

## Mental and behavioral effects of parasitic infections: A review

Anisha Jasti,<sup>1</sup> Suvash Chandra Ojha<sup>2</sup> and Yengkokpam Ibotomba Singh<sup>1</sup>

<sup>1</sup>Department of Microbiology, Manipal College of Medical Sciences, Pokhara, Nepal.

<sup>2</sup>School of Pharmaceutical and Biomedical Sciences, Pokhara University, Pokhara, Nepal.

**Corresponding author:** Anisha, Lecturer, Department of Microbiology, Manipal College of Medical Sciences, Pokhara, Nepal. e-mail: [anisha\\_choudhary@hotmail.com](mailto:anisha_choudhary@hotmail.com)

### ABSTRACT

Whether parasitic diseases-and in particular helminth infections because they are extensive and widespread-have an effect on mental functions and educational attainment is by no mean a new question. Concern about the possibility was evident in the early decades of the century, and the results of investigations designed to discover whether the effects of parasite infections had consequences on school children. Many species of helminth have been reported as causing infections in humans. Of the nematode infections, both soil transmitted helminthiasis and lymphatic filariasis are public health problem in the country. Any of these infections may result in morbidity, malnutrition, and iron-deficiency anaemia. Their possible contribution to impaired cognitive function and educational achievement is by the association between iron deficiency anaemia and malnutrition. Research on the effects of parasitic infection has focused on school-age children. Not only are these children the most vulnerable to parasitic infections-they are also the population group most likely to experience the impact of infection on cognitive function. This review paper discusses the mental and behavioral effects of parasitic infection on child's health. Infected children are less active; their behavior is said to be sluggish and both mental and physical activities and processes appear dulled and slow. A reduction in available energy is likely to cause a cascade of effects running through most aspects of the host's daily mental life and behavior.

**Keywords:** cognitive function, mental energy, behavioral effects, educational performance.

### INTRODUCTION

**Parasites - A leading undiagnosed health problem:** Being in good health is an important aspect of person's well being. It is a state we all seek to maintain and one we consider a justifiable expectation. Ill health, whether physical or mental, can have deleterious effects on cognitive functioning. Current research efforts are attempting to understand what these effects are and what can be done about them. In the course of this review, it is shown how the methods of psychology from the developed world can be applied to the problems of the developing world.

Indeed many countries recognize the right of the child to the enjoyment of the highest attainable standard of health.<sup>1,2</sup> Moreover; good health not only has consequences for individuals but also for families, societies, and populations. Health is a factor in economic growth, directly by affecting production and indirectly by the diversion of resources from production to treat sickness. An important linkage identified in the 1993 world Bank Report, Investing in Health,<sup>3</sup> holds that children's education, in turn, impinges on economic growth. Good health, it is believed, increases school enrollment, reduces school drop out rates, and generally makes children better able to learn. Conditions that produce chronic ill-health are especially insidious, because they threaten developmental progress at every level and interact cumulatively with other risk factors. Given the persistent influence that bacteria, viruses, and other parasites have had on human evolution it's astonishing that so little scientific attention has been devoted to theory impact on human psychology and human culture. There are extensive bodies of research documenting the role of parasites on evolved patterns of animal cognition and behavior. It is likely that the human mind too is characterized by mechanisms designed to recognize and respond negatively to individuals who show signs of parasite infections-and to do so especially under conditions in which the risk of parasitic infection is especially high.

**Extent of the problem:** Parasitic protozoans and helminths are among the most widespread infective agents. Are the effects debilitating? Absolutely. One can argue about strengths of effects, which of course can vary with severity of insult.<sup>4</sup> These maladies can make a significant unfavorable difference to cognitive functioning.<sup>5</sup> They are responsible for an enormous amount of morbidity and significant

mortality, especially in underdeveloped countries and particularly in tropical regions. Moreover, worm infections tend to concentrate in children from preschool to adolescence and a little beyond.<sup>6</sup>

More than 1 billion people worldwide are infected by *Ascaris lumbricoides*, the great round worm,<sup>7</sup> about 500 million, by *Trichuris trichiura*, the whip worm,<sup>8</sup> and around 800 million, by hook worm species, *Necator americanus* and *Ancylostoma duodenale*. In addition, more than 300 million persons are infected by *Schistosoma* species. With several species, prevalence peaks in childhood,<sup>9</sup> and there is some suggestion that the intensity of infection is greatest in school-age children.<sup>10</sup>

To date, medical Parasitology has mostly focused on physical symptomatology, perhaps because, on the whole, it is easier to detect and describe quantitatively. However, certain psychological symptoms have been loosely described for many years, most notably "lethargy and mental fatigue." Over the past decade, interest in possible psychological consequences of parasite infection has quickened, especially with regard to cognitive processes. Anything that compromises cognitive processes may directly affect a child's capacity to benefit from schooling.<sup>11</sup> A somewhat different aspect of this is the possibility that the developmental processes may be delayed or disturbed by the invasion of a parasitic organism, with consequences for educational outcomes that may themselves be altered or delayed.

**Parasitic infection and cognitive function: the evidence:** Whether parasitic diseases-and in particular Helminthic infections have an effect on mental functions and on educational attainment is a question. Concern about the possibility was evident in the early decades of the century, and the results of investigations designed to discover whether the effects of parasite infections had consequences on school performance were published 80 years ago. However, given the potential importance of the matter and the widespread nature of parasite infections; there have been surprisingly few studies. Many of the studies have used measures of educational attainment as the outcome variable. At first sight, this seems entirely sensible, especially if the primary issue concerns the effects of infection on educational performance. However, it is necessary to appreciate that school performance and even school attendance can be affected in large measure by variables other than parasitic infection.<sup>12</sup>

**Effects of parasitic infection on cognitive performance and behavior:** There are many reports that demonstrate that parasitic disease is likely to impair cognitive function.<sup>13</sup> Parasites cause changes in host behavior, changes that are advantageous to the parasite.<sup>14</sup>

**The effects of parasites on emotions and intellectual capacity:** Parasites can have a direct and profound effect on emotions and intellectual capacity. They can be the direct cause of depression, irritability, emotional swings, confusion, inability to concentrate, and restlessness. They have many indirect causes as well. Insomnia and broken sleep creates fatigue that in turn affects most things in life. This in turn leads to many other difficulties in relationships and overall quality of life. The emotional and intellectual effects of parasites on humans are huge.

Many people today are infected by a certain blood parasite. This infection always brings mental depression with it. This depression often disappears once the blood parasite has been eliminated. Parasites can have a major effect on the emotions of those they infect. As parasites are eliminated the vital force and the energy of the person slowly and gently increases. Once the energy has increased, people are then strong enough to deal with their emotions and emotional issues in life. It's amazing to see people almost come to life in front of our eyes and begin to find the energy, emotional strength and intellectual capacity to enjoy life again.

It's important to note that not all emotional imbalances, depression etc. are caused by parasites. There are many other causes for emotional difficulties. Parasites are often one of the causes and should be identified and eliminated to ensure they are not the only cause of our emotional difficulties. At times, parasites are the only major cause of emotional and intellectual difficulties.

**Parasites and mental function: causal linkages** It is not understood why working memory as opposed to other cognitive domains should be affected by helminths. But, one explanation could be that some of the working memory tasks, and in particular the central executive, involve the frontal lobe part of the brain,<sup>26</sup> and this is a part of the brain which seems to continue developing up to adolescence<sup>27</sup> during the time when children are most likely to be infected with helminths. Whatever the mechanism, it is important that working memory may be one of the cognitive domains that is affected by helminth infection and that can show rapid improvements following antihelminthic treatment.<sup>28</sup> Effects on working memory could have

broader implications for the educational achievement and development of a child, not least because of the underlying association with complex real-world tasks such as reasoning ability and reading comprehension.<sup>29</sup>

If we accept the proposition that parasitic disease can have deleterious effects on the mental function of the host, the question that immediately follows concerns is the causal pathways. This is fundamentally important for several reasons. The wide range of educational and psychological outcome measures is not linked or integrated within any theoretical framework. In a critical review and analysis of the links among parasitic infection, malnutrition, and cognitive performance in children, Connolly and Kvalsvig<sup>30</sup> argued that an analysis in terms of information processing is likely to be useful. Rather than relying on general measures of cognitive performance such as IQ's, they emphasized the advantages to be gained from examining the component processes that underlie intellectual performance. The affected children may be losing not just IQ points, but other kinds of abilities as well, such as creative and practical intellectual abilities.<sup>31</sup> What do such effects mean in practical terms, whether the losses are in the kinds of analytical abilities measured by conventional intelligence tests, or in creative or practical abilities?

There is a broad distinction between two classes of variables that contribute to intelligence.<sup>32</sup> The two classes are low-level processes (primarily a reflection of biological factors) and high-level processes (in essence a reflection of sociocultural variables). Both are necessary for intelligent behavior and they interact with one another in a number of ways. High-level processes are linked with learning and experience, particularly with education and the acquisition of cultural skills. On the other hand, high-level processes are linked principally with physiological systems and the efficiency with which various biological processes, particularly neural processes operate. This broad distinction was used to propose a general strategy that entailed exploring the effects on elementary cognitive processes.<sup>33</sup> The efficiency of these elementary processes would be compromised by the effects of pathological processes acting on biological systems. Any effects on these elementary processes would constitute a risk factor for educational performance.

**Direct and indirect routes:** How parasitic infection affects the mental function and behavior of the host? A broad but not too sharp distinction can be drawn between direct and indirect effects. If we assume that cognitive processes and behavior are organized and controlled by the Central Nervous System (CNS), then any variable affecting CNS might also have an effect on individual's , mental processes and capacity. The explanation offered by Mac Donald<sup>34</sup> for what he called "demoralization" among school children infected with hook worm would fall into the set of direct effects-he proposed the apathy that is typically reported among these children was caused by nerve toxin secreted by the hookworm.

Various parasitic organisms may invade the CNS is known for many years. Sprent<sup>35</sup> cites a case reported by Du Verney around 1706 in which a round worm was found in the brain sinus of a child. Invasion by these nematodes causes a variety of nervous impairment symptoms. The various pathological changes depend upon a number of things, including the parasite's route of entry, its size, and its mobility. Pathological changes may be local or diffuse, and they include hemorrhage, degenerative changes, and proliferative effects. Not surprisingly, the pathological changes associated with significant brain damage tend to be severe and include various forms of epilepsy and marked locomotor incoordination.

Rather than being clear-cut, the distinction between direct and indirect routes of effect is relative. Different parasites have different etiologies. For example, heavy infections of *Trichuris* may affect mental processes by producing a state of iron deficiency anaemia.<sup>36</sup> Oudin *et al*<sup>37</sup> argued that one of the consequences of iron deficiency is a selective diminution of central dopamine neurotransmission, which in turn, has consequences for dopamine-dependent behaviors, one of which is learning. Children with iron deficiency anaemia show minor defects of cerebral function: poor attentiveness,<sup>38</sup> poor coordination<sup>39</sup> and they tend to score lower on motor and mental tests.<sup>40</sup> Their capacity for physical work is also reduced.<sup>41</sup>

In contrast, heavy infection of *Ascaris* may affect mental processes by inducing a state of undernutrition.<sup>42</sup> A heavy worm burden may lead to a reduction in the food available to the host in a number of ways by causing malabsorption in the gut or by inducing anorexia. Our present state of knowledge is such that we know little about the processes, intervening between parasitic infection and the presumed altered behavioral and mental states. However, it is important to bear in mind that more than one pathway may be activated, so that the outcome is a consequence of a complex and variable pattern of contributing factors. Whatever the disease pathway, the deleterious effects on behavior and mental function are at some level a consequence of changes in the working of host's central nervous system.

**Energy and immune system: the behavioral immune system:** The behavioral immune system serves as an organism's first crude line of defense against potentially harmful parasites and pathogens. It would probably be more apt to refer to this as the 'psychological immune system' because the system involves emotions and cognitions as well as behavior. The behavioral immune system is triggered by the perception of specific kinds of stimuli (e.g., morphologically unusual appearance). When such stimuli are perceived, there ensues the automatic activation of the specific emotions and cognitions (e.g.; disgust, automatic inferences about disease-connoting traits) that facilitate functional behavioral reactions (e.g. avoidance, social exclusion).

A condition or state associated with parasitic infection is lethargy-the host is sluggish and lacking in physical and mental energy. Kvalsvig's measurements<sup>43</sup> offer a clear example linked to memory and sustained attention.<sup>44</sup> The inference drawn from such studies also gains some support from studies on work capacity in infected individuals. Mental activities and the processing of information have an energetical aspect. With respect to mental processes, organisms behave as if they are resource dependent systems, meaning that there are clear limits on their capacity to perform. In essence, there is competition for "energy" between tasks that have little structural similarity.<sup>45</sup> Much of the relevant experimental work relating energetics and information processing is discussed in terms of mental work load<sup>46</sup> or the effects of stress on performance.<sup>47</sup> These energetical constructs provide an indication of where to focus future studies directed at dissecting out the effects of parasitic infection on mental processes.

Not all the symptoms associated with infection are a consequence of pathology; some may be a consequence of changes in the host that serve a protective function. The various manifestations of infectious diseases could be classified as follows: (1) Adaptations of the host to counteract harmful effects of the disease, (2) Adaptations of the pathogen to manipulate the host and (3) Side effects of disease that do not serve an adaptive function for either the host or the pathogen.<sup>48</sup>

The invasion of the body by foreign material leads to the activation of the immune system. The immune system is made up of two major components- innate or nonspecific immunity and acquired or specific immunity. Innate immunity is present from birth and operates quickly in a nonspecific manner irrespective of the exact nature of the invading foreign matter. Evidence is steadily accumulating to indicate that psychological variables can modulate immune responses, and it also appears that communication goes in the other direction, from the immune system to the nervous system. Consequently, there is a pathway through which the immune system can affect behavior and mental function. The immune system acts, so as to speak, like sensory organ distributed throughout the body with cytokines serving as the messengers.<sup>49</sup>

But why should activation of the immune system lead to changes in behavior and psychological function? The innate immunity response involves many processes which together create a huge energy demand. To meet this demand, the organism must reduce energy expenditure elsewhere, which entails changes ranging from the metabolic level to the behavioral, although all are coordinated by the central nervous system. The behavioral changes deployed to reduce energy expenditure include reductions in such aspects of physical activity, exploratory behavior, and social interactions. These changes are strikingly similar to those that have been observed in individuals suffering from moderate to severe parasitic infections, and it is possible that they are a consequence of the host's efforts to counteract the harmful effects of the pathogen.<sup>50</sup>

## CONCLUSION

Throughout these centuries, some degree of medical, social, and/ or scientific concern has been manifested regarding the effects of parasite disease, particularly the helminthiases, on mental function. However, what aspects of mental and behavioral functions are affected is by no means clear, nor do we have any satisfactory model to help us examine the interrelationship of parasitic disease with other variables that affect mental and behavioral development in children.

As a rule the communities that suffer the most from parasitic disease also have to bear many other afflictions. Typically, these communities lack amenities such as clean water and adequate medical care. Children in these communities are commonly undernourished, and micronutrient deficiencies are by no means rare among them. Educational provision, particularly adequate material resources, well-trained teachers, and reasonable class size, leaves much to be desired. Children in these circumstances are not threatened and marginalized only by a single problem; they face many. Their situation may be such that one more difficulty, such as a parasite infection, produces no measurable effect on an already depressed performance.

The most general and striking observation that emerges from various studies has to do with lethargy. Infected children, and often adults, are less active; their behavior is said to be sluggish and both mental and physical activities and processes appear dulled and slow. Ironically, it is not just the disease that is

debilitating them, but their own body. Their body is telling them that this isn't the time for them to be engaging in strenuous mental activity, or, of course, physical activity. The body needs all the resources it can muster to fight the infection. To detect the effect and measure it reliably is not easy, but overall it appears to be the most pervasive and perhaps the most basic consequence of parasitic infection. A reduction in available energy is likely to cause a cascade of effects running through most aspects of the host's daily mental life and behavior. Irrespective of whether the prime cause arises directly from the pathogen's effects on the host and / or the host's attempts to counteract the harmful effects of the pathogen, limitations on available energy offer a starting point for constructing a theoretical framework to guide further attempts to explore the problem. Living systems are in a state of dynamic equilibrium, though the rate of change varies with the system in question and the developmental status of the individual. It is possible that a parasitic infection on a developing organism first interferes with the existing state of a system, and then moves on to disturb its subsequent development. A disturbance in the maturation of a system may well have long-term consequences for the subsequent development of other systems; moreover, organisms are generally more vulnerable when they are undergoing a rapid change. Obviously much remains to be done.

The question now is what we are going to do about all this. Do we want to support the research and development? People can ask themselves what they would do if there were a malady--easily studied and treated, that was robbing their country of millions of IQ points; that was physically devastating the children in their country; and that it was in their power to treat. They can ask themselves whether, because of the loss in cognitive skills, it is worth not only the fiascoes in the supermarket and bank lines, but also in the wars that are fought for no need, because people have not developed the cognitive skills to think clearly and well.

## REFERENCES

1. United Nations. Adaptation of a convention on the rights of the child. *UN Document No. A/44/736* New York 1989.
2. UNICEF. The state of the world's children. Oxford: *Oxford University Press* 1993.
3. The World Bank. World development report: investing in health. New York: *Oxford University Press* 1993.
4. Ricciuti HN. Malnutrition and cognitive development: *Research-policy linkages and current research directions* 1994; 59-80.
5. Sternberg RJ, Grigorenko EL, Nokes C. Effects of children's ill health on cognitive development. In M. Young (Ed.), *Early child development: Investing in our children's future* Amsterdam: Elsevier 1997; 85-126.
6. Awasthi S, Bundy DAP, Savioli L. Helminthic infections. *Brit Med J* 2003; 327: 431-3.
7. Crompton DWT. Prevalence of ascariasis. In: Crompton DWT, Nesheim MC, Pawlowski ZS, eds. *Ascariasis and its prevention and control*. London: Taylor and Francis; 1989.
8. Bundy DAP, Cooper E. Trichuris and trichuriasis in humans. *Adv Parasitol* 1989; 28: 107-73.
9. Kabatereine N, Tukahebwa E, Brooker S, Alderman H, Hall A. Epidemiology of intestinal helminth infections among schoolchildren in southern Uganda. *East Afr Med J* 2001; 78: 283-6.
10. Partnership for Child Development. The health and nutritional status of schoolchildren in Africa: evidence from school-based programmes in Ghana and Tanzania. *Trans Roy Soc Trop Med Hyg* 1998; 92: 254-61.
11. Nokes C, Grantham-McGregor SM, Sawyer AW, Cooper ES, Bundy DAP. Parasitic helminth infection and cognitive function in school children. *Proceedings Roy Soc London. Series B: Biol Sciences* 1992; 247, 77-81.
12. Gwatkin D. Country Reports on Socio-Economic Differences in health, Nutrition, and Population. *World Bank* 2000.
13. Watkin NE, Pollitt E. "Stupidity or worms": do intestinal worms impair mental performance? *Psychol Bull* 1997; 121: 171-91.
14. Thompson SN. Physiological alterations during parasitism and their effects on host behavior. In: Barnard CJ, Behnke JM, eds. *Parasitism and host behavior*. London: Taylor and Francis; 1990.
15. Stiles CW. Memory tests of school children. Memory span of 1,585 white school children in the city of X. *US Public Health Reports* 1915b; 30: 3738-45.
16. Stiles CW. The school grades attained by 2166 white school children in the city of X, classified by age, sanitation and intestinal parasites. *US public Health reports* 1915a; 20: 2060-67.
17. Waite JH, Neilson IL. Study of the effects of hookworm infection upon the mental development of North Queensland school children. *Med J Aust* 1919; 1: 1-8.
18. Smillie WG, Spencer CR. Mental retardation in school children infested with hook worms. *J Edu Psychol* 1926; 17: 314-21.
19. Gordon RM. The effect of Ancylostome, Ascaris and Trichuris infections on the health of the West African native. *Ann Trop Med Parasitol* 1925; 19: 429-60.

20. Bell RMS, Daly J, Komengoni E, Jones JJ. The effects of endemic schistosomiasis and of ascariasis on the mental ability of African school children. *Trans Roy Soc Trop Med Hyg* 1973; 67: 694-701.
21. Berlinguer G, Del Trono L, Orecchia P, Paggi L. Elmintiasi: intestinali, accrescimento e rendimento scolastico: indagine sugli alunni della scuola "D Chiesa" di Roma. *Revista di Parassitologia* 1964; 25: 77-92.
22. De Carneri I, Garofano M, Grassi L. Il ruolo della tricocefalosi nel ritardo dello sviluppo fisico e mentale infantile in base ad un 'inchiesta quantitativa nel Basso lodigiano. *Revista de oarassitologia* 1967 ; 28 : 103-22.
23. Castle WM, Clarke V de V, Hendrikz E. The effects of sub clinical bilharziasis on mental ability in school children. *South Afr Med J* 1974; 48: 2035-8.
24. Kvalsvig JD. The effects of Schistosomiasis on spontaneous play activity in black school children in endemic areas. *South Afr Med J* 1981; 60: 61-4.
25. Kvalsvig JD, Cooppan RM, Connolly KJ. The effects of parasite infections on cognitive processes in children. *Ann Trop Med Parasitol* 1991; 85: 551-68.
26. Shallice T. From Neuropsychology to Mental Structure. Cambridge: *Cambridge University Press* 1988.
27. Goldman-Rakic PC. Towards a neurobiology of cognitive development. Mehler J, Fox R, eds. *Neonate Cognition: Beyond the Blooming Buzzing Confusion*. Hillsdale, NJ: L. Erlbaum Associates 1984; 285-6.
28. Torlesse H, Hodges M. Antihelminthic treatment and haemoglobin concentrations during pregnancy. *Lancet* 2000; 356:1083.
29. Waters GS, Caplan D. The measurement of verbal working memory capacity and its relation to reading comprehension. *Q J Exp Psychol* 1996; 49A: 51-65.
30. Connolly KJ, Kvalsvig JD. Infection, nutrition, and cognitive performance in children. *Parasitol* 1993; 107: S187-200.
31. Sternberg R.J. Beyond IQ: A triarchic theory of human intelligence. Cambridge: *Cambridge University Press* 1985.
32. Anderson M. Intelligence and development; a cognitive theory. Oxford: *Blackwells* 1992.
33. Connolly KJ, Kvalsvig JD. Infection, nutrition and cognitive performance in children. *Parasitology* 1993; 107:s187-200.
34. MacDonald TF. Ankylostomiasis in Australia. *Lancet* 1908: 102-3.
35. Sprent JFA. On the invasion of the central nervous system by nematodes. I. Incidence and pathological significance of nematodes in central nervous system. *Parasitol* 1955; 45:31-40.
36. Pollitt E. Iron deficiency and cognitive function. *Ann Rev Nutr* 1993; 13: 521-37.
37. Youdim MBH, Ben Shachar D, Yehuda S. Putative biological mechanisms of the effect of iron deficiency on brain biochemistry and behavior. *Amer J Clin Nutr* 1989; 50: 607-15.
38. Pollitt, E. Iron deficiency and cognitive function. *Ann Rev Nutr* 1993; 13: 521-37.
39. Evans DIK. Cerebral function in iron deficiency: a review. *Child Care Health Dev* 1985; 11: 105-12.
40. Lozoff B. Behavioral alterations in iron deficiency. *Adv Pediatr* 1988; 35: 331-60.
41. Bruner AB, Joffe A, Duggan AK, Casella JF, Brandt J. Randomized study of cognitive effects on iron supplementation in non-anemic iron-deficient adolescent girls. *Lancet* 1996 ; 348: 992-6.
42. Nokes C. Parasitic helminth infection and cognitive function in school children. Proceedings of the Royal Society of London, Series B 1992; 247:77-81.
43. Kvalsvig JD. The effects of *Schistosoma haematobium* on the activity of school children. *J Trop Med Hyg* 1986; 89: 85-90.
44. Kvalsvig JD, Cooppan RM, Connolly KJ. The effects of parasite infections on cognitive processes in children. *Ann Trop Med Parasitol* 1991; 85: 551-68.
45. Kahneman D. Attention and effort. Englewood Cliffs, New Jersey: *Prentice-Hall* 1973.
46. Gopher D, Donchin E. Workload: an examination of the concept. In: Boff KR, Kaufman L, Thomas JP eds. Vol II, *Handbook of Perception and Human Performance*. New York: Wiley; 1986.
47. Sanders AF. Energetical states underlying task performance. In: Hockey G, Robert J, eds. *Energetics and Human Information Processing*. Dordrecht: Nijhoff; 1986.
48. Ewald PW. Evolutionary biology and the treatment of signs and symptoms of infectious disease. *J Theor Biol* 1980; 86: 169-76.
49. Maier SF, Watkins LR, Flesher M. Psychoneuroimmunology: the interface between behavior, brain and immunity. *Amer Psychol* 1994; 49: 1004-17.
50. Hart BL. Behavioral adaptations to pathogens and parasites: five strategies. *Neurosci Biobehav Rev* 1990; 4: 273-94.

**Table-1:** Effects of parasitic infection on cognitive performance and behavior

<b>Infective Agent</b>	<b>Age group affected(years)</b>	<b>Comments and results</b>
<i>Hook worm</i>	6-17	Infected children have: Low memory span, <sup>15</sup> lower school grades, <sup>16</sup> arrested mental development, <sup>17</sup> and lower IQ's. <sup>18</sup>
<i>Ascaris</i>	6-17	Infected children have: Low memory span <sup>19</sup> and there is no significant association between worm burden and school grades. <sup>20</sup>
<i>Trichuris</i>	10-22	Infected children show: Poor school performance, <sup>21</sup> and lower grades. <sup>22</sup>
<i>Schistosoma species</i>	8-18	Infected children tend to: Perform less, have mental fatigue, <sup>23</sup> have decrease in energy activity, <sup>24</sup> and show longer decision time. <sup>25</sup>