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Internet Use and Cognitive Development: a theoretical framework

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ABSTRACT The number of children and adolescents accessing the Internet as well as the amount of time online are steadily increasing. The most common online activities include playing video games, accessing web sites, and communicating via chat rooms, email, and instant messaging. A theoretical framework for understanding the effects of Internet use on cognitive development is presented. The proposed framework, based on the cognitive information processing model, the sociocultural perspective, the PASS cognitive processing model, and the neurological orientation, organises previous research in terms of the cognitive consequences of common online activities. From a cognitive-developmental perspective, the Internet is a cultural tool that influences cognitive processes and an environmental stimulus that contributes to the formation of specific cognitive architecture.

Introduction

Media is a contraction of the term *media of communication*, referring to organised dissemination of information and entertainment such as newspapers, magazines, film, radio, television, and the World Wide Web (McChesney, 2004). Media is currently a significant presence in many human environments (Gentile & Walsh, 2002). In a comprehensive survey of media use by pre-school children, Rideout et al (2003) reported that 99% live in a home with a television, half have more than two televisions in their home, and 36% have a television in their bedroom. 'Nearly half (48%) of all children six and under have used a computer, and more than one in four (30%) have played video games' (p. 4). Given such early and extensive use, the impact of media on children is of considerable concern (Roberts et al, 2004).

Research on the impact of media on children's development is subject to interpretation. Historically, panic surrounds the introduction of new technologies, particularly in relation to children and youth (Quigley & Blashki, 2003). Research conducted early in the social integration of new technologies is often 'governed by the myths of general cultural pessimism' (Boehnke et al, 2002, p. 193). Not surprisingly, television is associated with numerous undesirable developmental outcomes, including aggression and obesity (Bushman & Huesmann, 2001; Dennison et al, 2002; Gentile & Walsh, 2002), but viewing educational television improves academic and cognitive skills in children (Anderson et al, 2000, 2001; Bickham et al, 2001; Naigles & Mayeux, 2001). Video game playing is linked to social isolation and low self-esteem (Funk & Buchman, 1996), but Roe & Muijs (1998) found that children who played video games for more than two hours a day read more than children who did not engage in such *heavy use* of video games. Healy (1998) claimed that 'more and more college-age students are addicted to their computers' (p. 197), but recreational computer use is associated with increased academic achievement (Rocheleau, 1995). Public anxiety surrounds children's exposure to pornography and sexual predators via the Internet (Subcommittee on Telecommunications and the Internet, 2001), but schools have a mandate to enhance Internet access for children of all ages (Tarpley, 2001).

Such contradictory research findings and apparent inconsistencies between research and practice may be the consequence of inadequate theoretical frameworks for understanding the effects of media on children's development (Boehnke et al, 2002) as well as failure to organise the

effects of media relative to developmental domain. Cognitive theory, for example, is prerequisite to analysis of the effects of media on children's cognitive development.

Theories of Cognitive Development

Cognition is a general term encompassing mental processes such as attention, perception, comprehension, memory and problem solving (Solso et al, 2005). Cognitive development refers to changes in cognition over time. Theoretical frameworks for understanding cognition and cognitive development include the Cognitive Information Processing Model, the sociocultural perspective, the PASS Cognitive Processing Model, and the neurological orientation.

The Cognitive Information Processing Model

The Information Processing (IP) Model, as the name implies, conceptualised human cognition in terms of computer functions (Siegler & Alibali, 2004). The person (i.e. computer) has biologically predetermined neurological improvements (i.e. hardware upgrades), and learning results in increased knowledge as well as enhanced strategies for effective use of knowledge. IP assumes environmental stimuli move along a conveyer belt of cognitive processing. First, sensory stimuli register in the appropriate neurological sites. Attention to selected stimuli results in further processing which leads to perception. Perception moves the now meaningful stimuli (i.e. information) to various levels of memory (i.e. data storage) where subsequent processing ensures that it is available when needed. All stages of cognitive processing are facilitated by meta-cognition, which includes learning strategies and monitoring the effectiveness of processes (Solso et al, 2005). According to the IP perspective, as children develop, they become more able to focus attention on relevant stimuli, they have greater capacity to remember (i.e. store information), they recognise and interpret more stimuli due to increased knowledge base (i.e. stored information), and meta-cognition becomes more sophisticated, which improves the efficiency of all aspects of cognitive processing. This results in individuals who are progressively more able to function effectively in their environment (Klahr & MacWhinney, 1998).

The Sociocultural Perspective on Cognitive Development

The sociocultural perspective on cognitive development maintains that social and cultural activities mediate human interaction, which determines cognitive structures. Vygotsky, the central theorist associated with the sociocultural perspective, 'conceptualized development as the transformation of socially shared activities into internalized processes' (John-Steiner & Mahn, 1996, p. 192). Vygotsky (1978) proposed that all higher mental processes originate in social processes and that such processes can only be understood in terms of the tools of the culture. Cultural tools refer to both physical artefacts (e.g. printing press, abacus, telephone, computer) and socio-cognitive constructions such as signs, symbols, and language (Wink & Putney, 2002). Children develop cognitive structures in response to the use of cultural tools and, particularly, in response to the use of language. All languages have words for concepts and objects that are important to the culture (e.g. winter and snow); other languages have no words for the same concepts and objects. According to Vygotsky, language controls and is controlled by cognition. Further, if a culture provides children with, for example, Roman numerals for representing quantity, mathematical problem solving is limited. In this regard, the use of language and other cultural tools creates ways of thinking. From a sociocultural perspective, as children accumulate experience with people and things in their cultural and social environments, they become progressively more able to function effectively with the tools and corresponding thought processes required in their environment (Wertsch, 1991).

The PASS Cognitive Processing Model

The Planning, Attention-Arousal, Simultaneous and Successive (PASS) cognitive processing model links human cognition to specific neurological structures (Das & Naglieri, 2001). The PASS model

describes human cognitive processes within a framework of three functional units (Das, 2002). The first functional unit, Attention-Arousal, located in the brain stem and reticular activating system, provides the brain with appropriate levels of arousal that direct attention. The second functional unit receives, analyses and stores information through simultaneous and successive processing. During simultaneous processing, associated with the occipital-parietal areas of the brain, each element (i.e. environmental stimulus) is interpreted in relation to every other element and meaning is attained when all elements are processed simultaneously. Successive processing, associated with the frontal-temporal areas of the brain, involves the interpretation of stimuli in a specific serial order (i.e. each component is related to the next in a series). To illustrate, entering a classroom and identifying an appropriate desk at which to sit requires simultaneous processing; comprehending language requires successive processing. The third functional unit, Planning, located in the frontal lobes of the brain, provides for the regulation of behaviour such as asking questions, problem solving, self-monitoring, and impulse control (Luria, 1973). All of these cognitive processes result in an ever increasing base of knowledge which reflects 'all information obtained from the cultural and social background of the individual, because this determines the form of mental activity' (Das, 2004, p. 10). According to the PASS model, as children develop, neurological maturation and social experience result in increased ability to focus attention on relevant stimuli, improved simultaneous and successive processing capabilities, enhanced capacity to plan and regulate behaviour, and a larger knowledge base. This results in individuals who are progressively more able to function effectively in their environment (Luria, 1976).

The Neurology of Cognitive Development

Cognitive development and brain development are intricately related (Robinson, 2004). As the brain matures in size and neural connections, more complex cognitive processing is possible. However, neurological architecture also depends on environmental stimulation. Without an environment that causes neurological activity (i.e. a stimulating environment), cognitive processes fail to fully develop (Garcia et al, 2004). Experience is interpreted by the brain as patterns of neurological activity. Particularly during childhood when brain development is highly sensitive, such activity establishes patterns of brain functioning that influence cognitive characteristics (Solso et al, 2005). From a neurological perspective, as children develop, their brain functioning is modified by patterns of cognitive demands which, in turn, renders them well suited to function effectively in an environment that makes such cognitive demands (Johnson, 2004).

All cognitive theories, to various degrees and in differing ways, assume that mental processes are influenced by neurological maturation and environmental experience (Solso et al, 2005). From a cognitive-developmental orientation, media is an environmental experience, a cultural tool, and a set of stimuli that registers certain patterns of neurological activity. 'Any new medium brings with it new symbols systems which, in turn, influence the way the brain learns to take in and process information' (Healy, 1998, p. 142).

In formulating a theoretical framework appropriate for organising the effects of media on cognitive development, media is categorised in terms of varying cognitive demands which translate into cognitively distinct influences. The text in books is non-interactive and requires visual and language processing. Recorded music is non-interactive and requires auditory processing. Television is largely non-interactive and requires visual and auditory processing. The Internet is interactive, requiring the processing of visual input (i.e. text and images on a computer screen) that leads to manual output as devices (e.g. keyboard, mouse, response pad, controller) are manipulated.

Internet Use and Cognitive Development

The Internet, a relatively recent form of media, has grown rapidly in use and applications. Currently, children between the ages of 8 and 18 spend an average of over one hour each day in recreational Internet use (Roberts et al, 2004). Such figures, however, are misleading since children who do not have home Internet access, which may be more than one-third of the population (Rideout et al, 2003), are included in analysis. Adolescents are online more than any other age

group (Subrahmanyam et al, 2001). 'About 25 percent of 5-year-olds use the Internet, and this number rises to over 50 percent by age 9 and to at least 75 percent by ages 15-17' (National Center for Educational Statistics, 2003, p. iv). All trends indicate that the number of children accessing the Internet as well as the amount of time spent online is steadily increasing (Statistics Canada, 2004). Given such pervasive and extensive use in children and youth, from a cognitive-developmental perspective, the Internet is a cultural tool that influences cognitive processes and an environmental stimulus that contributes to the formation of specific cognitive architecture.

Internet use is not equivalent to computer use, although there is overlap in cognitive requirements. Like Internet use, computer use is interactive, with visual input and manual (i.e. tactile-kinaesthetic) output; unlike Internet use, computer use is limited to available software and does not connect the user to others for purposes of communication. While 'research suggests that computer use has changed the balance of cognitive skills from the verbal to the visual' (Subrahmanyam et al, 2001, p. 96), the cognitive consequences of Internet use are more complex than those associated with computer use. Additionally, the Internet is not like books or television 'in the sense that it is used primarily for communication, information gathering, and games rather than for passively experiencing narrative stories' (Tarpley, 2001, p. 551). To formulate a theoretical framework of the effect of Internet use on cognitive development, differing online activities require distinct analysis. The most common Internet activities for children and adolescents include playing video games, accessing web sites, and communicating via chat rooms, email, and instant messaging (Roberts et al, 2004).

Video Games and Cognitive Development

A video game is a programmed visual-digital activity that is rule-governed, goal-oriented, interactive, and used for recreational purposes (Subrahmanyam et al, 2001). While video games are not dependent on the Internet, the Internet provides access to many online video game experiences. Approximately one-third of the time that children are online, they report playing games (Roberts et al, 2004). There is no evidence that online game playing has negative cognitive consequences, although extreme use may restrict range of experience, thereby limiting development of all aspects of cognition (Healy, 1998). There is, however, a growing body of research that suggests certain cognitive processes improve with video game playing.

Supporting the neurological perspective on cognitive development, Koepp and colleagues (1998) established 'that endogenous dopamine is released in the human striatum during a goal-directed motor task, namely a videogame' (p. 266). Satyen (2003) reported that 'sufficient practice with video games could lead to the enhancement of response time performance' (p. 90). During video games, players are forced to simultaneously process a variety of tasks (e.g. detect enemies and avoid hazards). Greene & Bavelier (2003) noted that on a range of visual attention skills, video game players outperformed those not exposed to video games. They concluded that 'although video-game playing may seem to be rather mindless, it is capable of radically altering visual attention processing' (p. 536). Visual-spatial skills such as mental rotation of shapes are superior in those who play video games, although generalisation to novel situations does not always occur (Sims & Mayer, 2002). Blumberg & Sokol (2004) reported that as children learn to play video games, they are more likely to employ internal cognitive strategies (e.g. read instructions, trial and error) than external strategies (e.g. ask for help, watch someone).

In a comprehensive review of the research, Subrahmanyam and colleagues (2001) concluded that cognitive skills such as attention, spatial imagery, and iconic representation are improved with video game use and that 'children who play computer games can improve their visual intelligence' (Subrahmanyam et al, 2000, p. 128). From a cognitive-developmental orientation, playing online games enhances attention and concentration, visual perception, visual memory, simultaneous processing, meta-cognitive skills such as planning, and speed of information processing.

Accessing Web Sites and Cognitive Development

Approximately one-third of the time that children are online, they report accessing web sites (Roberts et al, 2004). From a cognitive perspective, web sites share some of the characteristics of

print material (e.g. magazines, encyclopaedias, brochures, fact sheets). Like books and magazines, web sites contain text and images that require interpretation. Although there are differences in the reading processes involved in decoding printed text and digital text, 'there are also many similarities, with meaning-making being central to the process' (Marsh & Thompson, 2001, p. 269). Unlike print material, web sites are, to varying degrees, interactive. Children make choices about accessing site features and links. 'Electronic texts are malleable and fluid; they are not firm and fixed in the manner of printed books and magazines' (Desmond, 2001, p. 42). In this regard, visiting web sites makes cognitive demands beyond those associated with simply decoding text. Meta-cognitive processes such as planning, search strategies, and evaluation of information are exercised when accessing web sites (Tarpley, 2001).

Public librarians refer to web access as a 'lifeline for children' and note that 'the Web keeps getting bigger and better for youngsters, with more helpful and enjoyable sites popping up every day' (McDermott, 2000, p. 36). 'About 72 percent of Internet users ages 5-17 (or 42 percent of all youth in this age range) use the Internet to complete school assignments' (National Center for Educational Statistics, 2003, pp. vi-vii). Approximately 90% of parents claim 'that the computer has had a positive impact on their child's learning ability, while 79% say that it has improved their child's homework quality' (Canadian Council on Social Development, 2001, p. 4). Turow (1999) reported that among adolescents, visiting web sites to complete schoolwork surpasses games as the most frequent online activity. According to early childhood educators, visiting web sites supports emergent literacy, builds problem-solving skills, and facilitates concept development (Gerzog & Haugland, 1999; Parette et al, 2000). From a cognitive perspective, accessing web sites enhances visual processing of information, increases language and literacy skills, builds knowledge base, and promotes meta-cognitive abilities such as planning and evaluation.

Online Communication and Cognitive Development

Berson & Berson (2005) note that the 'Internet has provided an expansive environment that has the potential to offer instantaneous interaction with people worldwide' (p. 29). The Internet is an increasingly popular form of interpersonal communication, particularly among adolescents (Quigley & Blashki, 2003). Approximately one-quarter of the time that youth are online, they report communicating with others via instant messaging, chat and email (Roberts et al, 2004). According to a recent survey by the National Center for Educational Statistics (2003), '65 percent of users (38 percent of all persons 5-17) use the Internet for e-mail or instant messaging' (p. vii). Research on the consequences of children's Internet communication has focused, rather exclusively, on social development, including online aggression and high-risk behaviour (Subrahmanyam et al, 2000, 2001; Ybarra & Mitchell, 2004). While communication is a social event that emerges in response to human interaction, language is a cognitive process (Solso et al, 2005) and a cultural tool (Vygotsky, 1978).

Consideration of the cognitive demands of online communication requires consideration of the processes of communication and language. Language is defined as a set of shared symbols used by a group for purposes of communication (Bochner & Jones, 2003). Communication requires that one person sends a message (i.e. expressive language) and another person receives and understands that message (i.e. receptive language). All forms of expressive-receptive language (e.g. speak–listen, write–read, sign–view) require similar neurological processing (Johnson, 2004). Currently, online communication primarily involves reading and typing text in real time (i.e. synchronous communication such as chat) or delayed time (i.e. asynchronous communication such as email). Dede & Kremer (1999) concluded that asynchronous communication provides 'richer, more inclusive types of interchange' (p. 4); Hines & Pearl (2004) argued that synchronous communication has 'the advantages of providing a greater sense of presence and generating spontaneity' (p. 34). From a cognitive perspective, both forms of online communication require expressive and receptive written language competencies which involve successive cognitive processing; synchronous communication may decrease reaction time.

Internet Use and Cognitive Development: a theoretical framework

The most common online activities for children and adolescents include playing games, visiting web sites, and communicating with others (Roberts et al, 2004). While Internet technology evolves rapidly, current use is associated with visual input and tactile-kinaesthetic output via manual manipulation of peripheral devices. During Internet use, language centres of the brain are active, particularly in online communication. Meta-cognitive abilities are required for a variety of online activities, including playing games and accessing web sites. Video games as well as synchronous communication decrease cognitive processing speed (i.e. reaction time). Video games require simultaneous processing; online communication requires successive processing. Video games make extreme demands on visual and meta-cognition skills. Accessing web sites builds knowledge base and contributes to concept development. Figure 1 presents a theoretical framework for organising the cognitive requirements of typical online behaviour in children and adolescents. Such requirements, when satisfied, contribute to patterns of neurological activity which, particularly early in life, influence neurological architecture and cognitive processes.

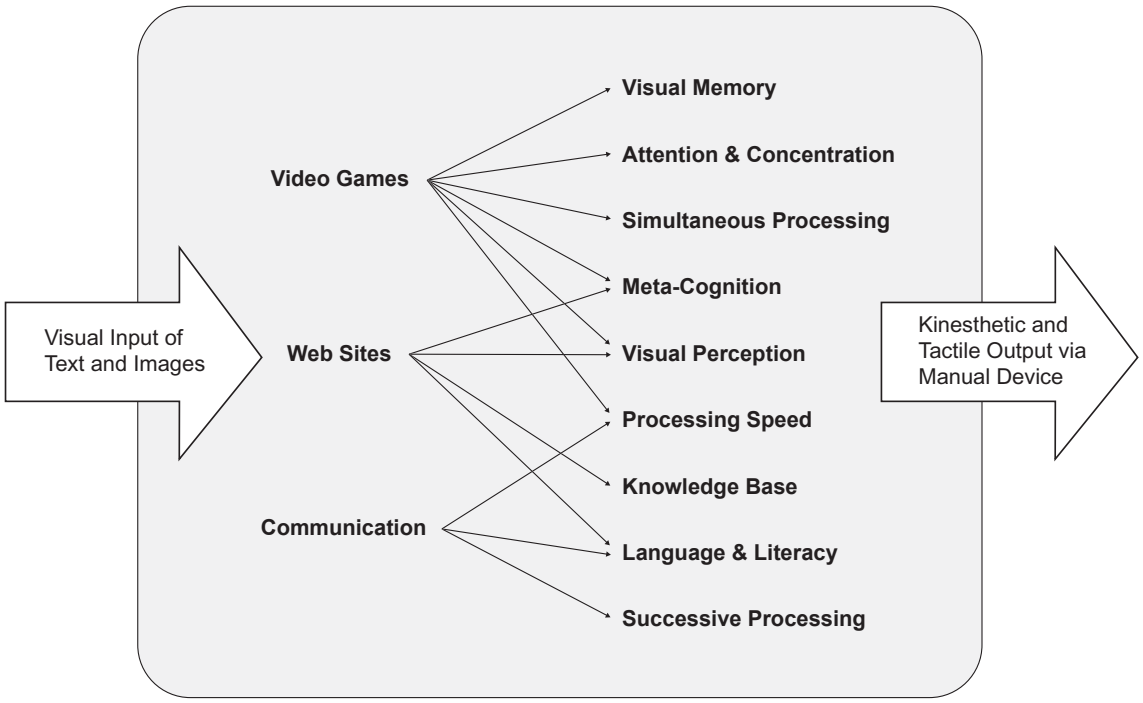

Figure 1. A theoretical framework for organising the effects of Internet use on cognitive processes.

According to Vygotsky (1978), human cognition creates tools and then, in turn, is created by those tools. The Internet is the most sophisticated tool that humans have thus far created and, as such, it may ultimately have greater cognitive impact than any previous cultural tool. As always, new technology is associated with apprehension and anxiety. For example, in the nineteenth century, 'the telegraph enabled a young woman, against her father's wishes, to maintain a flirtation with a number of men on the wire' (Quigley & Blashki, 2003, p. 311).

The majority of households currently have Internet access and those that do not are disproportionately characterised by low socio-economic status. 'In 1998, 74% of Canadian households in the highest-income group had computers, compared to only 18% of households in the lowest-income group' (Canadian Council on Social Development, 2001, p. 4). The majority of children and youth spend a significant amount of time online and those that do not are disproportionately characterised by low socio-economic status (National Center for Educational Statistics, 2003). Current anxiety surrounding children's Internet use should be for those whose cognitive processes are not influenced by the cultural tool (Henry J. Kaiser Family Foundation, 2004).

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