Cognitive processing differences between frequent and infrequent Internet users

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Abstract

The Internet is rapidly transforming a range of human activities; socio-cognitive theory assumes that engagement in transformed activities, over time, transforms human cognition. Four hundred and six college students completed four modified cognitive assessment system subtests, each assessing one dimension of the PASS model of cognitive processing (i.e., planning, attention, simultaneous and successive processing). Students also completed a rating scale that determined the extent and nature of their use of the Internet. Without exception, frequent Internet users cognitively outperformed infrequent Internet users. Results are interpreted as supporting the validity of two theoretical positions: tool use increases cognitive capacity and tools represent extension of cognitive processes. © 2007 Elsevier Ltd. All rights reserved.

Keywords: Internet use; Cognition

1. Introduction

Cognitive theorists have long been interested in the role of tools in the development of mental processes (Bruner & Olson, 1977; Luria, 1976; Vygotsky, 1978). Tools, broadly conceptualized as cultural artifacts, include both physical objects (e.g., printing press, abacus, telephone, computer) and socio-cognitive constructs such as symbols, systems, and language (Nickerson, 2005). “Tools are not just added to human activity; they transform it” (Tikhomirov, 1974, p. 374). Intense and prolonged engagement in the transformed

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activity, over time, transforms human cognition (Maynard, Subrahmanyam, & Greenfield, 2005). Bruner (2005) maintained “that our minds appropriate ways of representing the world from using and relating to the codes or rules of available technology” (p. x).

The Internet is rapidly transforming a range of human activities including education (Jones & Madden, 2002), communication (Nie, Simpser, Stepanikova, & Zheng, 2005), commerce (Fox, 2002), and recreation (Farley-Gillispie & Gackenbach, 2006). Approximately half of the population of the European Union, more than two-thirds of Australians and Canadians, and 76.3% of New Zealanders use the Internet (Internet World Stats, 2006). Not surprisingly, given such usage statistics, researchers have examined (and practitioners have observed) the impact of the Internet on cognitive functioning (Johnson, 2006).

2. Cognitive skills and Internet use

From a cognitive perspective, the Internet differs from others forms of media, although there is overlap in cognitive requirements. For example, like Internet use, computer use is interactive, with primarily visual-cognitive input (i.e., viewing a screen) and most commonly manual output (i.e., manipulation of peripheral devices such as a keyboard and mouse). Unlike Internet use, however, computer use is limited to available software and does not connect users for purposes of communication. While “research suggests that computer use has changed the balance of cognitive skills from the verbal to the visual” (Subrahmanyam, Kraut, Greenfield, & Gross, 2001, p. 96), the cognitive skills required when using the Internet are more complex than those associated with computer use. Further, Tarpley (2001) noted that 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” (p. 551). Johnson (2006) proposes a typology of online behavior in relation to user intention and noted that the most common intentions in using the Internet are communication, visiting websites, and playing games.

Across all populations and age groups, online communication is the most common use of the Internet (Australian Government, 2004; Statistics Canada, 2004; UCLA World Internet Project, 2004; US Census Bureau, 2005). Currently, Internet communication typically involves reading and typing text in real-time (e.g., chat and instant messaging) or delayed-time (e.g., email and message boards). In this regard, a range of cognitive skills are required to communicate online (Crystal, 2001). Merchant (2001) conducted a small qualitative investigation of female adolescent language in Internet chat rooms and concluded that “use of popular electronic communication is resulting in linguistic innovation within new, virtual social networks in a way that reflects more wide-reaching changes in the communication landscape” (p. 293).

Following communication, accessing information via websites is reportedly the second most common online activity (Nie et al., 2005). Typically, websites 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). Electronic texts are malleable and fluid; they are not firm and fixed in the manner of printed books and magazines (Desmond, 2001). Tarpley (2001) suggested that accessing websites requires metacognitive processes such as planning, search strategies, and evaluation of information. According to early childhood educators, visiting websites supports emergent literacy,
builds problem solving skills, and facilitates concept development (Parette, Hourcade, & Heiple, 2000).

Playing games is often identified as a particularly popular use of the Internet (Australian Government, 2004; Farley-Gillispie & Gackenbach, 2006; Nie et al., 2005). The majority of North American adolescents (Rotermann, 2001) and half of China’s 100 million Internet users play online games (Martinsons, 2005). A considerable volume of research has explored the cognitive impact of playing video games (Subrahmanyan et al., 2001). While video games are not dependent on the Internet, the Internet provides access to many game experiences and thus generalization of research findings is appropriate.

Koepp and colleagues (1998) established that endogenous dopamine is released in the human striatum during a goal-directed motor task, namely a videogame. Satyen (2003) reported that sufficient practice with video games could lead to the enhancement of response time performance. Visual–spatial skills such as mental rotation of shapes are superior in those who play video games (Sims & Mayer, 2002). Green and Bavelier (2003) found that on a range of visual attention skills, video game players outperformed those not exposed to video games. In a comprehensive review of the research, Subrahmanyan and colleagues (2001) concluded that cognitive skills such as attention, spatial imagery, and iconic representation are improved with video game use and that those who play computer games can improve their visual intelligence.

While a considerable volume of research exists on the relationship between cognitive skills and aspects of Internet use, such research has failed to include comprehensive measures of cognitive processing in relationship to a wide range of Internet activities. Based on the PASS model of cognitive processing, the cognitive assessment system provides a comprehensive measure of cognitive skills.

3. The PASS cognitive processing model and the cognitive assessment system

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, analyzes, 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 (e.g., entering a room and identifying an appropriate place to sit). Successive processing, associated with the frontal–temporal areas of the brain, involves interpretation of stimuli in a specific serial order (i.e., each component is related to the next in a series). The third functional unit, Planning, located in the frontal lobes of the brain, provides for the regulation of behavior such as asking questions, problem solving, self-monitoring, and impulse control (Luria, 1976). These four cognitive processes, used to varying combined degrees in all mental activities (Hildebrand & Sattler, 2001), contribute to increased 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).
Based on the PASS cognitive processing model, the cognitive assessment system (CAS) is an individually-administered test that measures planning, attention, and simultaneous and successive processing in individuals 6–18 years of age (Das & Naglieri, 2001). **Planning** is assessed with three subtests: matching numbers (find the two numbers that are the same in a series of numbers), planned codes (fill in symbols to match codes), and planned connections (connect a series in correct sequence). All CAS planning subtests require a strategy in order to solve tasks in an efficient and effective manner. In this respect, planning is an aspect of metacognition. **Attention** is assessed with three subtests: expressive attention (suppress a visual image to verbalize the correct response), number detection (identify numbers that match a stimulus), and receptive attention (underline pairs that match). Attention subtests require the individual to selectively attend to one aspects of a two dimensional stimulus. **Simultaneous processing** is assessed with three subtests: nonverbal matrices (select an option that best completes a matrix), verbal–spatial relations (choose a picture that answers a verbal question, for example, in which picture is the ball beneath the table), and figure memory (view a stimulus for 5 s and then identify it in a more complex figure). **Successive processing** is assessed with four subtests: word series (repeat a string of words in order), sentence repetition (repeat sentences that have syntax but reduced meaning, for example, the yellows have pinked a blue brown), sentence questions (answer questions about statements that have syntax but reduced meaning), and speech rate (repeat a series of words as fast as possible 10 times). Successive processing subtests require the individual to either reproduce a particular sequence of events or answer questions based on interpretation of the linearity of events. The CAS has established reliability and validity (Johnson, Bardos, & Tayebi, 2003), although clinical and diagnostic utility have been questioned (Hildebrand & Sattler, 2001).

4. Research hypotheses

1. There are differences in patterns of cognitive processing (i.e., planning, attention, simultaneous and successive processing) between individuals who frequently and infrequently use the Internet.
2. Patterns of cognitive processing (i.e., planning, attention, simultaneous and successive processing) vary as a function of patterns of Internet use (i.e., communicating, visiting websites, and playing games).

5. Methods

5.1. Subjects

Subject recruitment occurred in the context of a guest lecture on cognitive theory and cognitive assessment. Such a topic is meaningfully situated in introductory psychology classes. The guest lecture was offered to all introductory psychology instructors at a college in western Canada. Nine of 13 solicited instructors welcomed the guest lecture (some instructors taught multiple sections).

Via guest lecture, students in 11 sections of an introductory psychology course were invited to participate in the study (a total enrolment pool of 528 students). Primarily due to absenteeism, although three students choose not to participate, 406 students satisfied research requirements. Participating students ranged in age from 17 to 44 years (mean
Students were registered in a variety of programs including; general studies (30.8%), bachelor of science in nursing (21.1%), bachelor of commerce (12.9%), bachelor of arts (12.7%), bachelor of science (10.0%), and bachelor of education (5.5%). Students reported an average of 26.9 college credits complete (range 2–150), where 30 credits constitutes a full year of study. Approximately 72% of the sample was female which is characteristic of the participating college population.

5.2. Data collection instruments

5.2.1. Modified CAS subtests

One CAS subtest was selected for each PASS cognitive process. Based on ease of adaptability to group-administration, the modified subtests included: matching numbers, number detection, figure memory, and sentence questions. In order to force differences across subjects, the most difficult items within each subtest were selected and severe time limits imposed. Table 1 presents descriptive information on the scores obtained on each modified CAS subtest for the sample of participating college students.

5.2.2. Internet use rating scale

Students completed a rating scale that assessed patterns of Internet use. Five items assessed general Internet use (e.g., I use the Internet for schoolwork), five items assessed Internet communication (e.g., I use email), five items assessed website access (e.g., I use search engines), and four items assessed Internet game playing (e.g., I play strategy games online). Students rated each item on a 5-point scale (i.e., never, rarely, a few times a month, a few times a week, every day or almost every day). Table 2 presents the proportion of students selecting each rating option for the 19 Internet use items.

5.2.3. Data analysis

Students who selected the rating options never or rarely constituted the group conceptualized as infrequent users of the Internet. Students who selected the rating options a few times a week or every day or almost every day constituted the group conceptualized as frequent users of the Internet. Independent-sample t-tests compared means on the four measures of cognitive processing for frequent and infrequent users of the Internet.

6. Results

As summarized in Table 3, numerous significant differences in cognitive processing emerged between frequent and infrequent Internet users. In every case, significant cognitive processing differences favoured individuals who reported frequent use of Internet applications. Insignificant differences in cognitive processing were most apparent between
students who reported frequent and infrequent recreational use of the Internet (e.g., dating, downloading music and videos, playing games).

With respect to the specific item \textit{I am online}, Table 4 presents cognitive processing differences between students who selected \textit{a few times a week} or \textit{every day or almost every day} (frequent use) and those who selected \textit{never} or \textit{rarely} (infrequent use). Five of the 406 participating college students reported infrequent Internet use; 384 reported frequent Internet use. The five infrequent Internet users scored significantly lower on modified CAS subtests that measured the cognitive processes of planning (metacognition) and visual attention.

Review of the modified matching numbers CAS subtest is prerequisite to apprehension of significant differences in metacognitive planning. To assess the cognitive process of planning, the cognitive tasks booklet included a page with eight rows of numbers with six numbers in each row. Students had 60 s in which to underline the two numbers in each row that were the same (e.g., 5613820 5613830 5631820 5618320 5613821 5613802). Given the visual similarity of numbers within each row, strategy identification and execution were necessary in order to locate matching numbers (e.g., compare the first three digits of each number). As summarized in Table 5, college students who reported frequently using the Internet for help with schoolwork, on average, correctly underlined matching numbers in 4.62 of the eight rows. College students who reported infrequently using the Internet for help with schoolwork, on average, correctly underlined matching numbers in 3.76 of the eight rows. Such a difference did not occur by chance ($p = .018$).

Table 6 presents differences in cognitive processing scores for students who reported frequently and infrequently using the Internet to communicate. A significant difference

\begin{table}
\centering
\caption{Proportion of students selecting each rating option for Internet use items}
\begin{tabular}{lccccc}
\hline
Internet use item & Rating option\textsuperscript{a} (%) \\
& Never & Rarely & Monthly & Weekly & Daily \\
\hline
I am online & 0.5 & 0.7 & 4.2 & 28.3 & 66.3 \\
I use the Internet for schoolwork & 0.2 & 4.9 & 33.3 & 42.6 & 19.0 \\
I use the Internet to communicate & 2.2 & 9.4 & 11.8 & 32.8 & 43.8 \\
I use email & 1.0 & 2.7 & 8.4 & 33.5 & 54.4 \\
I visit chat rooms & 70.7 & 18.0 & 3.4 & 3.0 & 4.9 \\
I instant message & 14.5 & 13.3 & 13.5 & 23.9 & 34.7 \\
I use a nickname online & 32.8 & 22.5 & 5.9 & 15.3 & 23.5 \\
I online date & 93.3 & 4.9 & 0.7 & 0.2 & 0.7 \\
I visit websites & 0.5 & 6.9 & 14.0 & 36.7 & 41.9 \\
I use search engines (e.g., Google) & 0.5 & 2.7 & 20.2 & 43.1 & 33.5 \\
I access public information online (e.g., weather) & 2.0 & 10.1 & 39.5 & 35.6 & 12.8 \\
I access personal information online (e.g., grades) & 2.2 & 7.1 & 32.5 & 40.1 & 18.0 \\
I download or listen to music from the Internet & 8.4 & 11.8 & 20.0 & 31.5 & 28.3 \\
I download or watch videos from the Internet & 33.5 & 26.1 & 20.9 & 12.8 & 6.7 \\
I play games online & 36.7 & 36.9 & 14.5 & 8.4 & 3.4 \\
I play strategy games online (e.g., starcraft) & 70.9 & 18.0 & 6.4 & 3.4 & 1.2 \\
I play role playing games online (e.g., diablo) & 80.7 & 12.8 & 3.0 & 1.7 & 1.7 \\
I play action games online (e.g., counterstrike) & 82.0 & 9.9 & 3.4 & 2.5 & 2.2 \\
I play sports games online & 82.3 & 12.6 & 3.9 & 0.7 & 0.5 \\
\hline
\textsuperscript{a} Unabbreviated rating options: never, rarely, a few times a month, a few times a week, every day or almost every day.
\end{tabular}
\end{table}
emerged in terms of visual attention ($p = .009$). Visual attention was measured with a modified version of the CAS number detection subtest. That is, the cognitive tasks booklet included a page of numbers in two fonts (i.e., 1 5 4 2 1 3 6 2 6 2 5 3 1 4 6 5 1 4 2).

Table 3
Significant cognitive processing differences between students reporting frequent and infrequent Internet use

<table>
<thead>
<tr>
<th>Internet use item</th>
<th>Planning (metacognition)</th>
<th>Visual attention</th>
<th>Simultaneous processing</th>
<th>Successive processing</th>
</tr>
</thead>
<tbody>
<tr>
<td>I am online</td>
<td>*</td>
<td>*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I use the Internet for schoolwork</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I use the Internet to communicate</td>
<td></td>
<td>**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I use email</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I visit chat rooms</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I instant message</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I use a nickname online</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I online date</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I visit websites</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I use search engines</td>
<td>**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I access public information online</td>
<td></td>
<td>*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I access private information online</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I download or listen to music</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I download or watch videos</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I play online games</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I play strategy games online</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I play role playing games online</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I play action games online</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I play sports games online</td>
<td></td>
<td>*</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* $p < .05$.  
** $p < .01$.  

Table 4
Cognitive processing differences between students reporting frequent and infrequent general Internet use

<table>
<thead>
<tr>
<th>Cognitive process</th>
<th>N</th>
<th>Mean$^a$</th>
<th>SD</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planning (metacognition)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequent Internet use</td>
<td>384</td>
<td>4.54</td>
<td>1.57</td>
<td>$p = .031$</td>
</tr>
<tr>
<td>Infrequent Internet use</td>
<td>5</td>
<td>3.00</td>
<td>2.12</td>
<td></td>
</tr>
<tr>
<td>Visual attention</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequent Internet use</td>
<td>384</td>
<td>19.72</td>
<td>6.31</td>
<td>$p = .019$</td>
</tr>
<tr>
<td>Infrequent Internet use</td>
<td>5</td>
<td>13.00</td>
<td>8.09</td>
<td></td>
</tr>
<tr>
<td>Simultaneous processing (visual)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequent Internet use</td>
<td>384</td>
<td>3.78</td>
<td>0.81</td>
<td></td>
</tr>
<tr>
<td>Infrequent Internet use</td>
<td>5</td>
<td>3.40</td>
<td>1.14</td>
<td></td>
</tr>
<tr>
<td>Successive processing (auditory)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequent Internet use</td>
<td>384</td>
<td>2.26</td>
<td>2.34</td>
<td></td>
</tr>
<tr>
<td>Infrequent Internet use</td>
<td>5</td>
<td>1.80</td>
<td>1.10</td>
<td></td>
</tr>
</tbody>
</table>

$^a$ The higher the score the greater the cognitive processing capacity.
Students were given 60 s in which to circle all numbers that matched a visual stimulus in both number and corresponding font (i.e., 1 2 3 4 5 6). Credit was given for each correct number circled; the maximum possible score was 51. Students who reported frequently using the Internet to communicate scored almost 20/51; students who reported infrequently using the Internet to communicate scored approximately 17/51. The cognitive processing difference between frequent and infrequent Internet communicators was not a language difference (measured by the modified auditory successive processing subtest) but, rather, a difference in capacity to attend to visual stimuli.

Table 7 provides details of the cognitive processing differences between college students who reported frequently and infrequently using search engines (e.g., Google). While each measure of cognitive processing favoured individuals who frequently used search engines, the only significant difference to emerge was in planning (metacognition). As previously
described, planning was assessed with a modified version of the CAS number matching subtest (i.e., underline the two numbers in each row that are the same). Students who reported frequently using search engines, on average, correctly underlined matching numbers in 4.55 of the eight rows. Students who reported infrequently using search engines, on average, correctly underlined matching numbers in 3.15 of the eight rows. Such a difference did not occur by chance ($p = .001$).

The cognitive processing differences between students who reported frequently and infrequently using the Internet to access private information (e.g., course grades, personal banking) are presented in Table 8. College students who frequently used the Internet to access confidential or protected information were cognitively different than students who never or rarely used the Internet for such purposes. Those who frequently

<table>
<thead>
<tr>
<th>Cognitive process</th>
<th>N</th>
<th>Mean*</th>
<th>SD</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planning (metacognition)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequent use of search engines</td>
<td>311</td>
<td>4.55</td>
<td>1.50</td>
<td>$p = .001$</td>
</tr>
<tr>
<td>Infrequent use of search engines</td>
<td>13</td>
<td>3.15</td>
<td>1.91</td>
<td></td>
</tr>
<tr>
<td>Visual attention</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequent use of search engines</td>
<td>311</td>
<td>20.01</td>
<td>6.02</td>
<td></td>
</tr>
<tr>
<td>Infrequent use of search engines</td>
<td>13</td>
<td>16.92</td>
<td>6.76</td>
<td></td>
</tr>
<tr>
<td>Simultaneous processing (visual)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequent use of search engines</td>
<td>311</td>
<td>3.80</td>
<td>0.79</td>
<td></td>
</tr>
<tr>
<td>Infrequent use of search engines</td>
<td>13</td>
<td>3.46</td>
<td>0.88</td>
<td></td>
</tr>
<tr>
<td>Successive processing (auditory)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequent use of search engines</td>
<td>311</td>
<td>2.25</td>
<td>1.22</td>
<td></td>
</tr>
<tr>
<td>Infrequent use of search engines</td>
<td>13</td>
<td>1.69</td>
<td>1.18</td>
<td></td>
</tr>
</tbody>
</table>

* The higher the score the greater the cognitive capacity.

Table 8
Cognitive processing differences between students reporting frequent and infrequent Internet access of private information

<table>
<thead>
<tr>
<th>Cognitive process</th>
<th>N</th>
<th>Mean*</th>
<th>SD</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planning (metacognition)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequent access of private information</td>
<td>236</td>
<td>4.56</td>
<td>1.58</td>
<td>$p = .049$</td>
</tr>
<tr>
<td>Infrequent access of private information</td>
<td>38</td>
<td>4.00</td>
<td>1.74</td>
<td></td>
</tr>
<tr>
<td>Visual attention</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequent access of private information</td>
<td>236</td>
<td>19.99</td>
<td>6.05</td>
<td>$p = .011$</td>
</tr>
<tr>
<td>Infrequent access of private information</td>
<td>38</td>
<td>17.16</td>
<td>7.81</td>
<td></td>
</tr>
<tr>
<td>Simultaneous processing (visual)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequent access of private information</td>
<td>236</td>
<td>3.78</td>
<td>0.79</td>
<td>$p = .011$</td>
</tr>
<tr>
<td>Infrequent access of private information</td>
<td>38</td>
<td>3.42</td>
<td>0.79</td>
<td></td>
</tr>
<tr>
<td>Successive processing (auditory)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequent access of private information</td>
<td>236</td>
<td>2.26</td>
<td>1.23</td>
<td></td>
</tr>
<tr>
<td>Infrequent access of private information</td>
<td>38</td>
<td>1.95</td>
<td>1.18</td>
<td></td>
</tr>
</tbody>
</table>

* The higher the score the greater the cognitive capacity.
accessed private information online scored significantly higher on measures of planning (metacognition), visual attention, and simultaneous processing. Simultaneous processing was assessed with a modified CAS figure memory subtest in which students viewed a stimulus (i.e., projected on a screen for 5 s) and then traced it from memory it in a complex figure.

7. Discussion

Theoretical perspectives on the relationship between human cognition and the use of cultural artifacts (i.e., tools) may be distilled into three distinct, though related, positions: (1) tool use increases cognitive capacity (Salomon & Perkins, 2005); (2) tool use changes patterns of cognitive skills (Maynard et al., 2005); and (3) tools represent extension of cognitive processes (Nickerson, 2005). Results of the current investigation permit, to some extent, comment on the validity of each of these theoretical assumptions.

7.1. Tool use increases cognitive capacity

The first research hypothesis, there are differences in patterns of cognitive processing between individuals who frequently and infrequently use the Internet, was confirmed. In every case of significant differences (and most cases of insignificant differences), CAS subtest scores were greater for individuals who frequently, as opposed to infrequently, used the Internet, both in general and with respect to specific applications such as online communication. Comparison of group means, of course, does not permit determination of effect (Johnson & Howell, 2006). Indeed, it is difficult to envision an ethical research design that could determine the long-term effect of Internet use on human cognition. Socio-cognitive theorists (Piaget & Inhelder, 1973; Vygotsky, 1978) propose a reciprocal and spiraling relationship between cognitive capacity and environmental stimulation, that is, cognitive capacity causes the individual to seek out stimulating experiences, which in turn increase cognitive capacity, which causes the individual to seek out more stimulating experiences, and so on. Results of the current investigation may be interpreted from a similar perspective; 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.

7.2. Tool use changes patterns of cognitive skills

The second research hypothesis, patterns of cognitive processing vary as a function of patterns of Internet use, was not confirmed. That is, irrespective of specific online intention or application (i.e., completing schoolwork, communicating, visiting websites), cognitive superiority was consistently associated with those who frequently, as opposed to infrequently, used the Internet. Such a finding provides further confirmation of the first hypothesis and is consistent with data from 20 nations (virtually all English-speaking countries) that establish that “massive IQ gains began in the late 19th century, possibly as early as the industrial revolution” (Flynn, 1999, p. 61). Vincent (1993) proposed that the increasing complexity of modern society causes increased cognitive functioning and that “our grandparents, because of lack of environmental stimulation, were simply not bright enough as a group to have run the modern world” (p. 62). Results of the current
investigation suggest that the Internet, regardless of specific application, may function as a source of environmental stimulation that contributes to increased cognitive capacity.

7.3. **Tools represent extension of cognitive processes**

Nickerson (2005) suggested that tools, “as amplifiers of human capabilities” (p. 3), are meaningfully organized as increasing motor capability (e.g., moving large object), sensory capacity (e.g., viewing astronomical phenomena), or cognitive ability (e.g., storing information). Results of the current investigation, to some extent, validate the notion that the Internet represents an extension of human cognitive ability. For example, college students who reported frequently using search engines scored significantly higher on the measure of metacognition (i.e., planning) than students who infrequently used the same cultural artifact. Tsai (2004) described search engines as metacognitive tools that help students “select and filter information” (p. 526). In this regard, a specific Internet application (i.e., search engines) may be conceptualized as amplifying a specific metacognitive function (i.e., locating and evaluating information). From such a perspective, the continually increasing complexity of cultural artifacts (Maynard et al., 2005) reflects continual increase in human cognitive sophistication.

8. **Limitations and future research**

Albeit modestly, results of the current investigation increase understanding of the relationship between human cognition and patterns of Internet use and also permit comment on theoretical assumptions concerning cognition and cultural artifacts. The research, however, has several limitations, not the least of which is generalization of findings. Jones and Madden (2002) argued that college students are an ideal sample for Internet research because they “are heavy users of the Internet compared to the general population” (p. 2) and because they “have been at the forefront of social change since the end of World War II” (p. 5). Nonetheless, college students studying introductory psychology do not reflect the general population; future research may explore the relationship between cognitive processes and Internet use for samples that more accurately represent the general population. Further, the relatively small number of subjects who reported infrequent Internet use renders problematic interpretation of findings. That is, college students in a technologically advanced nation who do not frequently use the Internet could be described as idiosyncratic (e.g., Table 4, \( n = 5 \)). An improved research design would include equally large numbers of frequent and infrequent Internet users in order to identify differences in cognitive processing.

Reconciling the need for large sample size with valid measures of cognitive processing and Internet use resulted in a further limitation of the present study. Validity and reliability of the modified CAS subtests for group-administration to college students was not established. The validity of group-administered psychological tests is threatened by individual differences in motivation, attention, and comprehension of instructions (Flanagan & Harrison, 2005). It is possible that such variables were inadvertently measured by the modified CAS subtests. Indeed, it is also possible that subjects misrepresented their Internet use on the brief rating scale that assessed such use. Research utilizing individually-administered measures of cognitive functioning and alternate approaches to determining patterns of Internet use may not replicate the findings of the current investigation.
Results of the current investigation, at least with respect to college students and group administration of selected CAS subtests, strongly suggest a relationship between Internet use and cognitive processing abilities, particularly, metacognition and visual attention. Subsequent research may determine the extent to which findings can be generalized to other populations (e.g., children and the elderly) and may clarify the critical role of metacognition and visual attention in effective use of Internet technologies. As argued elsewhere, “Internet literacy is not the ability to use a set technical tools; rather, it is the ability to use a set of cognitive tools” (Johnson, in press).

References


