TACTILE INPUT FEATURES OF HARDWARE: COGNITIVE PROCESSING IN RELATION TO DIGITAL DEVICE

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ABSTRACT

Three relatively distinct types of devices have characterized the digital revolution; 1) the personal computer of the 1990s, 2) the mobile phone in the first decade of the new millennium and, most recently, 3) the tablet computer. Socio-cognitive theorists maintain that use of tools and technologies over time, changes the nature of human mental processes. For example, computer technology affords increased opportunities for cognitive stimulation (e.g., played games and reading) which, with prolonged use and in a general sense, improves human intellectual capabilities. While personal computers, mobile phones and tablet computers differ in terms of screen size and portably, touchscreen input may be particularly relevant to cognition. This paper reviews recent research which establishes that use of personal computers and mobile phones is associated with improved human cognition. Since tablet computers have penetrated popular culture in less than two years, their effect on cognitive processing remains largely speculative. To some extent, research findings on the cognitive impact of personal computers and mobile phones might reasonably be generalized to tablet computers, particularly the suggestion that technology increases cognitive stimulation which, over time, improves human cognitive processes. However, increased tactile connection with digital devices, as is the case with touchscreen technology, might reasonably be assumed to increase the impact of tools on human cognition. The use of hands and fingers is critically related to human brain functioning and evolution.

Keywords: *cognitive processing, digital devices, tablet computers, tactile input, touchscreen technology.*

1. INTRODUCTION

The digital revolution may be meaningfully organized in terms of the chronological popularity of three devices: 1) the personal computer of the 1990s, 2) the mobile phone in the first decade of the new millennium and, most recently, 3) the tablet computer. In every case but with increasing intensity over time, digital devices connect individuals to each other, to information and to activities (e.g., for commerce, learning and leisure). With respect to adults, initially, and to children, subsequently, each device has had considerable impact on a range of activities (Vasile, 2012). From a socio-cultural perspective, tools and technologies affect human experience which, over time, changes the very nature of humanness (Johnson, 2008a). For example, personal computers with internet connectivity have changed the nature of romantic attraction and mate selection (Chiou & Yang, 2012). Use of mobile phones during childhood has changed the nature of parental supervision (Bond E., 2010). Books and associated technologies (e.g., the printing press and the public library) have fundamentally changed human intellectual capacity (Cunningham & Stanovich, 1998); tablet computers are changing the nature of books (Brady, 2012). “Tools are not just added to human activity; they transform it” (Tikhomirov, 1974, p. 374).

The impact of tools and technologies on mental or intellectual processes is of particular interest to cognitive theorists (Bruner & Olson, 1977; Johnson, 2012a; Luria, 1976; Salomon & Perkins, 2005; Vygotsky, 1978). Bruner (2005) reiterated his fundamental theoretical assumption “that our minds appropriate ways of representing the world from using and relating to the codes or rules of available technology” (p. x) and described “human culture as a store of information-processing techniques” (p. ix). Johnson (2008a) argued that use of digital devices stimulates neurological pathways in the brain which, with sufficient use over time, results in improved cognitive functioning. For example, “cognitive capacity causes the individual to use Internet applications, use of Internet applications causes increased cognitive capacity which in turn causes the individual to seek out more stimulating Internet applications, and so on” (p. 2103). Flynn (1999) analysed data from virtually all English-speaking countries and concluded that “massive IQ gains began in the late 19th century, possibly as early as the industrial revolution” (p. 61). While improved nutrition is an important factor, Greenfield (1999) proposed that IQ gains in the general population are the consequence of increasingly sophisticated information and communication technologies.

2. THE IMPACT OF DIGITAL DEVICES ON COGNITIVE PROCESSING

For purposes of review of research findings and discussion of theoretical assumptions regarding the impact of digital devices on cognition, hardware is conceptually organized as 1) personal computers, 2) mobile phones and 3) tablet computers. Since personal computers and the internet are well-established contemporary cultural tools, a considerable volume of research has established their effect of human cognitive processing (Johnson, 2012b; Vasile, 2012) Comparable research on the effect of mobile phones on cognitive processing is emerging (Kemp, 2011; Lin, 2010). Since tablet computers have penetrated popular culture in less than two years, their effect on cognitive processing remains largely speculative (Rock, 2011). During the past 25 years, digital technologies have clearly evolved in terms of hardware and increased in terms of use to the point of extreme reliance and, perhaps, dependence (Califf, 2010). Consequently, detailed analysis of the effect of evolving digital technologies on cognition is both appropriate (e.g., to scientific inquiry) and necessary (e.g., for control of human destiny).

3. COGNITION AND PERSONAL COMPUTERS

With or without internet connectivity, computer use has been associated with enhanced cognitive ability beyond that explained by demographic variables such as socioeconomic status (Erickson & Johnson, 2011; Freese, Rivas, & Hargittai, 2006). Simpson, Camfield, Pipingas, Macpherson and Stough (2012) administered an online computer-based cognitive training intervention to 34 individuals between 53 and 75 years of age. Compared to a control group, "significant improvement in simple reaction time and choice reaction time task was found in the cognitive training group both post-training and at three-weeks follow-up" (p. 445). Tun and Lachman (2010) studied cognitive effects of computer use in a large national sample (n = 2,671) of adults aged 32-84 years. Their findings suggested "that frequent computer activity is associated with good cognitive function, particularly executive control, across adulthood into old age" (p. 560). Slegers, Van Boxtel and Jolles (2012) followed 1823 adults for nine years. "Protective effects of computer use were found for measures of selective attention and memory, in both older and younger participants" (p. 1). In a randomized double-blind interventional study, healthy older adults were assigned to either a personalized, computerized cognitive training group or to a computer games group (Peretz, Korczyn, Shatil, Aharonson, Birnboim, & Giladi, 2011). While both groups demonstrated improvements in cognitive performance, the computerized cognitive training was significantly more effective than playing computer games in improving working memory, visual-spatial learning and focused attention.

In reviewing the literature, Maynard, Subrahmanyan and Greenfield (2005) concluded that internet use has impacted on the cognitive functions of attention (i.e., simultaneous processing of multiple stimuli) and representation (i.e., iconic, spatial and verbal). Johnson (2008a) measured cognition (i.e., planning, attention, simultaneous and successive processing) and patterns of internet use in a sample of college students (n = 406). "Without exception, frequent Internet users cognitively outperformed infrequent Internet users" (p. 2094). In a related study, Johnson (2008b) examined verbal and nonverbal reasoning in relation to patterns of internet use. Significant group differences in nonverbal reasoning consistently favoured frequent internet users (e.g., in terms of use of search engines and playing games online). With respect to visiting chat rooms and downloading music, however, infrequent users demonstrated better verbal reasoning than frequent users. "Findings suggest that the distinction between verbal and nonverbal cognitive ability may be less important than the conclusion that extensive and appropriate use of the Internet is associated with increased human capacity to reason" (p. 382).

Some researchers have suggested that internet use (e.g., search engines) negatively affects cognitive functioning (Califf, 2010). For example, internet addiction has been associated with cognitive and neurological impairment (Dong, Zhou, & Zhou, 2011; Park, Park, Choi, Chai, Lee, Lee, & Kim, 2011). However, internet addiction disorders represent extremely unhealthy patterns of use and findings cannot reasonably be generalized to psychologically healthy individuals. Sparrow, Lui and Wegner (2011) reported the results of four studies and concluded that when faced with difficult questions, people were primed to think about the internet and that when expected to have future access to information, they had lower rates of recall of the information itself. "The Internet has become a primary form of external or transactive memory, where information is stored collectively outside ourselves" (p. 776). Such findings may be more accurately interpreted as suggesting that the internet is humanising, rather than dehumanising. Recall of factual information is the lowest level of cognitive functioning (Johnson, 2007) and may best left to machines thereby freeing humans to engage in higher-level thinking skills and creative activities.

4. COGNITION AND MOBILE PHONES

As is the case with the evolution of personal computers (e.g., size, processing speed and portability), mobile phones have evolved from simple communication devices to complex tools with a range of software and internet applications (Quirk & Brown, 2008). Because popularization of mobile phones is a relatively recent phenomenon (Farley, 2007), research on their cognitive consequences might be limited except for fear of the effects of Global System for Mobile Communications electromagnetic fields (GSM-EMFs) on the human brain (Barth, Ponocny, Gnambs, & Winker, 2012; Vecchio et al., 2010). In one study, for example, healthy adults performed a visual go/no-go task before exposure to GSM-EMFs or after a sham condition with no EMF exposure. In the go/no-go task, a central fixation stimulus was followed by a green or red visual stimulus. Subjects had to press the mouse after the green stimuli (go trials). Reportedly, exposure to GSM-EMFs "may enhance human cortical neural efficiency and simple cognitive-motor processes" (Vecchio, Buffo, Sergio, Iacoviello, Rossini, & Babiloni, 2012, p. 121). Similarly, Ng, Lim, Niti and Collinson (2012) investigated the association between frequent mobile phone use and cognitive change in older individuals, a vulnerable group experiencing age-related cognitive decline. Reportedly, mobile phone users typically possessed characteristics favouring better cognitive functioning and concomitantly demonstrated better performance on cognitive tasks. There was evidently no significant deleterious effect of mobile phone use on cognitive functioning. On the contrary, findings suggested "that digital mobile phone use may have an independent facilitating effect on global and executive functioning" (p. 176).

GSM-EMF emission during mobile phone use has been suspected to impair the core cognitive processes of memory. Wiholm, Lowden, Kuster, Hillert, Arnetz, Åkerstedt and Moffat (2009) studied the effect of mobile phone use on spatial memory and learning using a double-blind repeated measures design. The mobile phone exposure was designed to mimic that experienced during a real-life mobile phone conversation. The primary outcome measure was a spatial navigation maze task. Dependent variables were the distance travelled on each maze run trial and the level of improvement across trials (i.e., learning). Results suggested enhancing effects of GSM exposure on spatial memory and provide no support for the hypothesis that cognitive function may be adversely affected by acute mobile phone exposure. Similarly, Bond (2010) reported a study in which mice that were genetically predisposed to develop Alzheimer's disease and its accompanying memory impairment were exposed to GSM electromagnetic waves that approximated two hours of daily mobile phone use. The researchers hypothesized that radiation from mobile phones would accelerate progression of the disease because other types of radiation cause free radical damage. To the scientists' surprise, the mice that were dosed with GSM-EMF emission did not suffer from memory impairments as they aged, unlike their radiation-free counterparts. "The mice exposed to mobile phone waves retained their youthful ability to navigate a once familiar maze after time spent in different mazes" (p. 11). Researchers speculated that radiation may have prevented the accumulation of amyloid plaques, the sticky protein aggregates that are found in the brains of individuals afflicted with Alzheimer's disease.

Mobile phone use for sending text messages (TM) has also generated fear (Drouin, 2011; Kinzer, 2010). Given the extent to which youth use mobile phones to MS (Rideout, Foehr, & Roberts, 2010), a considerable volume of research has examined the effect of texting on, particularly, literacy (Kemp & Bushell, 2011). Wood, Jackson, Hart and Wilde (2011) studied 9- and 10- year-olds who had not previously owned a mobile phone. Children were randomly assigned to a control condition (i.e., not give a mobile phone) or a treatment condition (i.e., given a mobile phone only enabled for TM). Results demonstrated that "text messaging does not adversely affect the development of literacy skills within this age group, and that the children's use of textisms when text messaging is positively related to improvement in literacy skills" (p. 28). Durkin, Conti-Ramsdent and Walker (2011) reported positive relationships between textism density, number of types of textism and measures of adolescent literacy. Coe and Oakhill (2011) noted that children who were good readers used more textism in their TM than children who were poor readers. Plester, Wood and Joshi (2009) reported positive relationships between children's knowledge of textisms and measures of literacy including tests of phonological awareness, vocabulary and short-term memory. While popular media, based on anecdotal evidence, claims that TM is a harmful activity (Crystal, 2008; Thurlow, 2006), empirical investigations generally conclude the exact opposite (Kemp 2011; Powell & Dixon, 2011).

5. COGNITION AND TABLET COMPUTERS

"After years of limited success with tablets from a variety of vendors, in 2010, Apple's iPad created a tablet revolution as dramatic as it did with the iPhone" (Computers Desktop Encyclopaedia, 2012). Given the recent popularity of the tablet computer, research specifically addressing its cognitive correlates and consequences is not currently available (Rock, 2011). To some extent, research findings on the cognitive impact of personal computers and mobile phones might reasonably be generalized to tablet computers, particularly the suggestion that technology increases cognitive stimulation which, over time, improves human cognitive processes (Johnson, 2008a). Tablets such as the iPad, however, are relatively unique (except in relation to smartphones) in terms of individualization via personal selection and organization of applications. Ellis (2011) reported a case study in which iPads were used in school by children with disabilities and in a hospital setting by children receiving medical treatment. Based on interviews with school and hospital personnel, benefits of iPads reportedly included self-directed learning, personalized learning, extension of learning, accessibility, increased engagement and enhanced social interaction.

In comparison to traditional computers, Harrison (2010) argued for the educational superiority of iPads because the tablet is formatted to be an eBook, has multiple mechanisms of connectivity (e.g., WiFi and 3G) and is highly portable. According to Benson, Shah and Fershee (2010) tablet computers break the confines of the handset and create space to *play*. New possibilities of direct manipulation beyond dragging and pinching create deeper connections with the physical and digital world. "Mundane computing tasks become faster, more delightful -- felt." Reportedly, in observational studies, "when exposed to touchscreens large enough to accommodate them, people tended to use their entire hands for input." Indeed, the most fundamental difference between personal computers, mobile phones and tablet computers may be the nature of input. While hardware features such as screen size and portably are cognitively-relevant, differences in mechanisms of input force reconsideration of the importance of touch in human cognitive processing (Robles-De-La-Torre, 2006). "Touch is in a certain respect the most important and certainly the most primordial of the senses … it is scarcely to be distinguished from the having of a body that can act in physical space" (O'Shaughnessy, 2002, p. 658).

Mangen and Velay (2010) suggested that "the switch from pen and paper to mouse, keyboard and screen entails major differences in the haptics [a combination of touch and movement perception] of writing, at several distinct but intersecting levels" (p. 385). With a pen and paper, only one hand is used; with a computer keyboard, two hands are used; with a mobile phone, one hand commonly holds the device while the other hand inputs; with a touchscreen, sometimes one hand is used and sometimes two hands are used depending on the user and the task. With a pen and paper, fingers are relatively stationary; with a computer keyboard, all fingers move; with a multi-tap mobile phone, typically only a few figures move; with a touchscreen, wide variation in the number of fingers used in possible (e.g., enlarging an image with two fingers or typing with all fingers or some fingers). With a pen and paper, vision is fixed on the forming letters; with a computer keyboard, vision often roams form keyboard to screen and beyond; with a multi-tap mobile phone, vision is often extremely focused on the device but for a relatively short period of time; with a touchscreen and the applications of, for example, the latest iPad, visual perception and haptics are integrated into a vivid and controlled sensory experience (Taormino, 2012). According to Kress (2003), the combined effects on writing of the dominance of the mode of image and of the medium of screen will produce significant changes in the forms and functions of writing. "This in turn will have profound effects on human cognitive/affective, cultural and bodily engagement with the world, and on forms and shapes of knowledge" (p. 3).

6. CONCLUSION: HUMAN DIGITS AND DIGITAL DEVICES

Originally, the term *digital* was used to refer to human fingers; subsequently, the term referred to *numerical digits*; most recently, the term refers to *digital systems* in data technology that use discrete or discontinuous values (Online Etymology Dictionary, 2012). While similarities are apparent, the keyboard of personal computers, the multi-tap input of mobile phones and the touchscreen of tablet computers each represent relatively unique interaction between human figures or digits and input into digital devices. In the early days of computers, automated processes lead to innovation in human endeavours, for example, in manufacturing, business and education (Chandler, Hikino, & Von Nordenflycht, 2005). But personal computers with internet connectivity shifted the focus from technology to humanity (Chorost, 2011). Connectivity allowed for ease of individual communication with others and with information and activities. The evolution of personal digital devices could not have been predicted but, in retrospect, is obvious, -- increased personal useability (i.e., speed, memory, portability, convenience, individualization and security). As useability has increased, the relationship between hands and device has also increased.

Personal computer and mobile phone input features have modified and restricted tactile experience. "With new technologies, we are changing the role of the hands, as the haptic affordances of digital technologies are distinctly different than earlier technologies … We click and scroll with computer mice and tap keys on a keyboard" (Mangen & Velay, 2010, p. 389). According to Mitchell (2011), next-generation touchscreen devices will include touch-based feedback. "Haptic technology uses targeted vibrations to deliver tactile feedback that can vary in frequency, direction and intensity." Reaching for and touching that which is needed and desired are instinctive gestures. "Although some people still shy away from computer keyboards, mice, or trackballs, there is no hesitation when they can just touch a screen … they instinctively understand how to use the interface" (TE Connectivity, 2012). The keyboard, mouse and even stylus pen may constitute necessary technical intermediate developments in the evolution of the relationship between human digits and digital devices. The increasing focus on authentic touch experiences in virtual environments (Robles-De-La-Torre, 2006) and the seemingly spontaneous attraction of young children to, for example, iPads (Learmonth, 2010), signify reinvigoration of the tactile relationship between people and their tools. Such digital innovation will, over time, contribute to continued improvement in human cognitive capacities. Neurologist Frank Wilson (1998) argued that "any theory of human intelligence which ignores the interdependence of hand and brain function, the historical origins of that relationship, or the impact of that history on developmental dynamics in modern humans, is grossly misleading and sterile" (p. 7). Wilson concluded that "the hand is as much at the core of human life as the brain itself" (p. 277). Tablet computers with touchscreen input are more personal (i.e., tactile) than previous personal digital devices and, in this regard, more likely to impact on human cognitive processes.

7. DISCLOSURE STATEMENT

The author has no competing financial interests with respect to this manuscript.

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