-specific processes in cognitive development. In addition, cognitive development in adolescence has also supported the above linkage. Further, neuropsychological investigations of the prefrontal cortex have explained how different parts of the brain influence different cognitive functions. Accordingly, it is clear that both global and domain-specific processes play a vital role in cognitive development.

Is Universally Available Experience Sufficient for Cognitive Development?

Environmental influences can be defined as all nongenetic, external conditions. All these external conditions play a significant role in cognitive development. Research findings suggest that environmental influences significantly impact different aspects of cognitive development such as language, perception, and memory. It is important to understand the significance of universal experience or exposure to some environmental inputs in developing the areas in face processing and language.

Development of Face Processing

With respect to the development of face processing, especially the other-race effect, studies have found evidence for the importance of environmental inputs. The norm-based coding model suggests that the prototype that represents the average of all faces an individual has encoded, continues to adapt and to update as the person observes more and more faces within his visual environment. Others have suggested that infants tend to have broader dimensions of face prototype at birth and these dimensions develop according to the type of faces that infants observe [39]. When infants mainly see faces from a one particular group of individuals (their-own race), they alter or tune their face-space dimensions toward that particular race.

Research has suggested that exposure to faces of other races alters the tuning of an infant's face prototype. Infants preferred to look at faces from their own ethnic group compared to faces from other ethnic groups. This ability emerges very early age of their life [40]-[42]. Kelly and his colleagues [41] have suggested that infants' preference for their own group faces emerges as a consequence of different facial exposure from their own ethnic group. Findings of a study conducted with Ethiopian infants have also provided evidence for the influence of differential face input on own-group preferences [40]. In this study, Ethiopian infants were exposed to both Israeli and Ethiopian adults frequently. The researchers found that infants did not show any preferences when they were presented African and Caucasian faces. These findings highlight the importance of the visual environment.

Similarly, findings of gender preferences have demonstrated the impact of visual environment. The findings of a study conducted with 3- to 4- months old infants have revealed the importance of visual environment that infants observe the faces [43]. In this study, infants who were raised by a female caregiver showed preference for female faces over male faces and those who were raised by a male caregiver exhibited preference for male faces over female faces.

A study by Kelly and his colleagues [42] also highlighted the importance of visual environment in the development of face processing. The researchers focused on the impact of facial input from visual

ISSN 2545-904X (Print) | ISSN 2704-4157 (Online)

environment on the face-processing development during the first year of infants' life. They examined Caucasian infants' ability (3-, 6-, and 9-months old) to differentiate faces within their own race and within other races (African, Middle Eastern, and Chinese). Findings suggested that the face-processing system of 3-months old infants is broad and, consequently, they are able to process faces from different races. The researchers have found that, between 3- to 9-months, infants increase their sensitivity to faces of their own race more than faces of other races since they are greatly exposed to the faces of their own race compared to faces of other races. This reveals the importance of exposure to their visual environment in developing their face-processing.

Language Development

Language is another important domain of cognitive development that illustrates the importance of experience or the exposure to environmental inputs in language development. Theories that emphasize the innate contributions to language acquisition as well as theories that highlight the importance of learning process have attempted to explain the mechanism underlying learning acquisition. Findings of learning-oriented theories have suggested that children possess very strong learning mechanisms [44]. Accordingly, infants tend to use the statistical properties of their language environment during the learning process. It was found that they are capable of using statistical properties such as the distributions of sounds in words and the orders of word types in sentences, in order to learn the elements of language structure.

According to the constrained statistical learning framework, learning is very important for language development. Also, it indicates that the specific nature of language acquisition describes similarities across languages. According to this framework, similarities across languages can be observed as a consequence of constraints on the learning process as they are shaped by constraints on perception, processing, and speech production. In the language learning process, infants tend to find the statistical properties and to discover the word boundaries in their language environment.

A study conducted on usage of statistical learning to segment words supported the above concept [45]. In this study, the researchers exposed 8-months old infants, first graders, and adults to spoken nonsense languages. In these languages, statistical properties of the syllable sequences were the only sign of word boundaries. Findings suggested that all participants were able to use statistical properties, that is, word boundaries.

Infants can use these statistical properties in learning language in real-world [46]. Findings revealed that when infants are brought up in English-speaking environments, they tend to segment the sound strings and tend to regard the non-sense language patterns as English words. Additionally, research work in related areas has also indicated that 12-month old infants are able to segment the new words and able to find out the syntactic regularities that are associated with those words. Findings further suggested that the infants' mental representations created through this process are new statistical properties that would work as input to other learning processes.

The sound structure of human languages is another evidence for universal structural aspects of human languages that stem from constraints of human learning. Studies revealed that infants can acquire new regularities only if they are compatible with the patterns of natural language structure [47]. According to these findings, infants tend to learn language better when they are exposed to languages that have predictive dependencies compared to the languages that do not have predictive dependencies.

Related findings have also suggested that infants can learn language from exposure to it. "They learn rapidly from exposure to language, in ways that are unique to humans, combining pattern detection and computational abilities with special social skills. An absence of early exposure to the patterns that are inherent in natural language – whether spoken or signed – produces life-long changes in the ability to learn language" [48]. This statement clearly states the importance of exposure to the patterns of language that is crucial in language development during infancy.

Social influence on language learning highlights the importance of social interaction, especially in natural language learning in humans. Studies on speech-perception learning and speech-production learning have revealed that social interaction guides children language learning, especially in complex settings. In both situations, the interaction with another human greatly influences the child's language learning. "The impact of social interaction on human language learning has been dramatically illustrated by a few instances in which children have been raised in social isolation; these cases have shown that social deprivation has a severe and negative impact on language development, to the extent that normal language skills are never acquired" [48]. This reveals that experience (social interaction) plays a vital role in children's language development. Studies have found that social deprivation caused by aberrant

ISSN 2545-904X (Print) | ISSN 2704-4157 (Online)

brain function negatively impact on children's language learning.

Further, studies have illustrated that children's language learning is based on factors such as their admiration of others' intentions in communication, sensitivity to joint visual attention, and desire to imitate. A study with 9-months old American infants revealed the importance of social interaction in language learning [49]. In this study, infants were exposed to Mandarin in 12 sessions (live social interaction with televised foreign language materials) to identify the impact of exposure to a foreign language in their speech perception. Results suggested that infants learned the language during the live sessions. They were again tested to see whether this type of learning depends on live human interaction, by testing another group who were exposed to the same Mandarin speakers either on television screen or over loudspeakers. Results showed that those groups were significantly different from the group exposed to live sessions, suggesting the importance of live human interaction on learning natural language.

Studies of speech production have also provided evidence for the importance of social influence. In a study, mothers' reactions to their infants communication were manipulated: half of mothers were asked to react immediately to their infants by smiling, touching, and moving closer to them (contingent condition) and the other half were yoked controls, that is, those mothers responded at the same times, regardless of their infants' behaviours [50]. Findings suggested that infants in the contingent condition showed more vocalizations than those with yoked control mothers. Moreover, their vocalizations were more mature and adult-like than the other group. This underlines the importance of social influences when infants learn a foreign language (Mandarin) they tend to follow a speaker's gaze. It is said that gaze-following to an object is usual for 9-months old infants and is main predictor of vocabulary. This may also assist infants to segment words when they listen to continuing speech.

Some studies have suggested some of these abilities are not confined to humans. However, other species may not able to produce similar outcomes in every situation. For example, it was also found that Cotton-top tamarins (monkey species) could use the statistical properties to find out word boundaries [51]. Compared to these species, infants are able to use statistical properties in real-world language acquisition. With regard to language learning, other species, such as songbirds, can improve their communicative learning through social contact. However, these species' social contact is limited compared to human social interaction. Also, there are some unique experiences in infants' language learning. For example, experiences such as joint visual attention can be unique to humans in their learning process.

CONCLUSION

Considering the aforementioned factors, it is clear that environment plays a significant role in cognitive development in children. Research on developing face-processing as well as learning language revealed that greater exposure to environmental inputs and experience received from social environment is crucial for infants' cognitive development. All these external conditions are the inputs that a child receives from his or her environment. These environmental influences significantly impact many aspects of cognitive development such as language, perception, and memory. Future research could focus on investigating the influence of unique characteristics or factors within socio-cultural environment that contribute to children's cognitive development.

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ISSN 2545-904X (Print) | ISSN 2704-4157 (Online)