



A Proposed MaPS Framework for Cognitive Processing Skills

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Abstract

Cognitive processing skills are crucial in the areas of learning, academic achievements, intellectual functioning, and logical reasoning. One of the main elements of the cognitive process is processing speed can be defined as the fastest time taken for a person to perform a mental task with accuracy. Processing speed is affected by attention and memory. Strong processing skills is an advantage in academic learning while learners with poor processing skills will struggle in literacy (reading, comprehension, writing, and spelling) and numeracy (mathematical computation and solving word problems). To help educators in teaching learners improve processing skills, the authors of this paper proposed a MaPS framework of cognitive processing skills. This framework comprised of two components: (1) Memory (M) and (2) Processing Speed (PS) mediated with attention (a). The importance of each components and its implications in learning is discussed in this paper. It is hoped that educators are more aware on the implications on the lack of such factors in learning. With this awareness, it is then able to develop intervention programs aiming to improve learning outcomes of learners with poor processing skills.

Keywords: cognitive processing skills, memory, attention, processing speed, attention deficit hyperactivity disorder

Introduction

Students have to cope with many demands in school in their academic learning in Singapore context. This includes paying attention to what teachers are saying, remembering and retaining information being read, written, or taught. Students even have to complete online activities at home. With such heavy demand of schoolwork and overload of information, it is sometimes difficult for students to process multiple incoming information at the same time. This is even more challenging to students who have learning challenges such as autism spectrum disorder, attention deficit hyperactivity disorder, reading disabilities, or speech and language delay. The rate of how fast or slow an individual takes in incoming information, make sense of it, and respond appropriately is known as processing speed.

Slow processing speed impacts learning in all stages of learners in school. It can make reading, spelling, writing, and performing maths computation quickly and accurately. On its own, slow processing speed is not a learning or attention issue, but it can contribute to learning issues (e.g., auditory processing disorder, dyslexia, or dyscalculia) or attentional issues (e.g., attention deficit hyperactivity disorder).

One common type of processing speed is visual processing speed. Visual processing speed is how fast an individual can look at and process information on a task that does not take any more thinking than noticing the differences or sameness in the objects shown. This type of processing speed issue may be helped by vision therapy, or larger print. When children have difficulty with fine motor skills (e.g., writing), this becomes a visual-motor integration weakness. Another type of processing

speed is auditory processing speed. Auditory processing speed is the speed at which individuals respond to verbal instructions and executing it effortlessly. There are several required skills involved in auditory processing. For example, when given multiple-steps verbal instructions to a student (go to the computer lab, borrow a keyboard from Teacher Jennifer, and give it to the principal), he/she should be able to remember the instruction given (working memory), sequence the steps (auditory-sequential memory), and executing the steps correctly (execution).

Processing skill is essential in school-aged children in their learning. For example, visual processing skills are needed for reading, copying, and writing while auditory processing skills for receptive language (understanding instructions) and spelling. Students who have slow processing skills tend to be slower in their schoolwork, take a longer time to copy notes from the board to their books, hand in their assignments later than their peers, or take a longer time to answer questions from the teachers. Processing skills in children typically involve memory, attention and concentration, and processing speed. It must be noted that children with slow processing speed are not necessarily to have a learning disability, or are they having a low intellectual functioning.

A Proposed Framework of Cognitive Processing Skills

In the field of learning, there has been an extensive research on the various processing skills such as phonological processing and orthographic processing in language and numeracy (e.g., Hecht, Wagner, Torgesen, & Rashotte, 2001; Wagner & Torgesen, 1987; Cunningham & Stanovich, 1990)

[16, 27, 10] done over the past decades. In the findings from Hecht *et al.* (1987), it was found that phonological processing almost completely accounted for the relations between reading and general mathematical computation skills. There is evidence of bidirectional relations between general computation skills and simple arithmetic problem solving speed. In the area of orthographic processing, Cunningham and Stanovich (1990) [10] found that there are individual differences in word recognition ability of third and fourth-grade children caused by variation in orthographic processing abilities that are partially determined by print exposure differences.

There are many different components in cognitive processing skills which usually include attention, processing speed, auditory processing, visual processing, memory, and logic and reasoning. Such skills allow us to perform tasks such as hearing, seeing, physical activities, thinking, planning, remembering, and problem-solving.

In this paper, the authors proposed a framework of cognitive processing skills from two main constructs of (1) Memory (M) and (2) Processing Speed (PS), mediated by attention (a) with an acronym of MaPS as shown in Figure 1 below.

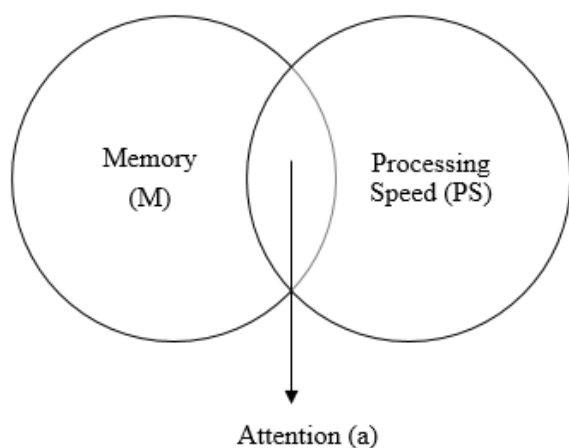


Fig 1: A Proposed MaPS Framework of Cognitive Processing Skills

Memory

There are numerous cognitive research in the area of human memory. Memory plays a very important role from early childhood days to late adulthood (Berk, 2010) [6]. Basically, memory is a process that takes in information from the surrounding, process it and helps to store information that is subsequently used for acquisition of complex skills and knowledge (Alloway, 2006) [1]. Any signs of poor memory capacity will result in disrupting learning as well as affecting the quality of one's life. The human memory acts as an information processing system that hold information in three parts: (1) the sensory memory, (2) working memory, and (3) long-term memory (Berk, 2010) [6].

Humans encounter sights, sounds, smells, taste and touch daily. All this information enter the sensory memory directly and are stored there. The sensory memory will register and retain traces of such sensory information for a short time after the original stimulus is gone (Sperling, 1960) [26]. This short period of time allows the brain to process on these incoming

sensations and allows one to make sense from these sensations. The main sensory memory has many sub-memories to help the human connect to the world better. For instance, the visual memory is a collection of information on what one has seen. It becomes a mental storage and when needed, it will be retrieved for usage. In the Educator's Diagnostic Manual of Disabilities and Disorders, Pierangelo and Giuliani (2007) [20] stated that visual memory plays an important role in our daily lives, especially more so in the learning process. Poor visual memory is linked to learning disabilities since the learner is unable to perceive whole words as visual forms or have difficulties in identifying patterns of letters when grouped together (Pierangelo & Giuliani, 2007) [20]. Likewise, the auditory memory plays an equally important role in taking in information that is presented orally. Upon hearing the information, it is processed and stored in the memory for subsequent recalling of familiar stories or events. Any auditory memory deficit will result in listening issues. From the learning perspective, it will affect a learner's understanding of words and information. Severe cases may result in inability to distinguish the smallest units of speech sounds and eventually inability to sort out the relationship between the visual appearances and sounds of letters and words (Pierangelo & Giuliani, 2007) [20]. The tactile memory refers to the sensory memory relating to the sense of touch. Developing the sense of touch is vital for the good quality of life. With a good sense of touch, one is able to feel one's hand in the pocket. The receptors in one's skin on the fingers and palm combine with another sensory memory, the kinaesthetic memory (Proske & Gandevia, 2009) [21]. The kinaesthetic memory gives one awareness in terms of the information from the joints and muscles. Working in an integrated fashion, when the hand in the pocket starts to flap on one's side body, the auditory information is also activated as well. Hence, one is able to feel the hand's movement (tactile), finger muscles touching the side body (kinaesthetic) and able to hear the flapping sound (auditory). The olfactory memory, on the other hand, is the sense of smell and taste. Both these senses work together to detect the flavour of food. One is able to smell the food before it goes into the mouth while taste buds will be activated when food goes into the mouth. Once the food is in the nasal cavity, the nerves are stimulated and it sends signals to the brain for it to process on the quality of the food (Sarafoleanu, Mella, Georgescu & Perederco, 2009) [22].

The second part of the memory system is the working memory/short term memory. As it is not the scope of this paper to dwell on the different theories about the distinction between working memory and short term memory, the authors have decided to treat working memory to be the same as short term memory. While psychological assessments measure the learner's knowledge on what had already learned, working memory indicates the learner's ability to learn (Alloway, 2006) [1]. Working memory plays a vital role in the entire learning process. It helps in writing, problem solving, executing instructions, doing math and coping with multi-tasking. From a reading perspective, working memory does affect a learner's ability to read. According to Alloway (2006) [1], in normal developing children, working memory tasks do affect reading achievements and this is attributed to the limited ability to process and store information (De Jong,

1998)^[11]. Educators need to be aware that as the memory load on children (especially for children with special needs) increases, there will be more processing demands on the children's working memory (Alloway, 2006)^[11]. Common techniques that are often used to cope in classroom include reviewing past lessons, reducing the content of lessons as well as use chunking as a means to breakdown tasks into manageable portions (Alloway, 2006)^[11].

The longer information is being held in the working memory, the higher the chances that it will eventually be transferred to another storage area which is the long term memory (LTM). Information held in the LTM can be stored there for an entire lifetime (Bauer, 2013)^[5]. The LTM is further divided into explicit memory and implicit memory. According to Bauer (2013)^[5], any information that is intentionally remembered is stored in the explicit memory. In addition, explicit memory is further sub-divided into episodic memory (information relating to events and experiences) and semantic memory (information relating to facts and concepts). Implicit memory, on the other hand, are not consciously recalled but influences one's behaviour and knowledge.

Working memory, short-term and long-term memories are essential when attending and performing tasks, especially during procedural learning. In addition, processing speed is associated to memory as evidence has shown that when people who have faster processing speed do not have to hold too many information in their working memory Fry and Hale (1996)^[13]

Attention

In this new era of information technology with computers, mobile phones, iPad, and social media that flood us, it is not easy to stay focus on a single task. Instead, we tend to do several things at one time. Multitasking, a term used in this modern world, is often what most people do in their daily lives. Students are seen doing their homework while texting their friends and listening to their iPods. Parents and educators often wonder if they can really learn in this way. With information flooding and overwhelming us daily, how can we remain focus and pay attention to what we are doing? How then can students stay focussed and remain attentive? According to Galinsky, (2010)^[15], she posited four components in the first essential skills (i.e., focus and self-control) and they are (1) focus, (2) cognitive flexibility, (3) working memory, and (4) inhibitory control. For more information, please refer to her book of *Mind in the Making* as she provided many tips to promote focus and self-control in children.

Attention is the process or act of concentrating on one or more environmental factors that our five senses experience (Barkley, 1997)^[2]. In case of learning, one will need to focus or concentrate on the subject matter being thought. However, individuals with Attention Deficit Hyperactivity Disorder (ADHD) might have difficulty to keep their focus and attention for long. As such, this makes the learning process challenging for them. The symptoms of ADHD stem from a deficit in executive functions (EF) which coordinate thoughts, regulate emotions, and goal-directed actions (Barkley, 1997; Brown, 2013)^[2]. Such deficits produce difficulties in inhibition, initiation, flexibility in thinking, planning,

organization, emotional control, or working memory skills. Hence, it is crucial to learn how to adapt by knowing the different types of attention related to cognition. According to Barkley (1997)^[2], there are four types of attention and they are (1) sustained attention, (2) alternating attention, (3) divided attention, and (4) selective attention. The following sections provide a brief description of each of them.

Sustained Attention

Sustained attention is the ability to maintain focus or concentration for long periods of time in a certain activity, even if the individual is exposed to the repetitive action or activity. This kind of attention is usually used for majority of the learning and working activities such as listening to a teacher lecture the entire hour, reading books and notes the whole night to prepare for examination, answering test or exercise questions, completing a project, or perhaps, regularly working on a repetitive task. Sustained attention is very difficult to acquire or achieve as it requires lots of mental effort.

Selective Attention

When encountered with a number of environmental factors or stimuli, the human brain naturally responds by selecting a particular aspect or factor to focus on. This is known as selective attention. Selective attention is the ability to select from the many factors or stimuli and focus to only a particular that one prefers. Almost all people use this cognitive ability almost all the time. Every day, people are usually exposed to a number of environmental factors at home, at the school, at the office, and others but their brains respond by focusing only to the particular factors that matter most or those that people choose to focus on. By better understanding it however, the person is better able to select the appropriate stimuli to devote his or her attention to.

Alternating Attention

As its name suggests, alternating attention is the ability to immediately switch or transfer one's focus or concentration from one activity to another. The brain also instantly adapts even if the succeeding activity has a different level of knowledge or comprehension required. Similar to selective attention, alternating attention is also an ability that is used almost in the daily life. For example, while waiting for a bus, one may be checking text messages and keep an eye on the oncoming bus. Upon seeing the oncoming bus, one needs to look away from the mobile phone and get the money ready and board the bus. This type of attention requires one to make quick and sudden changes on one's activity or action in everyday life.

Divided Attention

Divided attention is the ability of an individual to focus or concentrate on two or more environmental factors, stimuli, or activities simultaneously. This type of attention is simply known as the ability to multi-task. Multi-tasking is considered a desirable talent for those who are gifted with this ability. Not everyone can perform several tasks at the same time. Divided attention or the ability to multi-task can be learned through practice or gaining expertise in a certain kind of activity.

Regardless of any types of attention mentioned above, the ability to stay focussed is also dependent on various factors. In a recent paper by Chua (2017) ^[9], he reiterated that when student is focussing or attending to a task, he/she displaying engagement and that active engagement is crucial in the learning of all students. A TPE model was proposed by Chua (2017) ^[9] which consists of three components to promote active engagement for children's learning. They are: Task (T), People (P), and Environment (E). Tasks that are fun and creative can capture the attention and engage children better. In addition, tasks must also be meaningful in order for full attention and engagement. Research has shown that if students do not consider a learning activity worthy of their time and effort, they might disengage with the task and that children will only be engaged when the engagement is active by requiring them to be attentive as well as in attendance (Fredricks, Blumenfeld, & Paris, 2004; Schlechty, 2001, p.64) ^[12, 23].

There are many strategies of promoting attention in children in their learning. Some suggested examples are playing games that require children to pay attention such as putting puzzles, musical chairs, Stroop activities (with a variety of animals, letters, numbers, etc.), and fun card games like UNO, Blink, and Spot It!

Processing Speed

The third component, Processing Speed (PS), of the MAPS framework for cognitive processing skills is just like computers with a central processing unit (CPU) to process more information at a faster speed (clock speed). Humans too have a CPU like a computer in the brain. Different people process information at a different speed as they have different CPUs. In the field of neuropsychology, processing speed is also known as information processing speed and it is a complex process which is difficult to define and measure.

School-aged children who have slow processing speed encounter difficulties in reading rate and fluency, processing spoken information automatically, understanding fast directions, and writing information on paper. For example, children with slow processing speed may appear confused or forgetful when they are unable to process information (visual, auditory, or motor) at the speed being delivered. As such, teachers often call these children as lazy or slow and never seem to get things done on time. To parents, some even wonder why their children are so slow even though they are smart.

Processing speed can simply means the pace at which one is able to perceive sensory information (visual, auditory, tactile, olfactory, and kinaesthetic), make sense of that information, and then respond to it appropriately (Braaten & Willoughby, 2014) ^[3]. According to Jacobson *et al.* (2011) ^[17], processing speed refers to the speed with which individuals are able to complete a cognitive task with a reasonable degree of accuracy which involves speed of input (perception), speed of output, and the speed of integration of perceptual, cognitive, and output processes. In other words, processing speed is simply the quickest amount of time taken to get something done.

The speed of processing can affect automaticity and fluency with cognitive tasks (Kail, 1991) ^[18]. For instance, how fast a

student can decode words will adversely affect his reading rate and fluency, thereby ultimately affecting his reading comprehension. Likewise, taking a longer time to process auditory information may affect a student's writing fluency in spelling. According to Braaten and Willoughby (2014, p.4) ^[3], "processing speed does interact with other areas of cognitive functioning by negatively impacting the ability to quickly come up with an answer, retrieve information from long-term memory, and remember what you are supposed to be doing at a given time". Students with distractibility issues, such as ADHD, struggles with processing speed in performing school work as they find it difficult to stay focussed in the tasks. On top of ADHD, such students face more struggle in their learning when they also have other learning difficulties like reading disability (RD). Results have found that measures on processing speed and working memory were consistently lower among those with combined ADHD and RD than those with either type of disorders alone (Willcutt, *et al.*, 2005) ^[28]. Besides learning difficulties, slow processing speed can also be a result of other factors such as anxiety and self-doubt which involves an emotional component (i.e., emotional regulation). The child's inability to manage frustration and anxiety affects their processing speed which may result in taking a much longer time to complete a task (Butnik, 2013) ^[7].

According to Braaten and Willoughby (2014) ^[3], there are three main components when considering processing abilities and they are:

- (1) visual processing: how rapid a student's eyes perceive incoming information and relay it to the brain (e.g., such as reading directions or noticing a teacher's hand gestures),
- (2) verbal processing: how fast a student hears an auditory stimulus and reacts to it (e.g., such as following oral instructions or participating in a discussion),
- (3) motor speed: how strong a student's fine motor agility is which leads to academic fluency (e.g., answering timed math worksheets)

In the classroom, processing speed involves the ability to take in information, understand that information, and then formulate an oral, written, or physical response. For students with slow processing speed, they may struggle to keep up with the fast pace of lesson as compared to their typically developing peers. Children with poor processing speed can impede their learning in classroom as their mental activity needs more time and effort than other children. For example, due to their poor perceptual speed, activities require psychomotor speed (i.e., how fast something is copied, written or manipulated) will be greatly affected. As such, children find copying from board to books or writing a laborious job. They may also have difficulties in identifying identical items such as letters, numbers, objects, pictures, or patterns presented in a series or array.

Poor processing speed has a great impact on children with learning disabilities as they find it very challenging to quickly process incoming information, process and then execute the appropriate response to a given task as it will affect their planning and organising. Research has shown that students with reading disabilities such as dyslexia and ADHD have a

high degree of comorbidity and deficits in processing speed and this may partially explain the overlap in these two disorders (Shanahan *et al.*, 2006)^[25]. In addition, evidence has also shown that impairments in working memory for individuals with speech and language delay (Semrud-Clikeman, 2005)^[24] and ADHD (Jacobson *et al.*, 2011)^[17] often demonstrated challenges and that this play a crucial role in both processing speed deficits and reading fluency difficulties (Jacobson *et al.*, 2011)^[17]. In addition to reading fluency, slow processing speed is also associated with computational difficulties (Fuchs *et al.*, 2008)^[14]. In a study which involved 924 third-grade students, Fuchs and colleagues examined the mathematical computations. Results revealed that computational difficulties was related to weaknesses in attentive behaviour and processing speed while problem-solving difficulties was related to poor language. Another study by Hecht, Torgesen, Wagner, and Rashotte (2001)^[16] also discovered that there was a correlation between processing speed and computational skills in maths while controlling for vocabulary knowledge.

Processing speed is also associated with working memory ability. Individuals who can process incoming information at a faster speed do not have to hold too much information in the working memory. As working memory can only hold information for only brief periods of time, individuals who process information slowly (i.e., poor processing speed) will quickly fill up their allotted storage time. A large study on children, adolescents and adults were performed by Fry and Hale (1996)^[13] which examined the relationship between processing speed, working memory and intelligence. Results showed that as people get older, intelligence increases to a large extent, which is a product of improvements processing speed and working memory. It was also found that it was improvements in processing speed over time that caused improvements in working memory.

When poor processing speed go unrecognized and unaddressed, students with a slower pace can feel discouraged and demoralized. However, once they are understood and efforts are made to help reduce the impact of the slower pace, these students' best abilities can shine. Parents may need to take the lead and arrange for evaluations, educate those involved in their children's lives, and provide their child with unwavering support and encouragement.

It should also be noted that poor processing speed can be caused by many other factors. Hence, a good understanding of the source of the problem in children with poor processing speed is critical before helping them. According to Kaufman (1994)^[19], the Processing Speed Index (PSI) used in IQ test such as Wechsler Intelligence Scale for Children is "related to clinical, personality, behavioural, and neurological variables" (p. 209). Hence, thorough medical and psycho-educational evaluations are important when one has poor processing speed. For example, it can be associated with physical illness or injury such as epilepsy or traumatic brain injury. It might also be related to other physical problems (e.g., lack of adequate sleep or adverse effects to medications) or socio-emotional problems (anxiety or fear). Finally, poor processing speed might also be caused by distractibility, impulsivity such as ADHD, learning disabilities (e.g., dyslexia), and/or emotional factors.

Conclusion

The authors of this paper emphasised the importance of memory, attention, and processing speed in cognitive processing skills. A framework was proposed with two core components of (1) Memory (M) and Processing Speed (PS), mediated by memory (a), thus giving the acronym MaPS. The importance and the relationship amongst them were briefly discussed. Students who have challenges in any of these constructs will face problems in reading, writing, spelling, or maths. If not being addressed, such students with poor processing skills will be termed as lazy, slow, or uncooperative by the teachers. Hence, it is important for educators to identify the core deficits of poor processing skills. When addressed, then we can design appropriate intervention programs to address underlying deficits and help learners cope with their learning.

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