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Aging, Analogical Transfer, and Everyday Problem Solving

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Abstract

The current study investigated the relationship between technology (IT) use, aging, and everyday problem solving by examining the presence of analogical transfer from general life experience to the given problem solving tasks. Participants between 18 to 91 years old were surveyed about their daily technology use and then, tested for their ability to find information, plan efficient routes, and solve the tower of Hanoi (TOH) problem. The results suggested that visual-spatial ability in technology use transferred to solve information finding task, while the technology use inhibited the formation of subgoals in TOH. Aging was not associated with lower performances when the amount of technology use was accounted. The implications of the findings are discussed.

Aging, Analogical Transfer, and Everyday Problem Solving

There is no such thing as human intelligence without "artifact-free abilities" (Preiss & Sternberg, 2006, p.1). Technologies are amplifiers and affordances for our motor, sensory, and cognitive skills. Technologies, from the alphabetic systems to computers, have long been present in our daily lives, and human skills required in societies have been changing by the introduction of new technologies (Sternberg & Preiss, 2005). In particular, the emergence of information technology (IT) in our daily lives has been prominent in the past few decades, and the skills required to solve everyday problems have changed. For example, when navigating from one place to another, we now type an address into a Global Navigation System (GPS) instead of looking at a classical map and figuring out the best path. Reading maps requires forming spatial representation, selectively attending to key objects, and then choosing the best way to reach to the destination (Schmid, Richter, & Peters, 2010). With the use of the Internet and smartphones, we now have an instant access to the desired information without going through encyclopedias or dictionaries to look up facts or words; instead, we type keywords into Google. Information Technology, '*the study or use of systems (especially computers and telecommunications) for storing, retrieving, and sending information*' (Oxford University Press, 2013), inevitably simplifies or alters the multi-step required to solve the everyday problems by readily providing necessary information.

Although technological interventions historically have changed the nature of problem solving skills (e.g. change in mathematical representation as the introduction of calculators see Preiss & Sternberg, 2006; Sternberg & Preiss, 2005 for the review), the impact of quick emergence of IT in our daily lives seems to be larger than ever; the term '*Digital Natives'* is used to distinguish and describe the generation who grew up with computers and Internet use (Jones, Ramanau, Cross, & Healing, 2010; Kennedy, Judd, Churchward, & Gray, 2008; Prensky, 2001). Prensky (2001) argued that the environment in which Digital Natives had matured influences the skills that they have acquired and prefer. As Digital Natives enter to school systems with rather new skills, the educational institutions seem to focus on investigating the nature of Digital Natives and exploring the way to accommodate their learning experiences suited to their technological skills (Jones et al., 2006, Kennedy et al., 2008). Although the effort is made to provide suitable environments for such learners, and societies, indeed, demand the skills to utilize IT, the question concerning the cognitive consequences of adopting IT in daily lives and altering the skills necessary to solve problems. Little research has investigated the effects of IT on human cognition, specifically on problem solving. Given the increase emergence of IT in our daily lives and the changes in the process of daily problem solving, it is imperative to investigate the use of IT in relation to human cognition. Furthermore, considering the rising awareness of Digital Natives, it is also essential to investigate the effects of IT across the generations.

Much of our problem solving skills derive from higher-level cognitive abilities, that is, fluid intelligence that supports abstract reasoning to solve a novel problem (Morrison & Knowlton, 2012). Abstract reasoning in problem solving is often enabled by drawing an analogy from one’s past experiences and skills. The process in which individuals draw inferences from the past experiences by assessing the relationships between the problem and the experience is called analogical transfer, and it is an essential part in human intelligence and problem solving (Holyoak, 2012; Holyak & Koh, 1987). Thus analogical transfer enables us to see the relationship between technology use and problem solving by examining if the skills mediated by IT use are transferred to the novel problems. As IT is rapidly emerging in our daily lives, people solve everyday problems with the aid of IT. Everyday problems in traditional manner are used to assess the role of IT in everyday problem solving in addition to the general problem solving skills. Everyday problems differ from the laboratory problem solving tasks that they reflect multiple cognitive activities, rehearsed daily, and provide the familiar contexts, and are known to be independent from the cognitive aging effects despite the fact that aging accounts for the substantial changes in fluid intelligence and analogical reasoning (Morrison & Knowlton, 2012; Redick, Unsworth, Kelly, & Engle, 2012). Thus employing the classic everyday problems not only enables to examine the transfer of the skills to the task that requires more complex cognitive abilities, but also provides the better understanding of the role of IT in problem solving and aging. The purpose of the current study is to explore the relationship between age, technology (IT) use, and problem solving. In particular, the goal is to examine the analogical transfer of the skills mediated by IT in the classic everyday problems and the general problem in relation to the generational effects.

Literature Review

Previous researchers have recognized the importance of mental representations and setting goals and subgoals in problem solving (e.g. Duncker, 1945; Newell & Simon, 1972). Problem solving is a goal directed behavior that requires identifying the problem, formation of mental representations, and planning solutions by organizing the existing knowledge about the problem (Bassok & Novick, 2012; Pretz, Naples, & Sternberg, 2003). Problem identification is only possible when the mental representation of the perceived context is matched with those with the past. The mental representation serves to organize the perceived information as the initial state and identify the goal state to plan the solution (Bassok & Novick, 2012). When one is presented with a novel problem, the metal representation of the problem is formed. Comparing that with the past encountered problems, planning occurs to solve the problem by setting the goals and subgoals.

Mental representations, goals and technology uses

A few studies have investigated the IT effects on cognition, and the findings confirm that IT alters the mental representation of the task problems and changes their goal state. The recent ‘Google effect’ study by Sparrow, Liu, and Wegner (2011) indicated that the participants remembered the location of the given trivial facts rather than the actual facts when they were shown where the information was saved on the computer file. Furthermore, the participants had a lower recall rate of the actual information when they were told that they could ‘Google’ the facts later. Sparrow et al. (2011) concluded that the notion of instant access to the information induced the formation of transactive memory causing the participants to remember ‘where’ the information is instead of ‘what’ was the information (p.778). This study provided the evidence that people change their perception of the problem as a response to the availability of IT, furthermore, the goals of the task, to remember the trivial facts, was altered to remember the location of information.

Other studies find that learning is interfered by the use of IT. For example, GPS users failed to form the accurate spatial representation of the new routes (Ishikawa, Fujiwara, Imai & Okabe, 2008). When the participants traveled the novel route with the aid of GPS the subsequent sketch of the traveled map by the participants was less accurate than those of the participants who traveled the route with the aid of classical map (Ishikawa et al., 2008). Moreover, similar study by Dickmann (2012) found the same GPS effects on spatial learning and concluded that the information provided by GPS are rather fragmented and do not transfer when sketching a map. Unlike the Google effect study, the use of GPS does not change the goal of the problem (to reach to the destination); however, the mental representation of the problem was changed. The availability of GPS subsequently changed subgoals required to navigate to the location. With the aid of GPS, the multistep process required in wayfinding such as locating the current location, selectively attending to the surrounding contexts, and planning the optimal way (Ishikawa et al., 2008, p.74; Schmid, Richter, & Peters, 2010, p.187) are converted to one task, that is, to follow the instruction on GPS.

The learning experiences of solving past problems change the representation for future problems (Blanchette & Dunber, 2002; Dumber & Blanchette, 2001). Thus, the intervention of technology can be assumed to alter problem representations that influence the proposition of future problems. Previous studies have provided evidence for that IT such as Internet search engines and GPS affect human cognition. However, in real life, people rely on different information technologies to various degrees. Some may not use GPS yet, they may regularly engage in online activities, while others may use both, or neither of these devices. In other words, the representation altered by the intervention of IT in daily lives lie across domains. Thus, it is imperative to investigate how overall information technology use, the amount on which individuals rely daily, affects problem solving skills in general.

Analogical Transfer

Analogical transfer is the ability to come up with a solution that is appropriate to a novel problem by transferring the knowledge from the past experiences, and it is a powerful and common problem solving tool on which humans rely in everyday activities (Day & Goldstone, 2011; Dunbar & Blanchette, 2001; Holyoak & Koh, 1987). This ability is signified where individuals can construct the abstract concept of the source problem that they had previously encountered and apply that concept to solve the target problem despite the dissimilarities of problem presentations (Holyoak, 2012; Holyoak & Koh, 1987).

There are four factors interacting for the knowledge transfer to occur, (1) constructing mental representations of the source and the target domain at the point of learning; (2) the target domain works as the retrieval cues for selecting the sources as a relevant domain; (3) mapping which is the process of identifying the analogs between sources and target occurs to form inferences; and (4) extended mapping and the inferences provide the solution of the target problem (Gick & Holyoak, 1980, 1983; Holyoak, 1984, 2012; Hummel & Holyoak, 2005).The introduction of technology changes the first step by providing the altered representation of the source domain or the target domain hence it should subsequently affect the process of analogical transfer. For instance, finding the pharmacy's phone number that is open 24 hours, the traditional solution for this problem is to find the phone numbers on Yellowbook and call several pharmacies for their operation hours. On the other hand, the experienced Internet users may solve this problem by searching the phone number via Internet by typing the relevant keywords into the internet search engines. In the given example, the target problem is to find the phone number; however, past experience with the Internet created a new knowledge about the target domain and led to reference the different source domain. This kind of feature in our cognition is what makes the analogical transfer as a powerful problem solving tool (Holyoak & Thagard, 1989).

Analogical Mapping

The analogical mapping, also called *relational reasoning*, is a critical factor for analogical transfer. It is a process to identify the relationship between the structures of two problems and identify similarities. The key to the successful transfer, often times, is to realize the commonalities and alignable differences (similar but differ in surfaces) between two domains (Gentner & Markman, 1994). Analogical mapping plays a crucial role for the successful transfer in superficial level, structural level and procedural level (Chen, 2001; Blanchette & Dumber, 2002; Dumber & Blanchette, 2001; Gertner & Markman, 1994; Gick & Holyoak, 1983; Holyoak, 2012). If people can realize the alignable differences between source domains and target domains in any level, they can transfer the knowledge from the source domain to solve the target problem (Gick & Holyoak, 1983; Holyoak, 2012). On the other hand, when one fails to see the similarities, the transfer failure occurs (Gick & Holyoak, 1983). People often find the problem difficult when they have a hard time seeing alignable differences. The consequence of analogical mapping is the creation of abstract concepts (Gick & Holyoak, 1983). Analogical mapping contributes to create the general schema about the source and target domains as the byproduct of applying source domain to the target domain. Furthermore, the repeated exposure to the problem makes schema more generalized (Chen, 2002).

Importance of concrete mental models. Analogical transfer can be seen from the quite dissimilar domains such as physical task or spatial talk to solve the conceptual problems. Pertaining to the presence of concrete mental models, alignable differences are more likely to be noticed. Day and Goldstone (2011) showed that the concrete mental models are much more important than it had been assumed when one domain is transferrable to quite dissimilar domain (p. 565). The participants first engaged in the physical task that required turning on the fan to maintain the ball, which was attached to two elastic bands, in the middle of two pins. And then, they were presented with a conceptual problem to come up with a solution to maintain the town population. The participants needed to decide when to broadcast the advertisements on TV that decreases or increases the town population (Day & Goldstone, 2011). Although these two tasks ostensibly differed in the surfaces, the key solution in both tasks was to add the certain stimuli at the certain timing thus there were alignable differences between the problems. When the conceptual problems contributed to construct the concrete mental models the spontaneous transfer occurred between overtly dissimilar problems, that is, successful retrieval of source domain and mapping.

In the context of everyday problem solving, the processes of analogical transfer rather occur unconsciously. Analogies are drawn from the past experiences of individuals and then, spontaneous transfer occurs. The representation of the target problem retrieves the memory of the past experiences, and the relationship between the past experience and the target problem is formed. In experimental settings (i.e. Novick, 1998; Day & Goldstone, 2011), the participants are able to focus on the two analogies presented and know that they are supposed to compare these two, therefore, they can explicitly form representations about the problems and compare and contrast (Holyoak, 2012). In non-experimental contexts, people often draw analogies from the familiar domains. Dumber and Blanchette (2001) observed the series of laboratory meeting, and found that the biologists drew analogies from the biological domains although the structural similarities were present in other domains such as economics or astrophysics. Everyday problems are rehearsed daily and it can be said that one is an expert in solving these problems regardless of IT usage. Repeated exposure to the problems leads the formation of general schema, and expertise in the domain contributes to the deep abstract understandings and flexibility in identifying the similarities resulting in the spontaneous transfer.

When technologies are introduced, the process required to solve problems is converted or simplified. People engage in analogical transfer to perform everyday tasks by drawing inferences from the general background knowledge. The change in the general schema of the task problems modifies the source-target domain relationship, consequently the process of analogical mapping. Analogical mapping in everyday context may be attributed to relational priming, that is, one is primed to form relations rather than engaging in mapping. Holyoak (2012) argues that long term priming may occur when a source analog was deeply processed. In either case, the degree to which individuals adopt IT in daily problem solving should be attributed to the differences in general schema that mediates the relationship between source and target domains (Holyoak, 2012). Thus, examining the success or failure of analogical transfer by using traditional everyday problems could highlight the role of IT use in problem solving. If the intervention of IT inhibits the transfer of the skills required to solve everyday tasks in classic manner, individuals who rely on technology should not be able to solve such problems or take longer due to the inability to form relationship between their past experiences and the target problem. Another possibility is that the skills are conserved despite the conversion of the required skills. In that case, the analogical transfer should still occur reflected by the ability to solve the problem, no difference in reaction time should be observed.

Developmental Effects of Analogical Transfer

Krawczyk et al. (2008) suggests that the developmental effects of analogical transfer are attributed to analogical mapping or relational reasoning that is governed by the prefrontal cortex (PFC) function. Individuals with PFC damage show severe impairments in relational reasoning when compared with healthy individuals signifying the role of PFC in analogical mapping (Krawczyk et al., 2008). Although young children seem to understand the relational correspondence they seem to focus on surface similarities rather than alignable similarities (Gentner & Toupin, 1986). Children’s ability of relational reasoning increases as they age and cultivate the knowledge about the world. The current notion is the development of PFC reaches maximum at adolescence, then declines as one ages (Holyoak, 2012; Viskontas et al., 2004). The PFC, which is related with executive functioning, serves to inhibit the attention given to inappropriate cues and also to manipulate the complex information processed in the working memory (Holyoak, 2012; Thomas & Hasher, 2012). As one ages, the ability to process the complex representation in working memory to form relational reasoning declines due to the inability to selectively attend to the relevant cues, thus the ability to transfer the domain decreases (Viskontas et al., 2004; Thomas & Hasher, 2012).

Thomas and Hasher (2012) demonstrated that older adults are implicitly and explicitly affected by the irrelevant cues when they were given word lists to memorize with the distractors while young adults were explicitly distracted by the irrelevant cues. When they asked participants to recall the words from the word list, the younger generation outperformed the older adults. However, when asked to recall the distractors which were also words, the older adults remembered significantly more distractor words than younger adults. The older adults were able to do so without explicit reminding, suggesting that the knowledge of transfer occurred spontaneously among older adults (Thomas & Hasher, 2012). Viskontas et al., (2004) examined the inhibitory effect and the generational effects in terms of relational reasoning using Learning and Inference with Schemas and Analogies (LISA) (see Hummel & Holyoak, 2005). They concluded that the inability to selectively attend to the relevant cues interfere the relational reasoning among older adults and this effect was salient as the number of the relationship in items increased.

The use of technology may be perceived as difficult among older adults due to the inability to construct relationships between the former skills and the skills offered by technological devices. Zhang and Xu (2011) suggested that the acceptance of new technology depends on whether it requires the change of mental representations about the task or the existing technology. Using the Technology Acceptance Model (TAM) survey, the perceived usefulness of the technological device was measured depending on the technology type. When the participants perceived that the technology required the new learning or building the new mental representation, the participants rated the technology as low usefulness and easiness to use, while the participants rated the high perceived usefulness when the technology did not require changing the mental representation about the task. The study suggested that the training that points out difference between former and new technology may help older adults to better adopt new technology. The finding of the study is consistent with the analogical transfer literature, which is to construct the deep abstract concept about the new technology enables one to perceive the easiness of adoption. Moreover, the suggestion is in line with analogical mapping.

Given that the adoption of technology among older adults may be difficult due to mapping and altering the abstract concept of the target task, it may be possible that those who adopt the technology may show some tendencies, when given the analogical transfer task, to solve the problem within a classic manner. Furthermore, it is imperative to investigate the moderation effects, whether the effects of technology on the older population differs from the young adults who adopt technology. Regardless of the amount of current technology use, older adults have spent a considerable amount of time engaging in classic everyday problem solving tasks prior to the IT emergence. Conversely, young adults have not been exposed to the classic everyday problems as much as older adults. Since the repeated exposure of the problem induces the generalized schema of the task, it can be hypothesized that there should be a difference in the ability to transfer source knowledge between older adults and young adults.

Aging and Problem Solving

Consistent with the decline in PFC functions in relational reasoning, there is a central notion that the ability to solve problem declines along with aging. It is attributed as declining in fluid intelligence. Fluid intelligence posits the ability to reason flexibly and form a solution for a new problem independent from the previous knowledge (Preusse, van der Meer, Deshpande, Krueger, & Wartenburger, 2011; Aizpurua & Koutstaal, 2010, Redick et al., 2012). Higher fluid intelligence is associated with higher ability in analogical reasoning (Preusse et al., 2011) and is known to decline along with age due to the decline in working memory, perceptual speed (Redik et al., 2012), and episodic memory (Aizpurua & Koutstaal, 2010) while crystalized intelligence, the ability to process semantic knowledge, is not affected by aging (Morrison & Knowlton, 2012). Declining ability in problem solving is also attributed to the lower executive functions which is the collective cognitive process such as inhibitions and attentions that enable planning and goal directed behavior (Salthouse & Siedlecki, 2007; Sorel & Pennequin, 2008). Although the executive functions and the fluid intelligence both decline with age, the examination of the relationships between the level of executive functions and the fluid intelligence have been inconsistent (Arffa, 2007). However, it seems that both executive functions and fluid intelligence are related to working memory capacities that are also related with relational reasoning (Redik et al., 2012; Thomas & Hasher, 2012). Miyake et al. (2000) proposed that a three-factor model, inhibition, shifting, and updating, in executive functions predict the individual performance in executive task. The current trend in the aging and problem solving literature seems to focus on the investigation with which functional components in executive functions are related in various types of problem solving.

For example, Sorel and Pennequin (2008) examined the decline of executive functions among older adults using the Tower of Hanoi (TOH) puzzle. TOH requires one to plan subgoals for the solution and to modify them as a response to the environmental change (Anderson & Douglass, 2001; Patsenko & Altmann, 2010; Sorel & Pennequin, 2008). The result indicated that planning subgoals in the TOH task was related to the declining executive functions, specifically, shifting and processing speed, among older adults in comparison to the younger participants. There is a global notion that older participants perform at a lower level than younger participants in laboratory settings. Salthouse and Siedlecki (2007) examined the ability to plan the efficient routes using a zoo map as a relation to age and executive functions, and cognitive abilities such as fluid intelligence. The result indicated that lower efficiency was associated with aging and cognitive abilities; however, when cognitive abilities were accounted, no specific executive function measure was associated with the selection and planning the efficient routes (p.285). In terms of daily functions, Vaughan and Giovanello (2010) examined the role of executive functions among older adults and concluded that inhibition, shifting, updating were all significantly related to the performance in everyday functions. These findings suggest the unique contributions of executive functions depending on the problem types.

The previous literature also suggests that the decline in cognition makes it difficult for older adults to use technology. For example, the perceived difficulty of navigating through the menu screen of Personal Digital Assistance device (PDA) among older adults was due to the declining spatial cognition (Arning & Ziefle, 2009). Suto and Kumada (2010) indicated that the difficulty of buying the bullet-train tickets on the webpage was due to the difficulty of planning subgoals and goals and maintaining the sequence behavior.

However, there is considerable evidence that older adults are capable of solving ‘real-life’ problem despite cognitive aging. For example, older adults performed as well as young adults making inferences about the world using the recognition heuristics (Schooler, Pachur, & Mita, 2009). Crawford and Channon (2002) provided everyday problems for older adults and younger adults, and found that older adults generated fewer solutions; however; their solutions were more qualitative than younger adults. They concluded that older adults have better understanding about the everyday problems, and can make better inferences to generate the solution than younger adults. Hoppman and Blanchard-Fields (2010) demonstrated that, when the goals are given, older adults were better at selecting the strategies for social problems.

The generational effects in well-defined problems such as spatial learning are also known to be moderated by the contexts. In the study by Maneghetti, Borella, Grasso, and De Beni (2012), the three groups of older adults were given the route description by map (M), map and description (M+D), and description only (D), and they found that no age effect was observed in M and M+D groups. The study suggested that older adults are able to learn a route when the encoding method was relevant to them (Meneghetti et al., 2012). When they are given the relevant context the generational effects were moderated. Their life experiences and knowledge can serve them to solve problems as good as young adults when the problem context is relevant to their daily lives. The generational study on the ability to create a representation of the texts (situation model) by Radvansky, Zwaan, Curiel, and Copepland (2001) suggests that older adults are better at forming the representation of the given texts (what the text is about) than remembering the texts surfaces (how exactly the text was written). Despite the decreasing speed in information and memory processing, older adults perform better than young adults in recalling the concepts of the texts (Radvansky et al., 2001). Adopting problem solving tasks that are relevant to their daily lives in the current study allows an examination of the role of technology independent from the cognitive aging.

Overview of the Experiment

The current study attempts to answer three questions; (1) Are technology (IT) use, age and the ability to solve problems related? (2) If so, how are they related? (3) Are there interaction effects between age and technology use on problem solving? Given the importance of mental representation and analogical mapping and its role in analogical transfer, we do not know how technology impacts our ability to solve problems.

More importantly, the current study examines whether general technology use has caused the skills required for typical problem solving to deteriorate. Everyday problem solving requires multidimensional abilities. The concepts of analogical transfer and the mental representation provide the methodology to measure the multidimensional skills reflected by fluid intelligence, moreover, the investigation of the presence of analogical transfer in problem solving can provide the evidence for the conservation of skills.

Prior research in analogical transfer has used two protocols; success and failure of given tasks or thinking aloud, to assess the presence of transfer (Novick, 1988; Dumbar & Blanchette, 2001). However, Day and Goldstone (2011) argued that not only the success and failure of the task, but also the task completion time can be an indicator of a successful transfer. When involving the interaction between complex systems to solve the problem to achieve the goal, participants' solution time can provide the sensitive measurement for analogical transfer (p.552). Everyday problem solving requires the complex cognitive process that interacts with several mental representations. When assessing the transfer dealing with the everyday problem solving, the solution time of the task was considered to serve the measurement for analogical transfer.

If there are no representations or source to retrieve the cues to solve the classical everyday problem, the tasks should be perceived as difficult; hence, the participants should fail or take longer to complete the task. On the other hand, the successful transfer can be reflected by participants easily completing the task. If the technological intervention had somewhat affected the problem representation and the relational reasoning, the analogical transfer should not occur or the task will take longer than those who use technology less.

Three problem solving task are used to assess the ability to solve everyday problems; looking up phone numbers, finding a destination on the map, and solving Tower of Hanoi (TOH). Looking up phone numbers and finding a destination on the map reflects the ability of everyday problem solving. As these tasks require complex cognitive ability, they are usually used to assess the cognitive decline of older adults (Diehl, Willis, & Schaie, 1995; Salthouse & Siedlecki, 2007). General problem solving skills are assessed by the TOH task. The TOH puzzle is often used to assess the cognitive ability across the age (Sorel & Pennequin, 2008). TOH provides less variable problem representation, thus, if there were differences in performance level across groups between TOH and other two tasks, it validates the role of representation change caused by the age or technology usage.

Method

Participants

The participants were 47 individuals between 18 and 91 years of age. Twenty six of them were undergraduate students who enrolled in the introductory psychology courses at the University of Central Oklahoma. All the students signed up for the study through SONA system, an online recruiting program, and were awarded one hour credit after the participation for the partial fulfillment for the course. Twenty one participants were local residents, over 65 years old, recruited at Epworth Villa (retirement community located in Oklahoma City, OK) by the faculty, by the researcher, via advertisements on bulletin board, by flyers in the community, and by referrals from other participants. The older participants were independent living residents thus we assumed that they function at sufficient level of cognition for the current study. No older participant performed at significantly lower level in solving problems when compared with the other participants. Participation in the study was completely voluntary for the local residents. All older participants and approximately 46% of the younger participants (the undergraduate students) were Caucasians, and the remaining younger participants represented a variety of ethnicities. About 86% of the older participants reported that they had completed college education including two years and four years college, with 38% of them completing advanced degrees (Master’s and Doctorate Degree). Two undergraduate students reported that they had completed two years and four years college education. All the participants had normal or corrected vision, and their hearing was not impaired.

Materials

Technology survey. The participants were given a survey (see Appendix A) regarding their demographics (age, sex, ethnicity, and education), and their amount of usage of information technology (IT) on daily basis. The technology survey was created to measure the participants’ purpose, amount of usage and attitudes on five technological devices; desktop computers/laptops, cell phones, Smartphones (iPhones, Android, Windows phone), tablet computers (Ipad, Galaxy note, etc.), and Global Positioning System (GPS). Brand name examples were given for the Smartphone and the tablet computer for clarification.

In order to assess participants’ purposes of using cell phones, Desktop/laptop computers, Tablet computers, and Smartphones, a matrix was created with seven different purposes (i.e.

online searching, finding resources, Emails, Social Networking Sites, playing games, watching videos clips, and offline activities) representing each row, and four devices representing each column. The participants checked each box that applied to them. Given the rather unique nature of GPS from other four devices, the purpose of GPS or navigation program use was formatted differently. Participants checked all items that applied to them on five sentences describing different purposes for GPS (i.e. finding the route to the destination that I have never been, finding the route to the destination that I have been before but don't remember exactly, everytime I drive, I own GPS or navigation systems but never used it, and I do not have GPS).

The amount of time spent on each device measured in self report format by having participants report how many hours they think they use the devices everyday for online activities and personal communications including Emails and Social Networking. For GPS usage, the usage frequency was asked (i.e. never, less than once a month, once a month, 2-3 times a month, once a week, 2-3 times a week, and daily).

Anticipating the confounding effects due to variable familiarity in technological devices across generation, the current study was purposely designed not to involve any measurement using technological devices, which is using the paper survey and wooden TOH tasks. However, there was also a possibility of confounding effects using pen and paper procedure. If participants were used to type and work on computers, they may be disadvantageous on the procedure involving the use of pens and pencils. Therefore, the questions asking the preference for pen use (yes/no) and the hours engaged using pens and pencils in daily lives were also included.

In addition to the purposes and hours of the use IT devices, the attitudes towards each device was measured using technology acceptance model (TAM) survey (Davis et al., 1989; Venkatesh, Morris, Davis & Davis, 2003). The TAM was developed based on theory of reasoned action to explain people's behavior in using IT. The model postulates the mediating role of perceived usefulness and perceived easiness of the device in relation to the actual intention to use and the actual use of device (Venkatesh et al., 2003). Therefore, seven questions (four questions to assess perceived usefulness and three questions to assess perceived easiness) were adopted from TAM survey in the current study to assess the participants' attitudes towards each device. Although originally developed for the IT adoption in workforce, validities of modifying TAM survey questions to assess specific technological device in everyday circumstances have been well established (see Hong & Thong, 2006, Hong, Thong, & Tam, 2006; Hong, Thong, Wong, & Tam, 2001, Zhang & Xu, 2011). In the current study, each question was modified to assess perceived usefulness and easiness in daily lives (e.g. I use tablet computers to improve my daily performance of tasks). Furthermore, the original likert scales ranging from 1 to 7 (strongly disagree to strongly agree) were modified to four point scale ranging from 1 to 4 (strongly disagree to strongly agree) in order to provide more clear data.

Santa Barbara Sense of Direction Scale (Hegarty, Richardson, Montello, Lovelace, & Subbiah, 2002) was used for assessing the self-reported sense of direction. Sense of direction was shown to be related with the ability to orient and locate the self in space. Although the current study did not involve any actual location of self in the space, it was possible that the ability to locate and orient themselves could transfer to the ability to plan the efficient route and trace the route thus this measurement was included for the possible predictor in the map task. The original likert scales ranging from 1 to 7 (strongly disagree to strongly agree) were modified to four point likert scale (see Appendix B).

Observed Task of Daily Living (OTDL) task. The ability to find information was assessed using the part of Revised Observed Tasks of Daily Living (OTDL-R) (Diehl et al., 2005). OTDL-R is an objective behavioral measurement of daily life activities created for older adults to assess their various cognitive abilities related to daily living (Diehl, Willis, & Schaie, 1995; Diehl et al., 2005). The measurement includes three everyday problem solving domains including telephone use. For the current experiment, only the telephone use domain was adopted. This part consisted of three separate tasks. Prior to each task, the experimenter read the instructions and then, showed them the script of the instruction. The first two parts involved finding the phone numbers on the given sheets (e.g. find a phone number for subsidized housing), and the last part involved finding the long distance call rate for the given time and the day. The original task also included actually dialing the phone numbers using the phone. This part of the task was omitted; instead, the participants marked the phone number or the name of the rate with pencil. The instruction, materials, and scoring instruction was obtained from the website (http://marsiskelab.phhp.ufl.edu/otdl/otdl.html).

The modified instructions and scoring criteria were used for the current experiment (see Appendices C, D, and E for complete materials used for the current experiment). OTDL-R scoring instruction provides the sub-steps of the tasks and the standardized scoring criteria. The observer scored their process of completing the task following with the given scoring criteria. The scores were recorded either 0 (wrong behavior) and 1 (correct behavior) for achieving the given subgoals and goals. When participants needed prompts to achieve goals and subgoals, 1 point was given, and 2 points were given when participants completed the goals and subgoals without prompts. Prompts were given, for example, when participants only found the ‘housing’ section in the phone book when they need to find the specific phone number under the section. The time to complete the task was also recorded.

Map navigation. The methodology to assess plan efficient route was based on the previous study in Salthouse & Siedlecki (2007). A map of the zoo was given with 13 exhibits, and the participants were asked to find the shortest way to visit seven designated visits (see Appendix F). Seven exhibits to be visited were listed in the bottom right corner of the map. They were given a pencil and asked to trace their route to the destination. The process of wayfinding was recorded to measure their performances of wayfinding. The recorded measurements were the reaction time, the distance traced, and the number of stops made. The number of stops made was defined when the participants stopped their pencil movement for more than 10 seconds. The route inefficiency was calculated by subtracting the actual route distance taken by the participants from the optimal route. Both optimal distance and actual distances were measured based on Salthouse and Siedlecki (2007). They measured distance as a straight line from one exhibits to the other and concluded that it is more reliable than measuring the actual traced route.

Tower of Hanoi. ‘Tower of Hanoi’ (TOH) was used to assess the general problem solving ability. It is the mathematical puzzle that is often used to assess the executive functioning and the planning ability (Anderson & Douglas, 2001; Patsenko & Altmann, 2010; Sorel & Pennequin, 2008). Solving TOH requires moving the multi-size discs that are arranged in pyramid on the right rod to the far left rod. Usually there are three rods, and the goal is to move all disks located in the right rod in ascending size to the left rod in the same ascending order. There are three rules to follow when moving the discs, 1) only one disc can be moved at a time 2) only the upper disc can be moved and placed on top of the other disc or the empty rod 3) smaller discs have to stay on top of the larger discs. The numbers of sub-steps when solving the problem differ as a function of the number of discs.

The present study utilized the TOH with five disks which requires total of 31 sub-step moves. The score of this task was determined by the number of errors made and the number of total moves participants required to complete the task, and the time to complete the task was recorded. In previous studies, participants were usually given the practice phase with fewer number of disks. In the current study, the aim of the study was to assess the presence of analogical transfer from their life experiences, thus no practice phase was given in order to avoid the transfer from the practice phase. Instead the participants were corrected by the researcher when they attempted to illegally move disks. The number of errors represented the errors that the researcher could not detect during the observation but found later by reviewing the recorded video.

Procedure

The data was collected at two locations. For the younger participants, the data was collected in the laboratory on campus at the University of Central Oklahoma. The data for the old participants was collected in a room provided at their retirement community. The same room was used for each participant within the age group. Two rooms differed in size; however, both rooms provided desks, chairs, and silence. The participants were tested individually in a session lasting about an hour.

Upon obtaining the informed consent, the participants answered the survey questions about the technology usage and filled out the sense of direction scale. After the completion of the survey, the researcher explained that the participants would have a ‘give up’ option for every task they were going to engage. The researcher also clarified that the participants had to explicitly state that they wish to stop if they want to give up on any tasks and made it clear that it was different from the withdrawing from the experiment. Once the explanation was done, the researcher started the video recording of their hand movements to be followed by OTDL, map and TOH tasks. The order of these three tasks was counterbalanced. The completion of the task (yes or no) was also recorded.

The purpose of the current study was to explore the role of aging and technology use on problem solving ability hence these variables were tested to see if they fit in the general linear model predicting the problem solving ability. There were two independent variables; age and the amount of technology use, and six dependent variables; the scores and the reaction times for the three problem solving tasks; OTDL, map, and TOH. Standard multiple regression analyses were run for TOH and OTDL tasks. For the map task, in addition to the age and the technology, sense of direction was also included as an independent variable. Hierarchical regression analyses were performed for the map task since sense of direction was considered to be associated with the ability to plan efficient route, the sense of direction was needed to be accounted in the model prior to the age and technology use.

Results

Technology Use

Variables reflecting technology use were calculated by adding the scores of selected responses in the technology survey. The purposes, hours, desktop perceived usefulness, and desktop perceived easiness were selected to create a technology use variable. Responses for pen use preference, pen use hours, GPS purpose, GPS frequency, and modified TAM scores (perceived usefulness and easiness) for tablets, Smartphones, and GPS were not included in the calculation.

Excluded responses. GPS purposes and GPS use frequency were excluded due to the inadequacy of question format. Due to the difference in GPS from other devices, the questions were formatted differently to measure the purposes and frequency of use from other devices. GPS is a device created for special purpose, consequently, there were no clear differences in purpose for using GPS, and two questions did not seem to differentiate purpose and frequency.

TAM questions for tablets, Smartphones, and GPS were excluded due to the substantial missing responses. There were substantial missing responses in modified TAM questions for tablets (63%), Smartphones (46%), and GPS (34%). The participants filled out this part of the survey only if they own the devices. Technology acceptance was assessed for each device, except for cell phones, to measure perceived usefulness and easiness. If they did not own the device, or have limited access to the device their responses may not reflect the acceptance. In addition, not owning the devices does not always indicate low perceived usefulness or easiness.

Included responses. The seven purposes for using each device (cell phones, desktop/laptop computers, tablets, Smartphones) were coded from 0 to 7. The hours using each device (cell phones, desktop/laptop computers, tablets, Smartphones) for online activities and personal communications were added together to reflect the amount of time the participants engage in using the devices every day. This number ranged from 0 to 16 hours. Several individuals reported eight or more hours of use for each purpose, and this was only observed among the younger participants. The hours reported has higher than eight hours was trimmed to eight hours since using each device more than eight hours a day was considered unrealistic. Desktop perceived usefulness and easiness were part of modified TAM survey. The first four questions assessed perceived usefulness and the latter three questions assessed perceived easiness of each device. The participants answered these questions marking strongly disagree, disagree, agree, or strongly agree, and these responses were coded as 1, 2, 3, and 4, respectively. The numbers were added to create perceived usefulness and easiness score. Adding these 10 responses together, technology use variable was created yielding acceptable reliability for research purpose (Chronbach's $\alpha = 0.66$).

Sense of Direction

Modified Santa Barbara Sense of Direction Scale (M-SBSDS) was used to assess the sense of direction of the participants. The survey included 15 questions, and the participants answered from strongly disagree to strongly agree (four point scale) to each question. Questions 2, 6, 8, 10, 11, 12, 13, 15 were reverse coded, otherwise, the other questions were coded strongly disagree as 1 through strongly agree as 4 giving a total score to indicate the higher the score the higher the sense of direction. There was a significant positive relationship between the score and age, $r(45) = .50$, $p < .001$, indicating that the older participants tended to have higher sense of direction. There was no significant correlation between sense of direction and the technology use.

Relationship between Age, Technology, and Problem Solving

The variables of technology use, sense of direction, and age as predictors (IVs), six multiple regressions were run for each dependent variable to explore the relationship between age, technology use, and the ability to solve problems. The sense of direction variable was only used to predict map RT and map score. Dependent variables were RTs and the scores for three task; OTDL, Map navigation, and TOH. The OTDL score is the total score of finding information for each OTDL task. Map score was calculated by subtracting optimal distance from the actual distance indicating the route inefficiency. TOH score is the total number of the disk movements. Means and standard deviations for each variables used in the analyses are reported in Table 1. Although, in the analyses, age was entered as a continuous variable, collecting samples from two locations (at the university and the retirement community) shaped two distinct age groups (old and young). Therefore, looking at each variable as a function of age group was helpful in understanding the overall relationship between variables. Correlation coefficients between IVs and DVs are reported in Table 2.

Due to the technical and human errors, and the incompletion of the task, several participants were excluded from OTDL RT (three participants), map RT (nine participants), OTDL score (one participant), map score (seven participants), TOH RT, and TOH score (eight young participants and 14 older participants). In TOH task, eight participants started over the task one or two times, of which four completed the task and four did not. Since the multiple attempts did not give an advantage to complete the task, four individuals who completed the task were included in the TOH analyses. Recorded RT and the score were those of the last attempt. One person moved five disks onto the middle rod instead of the left rod in ascending order. Although moving all disks to the middle rod required the same process and number of movements, the case was counted as the task was not completed. One of the strength of TOH is that it gives a clear goal state where fixed mental representation is formed about the goal state. Thus this case was concluded that there was a change in the goal state thus the participant worked to achieve a different goal from the others. Binary logistic regression was conducted to see whether age and technology use can predict the completion of TOH task. When age and technology use were entered to the model together, the model was not statistically significant indicating that inclusion of neither age nor technology use improved the prediction of TOH completion in the model than chance. One person had seen TOH before but never solved it. The RT and score of this participant did not differ from the rest of data thus it was included in the analysis.

Table 1

Descriptive Statistics

	young			Old			Total		
Variables	*n*	*M*	*SD*	*N*	*M*	*SD*	N	*M*	*SD*
Age	26	20.6	4.8	21	80.9	6.9	47	47.6	30.8
Technology Use	26	43.9	8.3	21	28.3	10.0	47	37.0	11.9
Sense of Direction[a]	26	36.0	8.4	21	44.2	6.3	47	39.7	8.5
RTs (s)									
OTDL	26	156.8	56.0	18	185.7	70.8	44	168.6	63.3
Map	25	112.2	49.8	13	189.4	122.2	38	136.6	86.3
TOH[b]	18	289.4	140.3	7	408.1	171.6	25	332.7	155.7
Scores									
OTDL	25	15.0	1.5	18	16.2	1.3	43	15.5	1.5
Map (cm)	25	10.6	11.3	13	13.4	12.9	38	11.5	11.8
TOH[b]	18	71.2	28.0	7	63.7	26.7	25	69.1	27.3

Note. Technology Use scaled from 0 to 56. Sense of Direction scale ranged 0 to 60. OTDL score ranged from 0 to 18.

[a] Modified Santa Barbara Sense of Direction Scale. [b] The reported measurements in TOH task reflect the participants who completed the TOH task.

Table 2

Correlations

	Age	Technology use	Sense of direction
Age	1		
Technology Use	-.69**	1	
Sense of Direction	.50**	-.26	1
RTs (s)			
OTDL	.27*	-.39**	
Map	.44**	-.34*	.14
TOH	.32	.12	
Scores			
OTDL	.38*	-.43**	
Map	.15	-.25	-.12
TOH	-.16	.51**	

** Correlation is significant at the .01 level (two-tailed)

* Correlation is significant at the .05 level (two-tailed)

Overall result indicated that age and technology related differently with the ability to solve problems for each dependent variable (Table 3). Only technology use significantly predicted OTDL RT and TOH score. Both age and technology use predicted TOH RT. OTDL score was predicted by both age and the technology use, however, no unique prediction by each variable was found. There were no relationship found in map RT and map score.

Table 3

Regression Coefficients

						Technology Use				Age			
		R(SE)	R^2	*F(df)*	*p*	*B(SE)*	*β*	*t(df)*	*p*	*B(SE)*	*β*	*t(df)*	*p*
RT(s)													
	OTDL	.395 (59.55)	.156	3.784 (2,41)	.031	-2.170 (1.07)	1.065	-2.038 (43)	.048	-.062 (.42)	-.030	-.147 (43)	.884
	TOH	.514 (139.51)	.265	3.957 (2,22)	.034	8.231 (3.75)	.505	2.196 (24)	.039	3.47 (1.27)	.628	2.730 (24)	.012
Scores													
	OTDL	.441 (1.41)	.195	4.834 (2, 40)	.013	-.039 (.03)	-.314	-1.539 (42)	.132	.008 (.01)	.158	.775 (42)	.443
	TOH	.543 (23.97)	.295	4.607 (2,22)	.021	1.866 (.64)	.644	2.897 (24)	.008	1.866 (.22)	.233	1.037 (24)	.311

OTDL RT. A standard multiple regression analysis was conducted using age and technology use as IVs and OTDL RT (s) as a dependent variable. Three participants were excluded from the analysis due to the technological error for the time measurement. The result indicated that age and technology use predicted 15.6% of the variance, and the technology use was a significant predictor (Table 3).

Map RT. A hierarchical multiple regression analysis was conducted entering sense of direction at first, then age and technology use in the second model. Dependent variable was the RT in map task. The result indicated that neither sense of direction itself nor addition of age and technology use variables improved the prediction of map RT.

TOH RT. A standard multiple regression analysis was conducted using age and technology use as IVs and TOH RT as a dependent variable. The result indicated that the model explained 26.5% of the variance, and both technology use and age were significant predictors (Table 3). Neither age nor technology use have significant bivariate correlations with TOH RT (see Table 1), however, when entered in the regression model, each predictor significantly predicted the DV indicating that controlling for each variable, two variables were uniquely correlated with the RT in TOH. Further analysis revealed that addition of technology use variable significantly improved the R value from .322 (p = .12) to .514, when only age predictor model and age and technology use predictor model were compared. This indicates that technology use is a suppressor variable meaning that it suppresses the age effect in the given regression model.

OTDL score. A standard multiple regression was conducted using age and technology use as IVs and OTDL score as a dependent variable. The result indicated that the model explained 19.5% of the variance (Table 3), however, neither age nor technology use significantly predicted OTDL score.

Map score. A hierarchical multiple regression analysis was conducted entering sense of direction at first, then age and technology use in the second model. Dependent variable was the map score (route inefficiency). The result indicated that none of sense of direction, age and technology use do not explain the variance in map score.

TOH score. A standard multiple regression analysis was conducted using age and technology use as IVs and TOH score as a dependent variable. The result indicated that the model explained 29.5% of the variance (Table 3), and the technology use was a significant predictor.

Moderation effects. OTDL RT, TOH RT, and OTDL score were tested for moderation effects to see if there is an age and technology use interaction effects present to assess the possibility of age specific technology effects on these DVs. Moderation was tested by calculating centered score for age and technology use. Then the interaction score was calculated by multiplying two centered scores. Hierarchical regressions were performed by entering age centered score and technology centered score first, then the interaction score. None of the models were improved by the addition of age x technology interaction score indicating that there were no moderation effects on these DVs.

Discussion

The purpose of the current study was to understand the relationship between technology use, age and the ability to solve everyday problems by examining the presence of analogical transfer. In order to examine this problem, the study investigated (a) whether age and technology use predict the ability to solve problems (b) if so, how age and technology use predict the problem solving ability. The ability to solve problems was assessed by three problem solving tasks. OTDL and map tasks represented everyday problem solving ability, and TOH task was used to measure general problem solving ability. The visual interpretations of the results are summarized in Figure 1.

	RTs			Scores		
	OTDL	Map	TOH	OTDL	Map	TOH
Age	+	+	+	+	ns	ns
Technology	-	-	+	-	ns	+

Figure 1. Summary of findings. Significant predictors are presented with shades. The darker shade represents better performance (i.e. faster speed to complete the task), and the lighter shades represent worse performance (i.e. slower speed to complete the task, more erroneous disk movements to finish the task). Signs (positive or negative) of significant correlations were represented in the cells. “ns” means a nonsignificant correlation.

Presence of Analogical Transfer

Overall results indicate that analogical transfer was present for the speed of information finding task (OTDL), and the transfer was not present in the TOH task. The higher technology use predicted the faster response in the information finding task suggesting that visual search process was transferred from the technology use. On the other hand, technology use inhibited the subgoal formation in TOH task. The speed of TOH task was positively predicted by both age and the technology use, in addition, technology use was found to suppress age factor specifying that higher technology use reduces the proportion of slower performance accounted by aging. Although the more technology use and aging predicted slower completion time in TOH aging was not associated with the error movements in TOH suggesting the inhibition of transfer due to technology use. Technology use did not have an effect on planning efficient route (map) and the accuracy in information finding task (OTDL score).

Considering other significant relationships (but not predictors), aging was generally associated with slower speed to complete the tasks, however, it was not related to participants successfully solving the given tasks. In fact, the older the participant, the accuracy of locating the information increased. On the other hand, technology use had an altered relationship between everyday problem solving task (OTDL and map) and TOH task. For the everyday problems, technology use was associated with faster performances in comparison to the slower performance in TOH task. These unique relationships of age and technology use with each task suggest that the effects of technology use are domain specific.

Everyday Problems vs. TOH.

All the problem solving tasks used in the current study had well defined goals (i.e. find the information on the page, plan the most efficient route, move five disks in ascending order), and required subsequent planning of subgoals to solve the problems. However, planning to solve TOH was rather complex and required participants to consciously formulate subgoals to move disks to the final state against their intuition whereas the other everyday problems could be performed with fewer subgoals. Although all the participants were told that they have a ‘give up’ option for all the tasks, none of them gave up on everyday problems in comparison with 22 participants giving up on the TOH task. Many individuals also commented that TOH was very challenging, and the other tasks were easy. When having difficulty to select relevant source domain to solve a target problem, people perceive the problems as difficult. Increased disk movements in TOH indicate the failure to form subgoals to reach the goal state, and this error was positively predicted by the technology use. It seems that increased technology use has changed the previous problem perceptions that required formulating complex subgoals and subsequently inhibiting the knowledge of transfer.

TOH task was used to assess the general problem solving ability. General problem solving ability has been known to decline along with age. TOH requires the planning and formation of subgoals that involves executive functioning. Numerous studies have found a decreased executive functions with age could interfere with the ability to plan subgoals to solve problems, and the number of disk movements that reflects the ability to form complex subgoals is known to increase along with age (Salthouse & Siedlecki, 2007; Sorel & Pennequin, 2006). The current study did not find the relationship with age and the number of errors. Considering that age and technology use predicting reaction times but not the number of movements, this suggests that subgoal formation is inhibited by technology use rather than the decline in executive functioning.

When TOH was presented and the rules were explained, most of the participants instantly started moving disks, and a few people spent time planning before moving disks. Although the researcher did not ask them to think aloud, many individuals were thinking aloud. Moreover, as they were moving disks by trials and errors, some people have stopped moving disks and started to planning (or thinking) while others never really stopped and kept moving disks. This poses another question if these differences in individuals are mediated by technology use. TOH is a sequential task, and once the basic sequence is learned, the knowledge could be transferred to subsequent disk movements but differ in number of disks. Since TOH task was a novel problem for the participants, they learned and transferred the knowledge as they solve the problem. Failure or delay of transfer within this process also reflects the increased number in disk moves. Thus further analysis may be done to examine whether technology use inhibits the subgoal formations from the past experiences or the learning occurring during the course of solving the problem or both. Pastenko and Altman (2010) proposed that once initial learning is established, moving disks can become a routine, that is, the disk movements becomes a response to the environment by selective attention instead of subgoal and goal directed behavior. Hence examining the point of learning, the point when the behavior becomes a routine, in relation to the use of technology could further provide the understandings of how technology use interfere subgoal formation.

With respect to the speed in the information search task and TOH, there could be two possible explanations for the transfer. One explanation is the difference in required ability to solve these tasks. OTDL task owes to the ability to visually search items from the list while TOH was a pure subgoal formation task, and there was no flexibility in which how one forms subgoals while one could employ different strategies. Although OTDL task was scored using scoring criteria that reflects subgoals (e.g. finding ‘Housing’ section prior to find the phone number for subsidized housing), these subgoals were often not observed or apparent. When individuals operate technological devices it requires them to search target items, and it is known that individuals employ different cognitive strategies to find the items on computer screens (Hornof, 2004). Thus, it is reasonable to assume that people who engage in more technology use have more experience in visual search strategy that were transferred in the given task. In addition, many individuals scored lower for the third section of OTDL task that differed from the first two sections. In the third task, unlike finding the given phone numbers, the participant needed to identify, the time, day, and the shades that represents different rate plans in the long distance call chart to find which rate plan applies to the given day and time adding the complexity to the task. This fact also adds the point that the more people use technology they may rely on visual search rather than forming a strategy to solve problems.

Another explanation accounts for the difference in physical movements required to complete the everyday problems and the TOH task. OTDL and map task both were pen and paper format, that is, to solve a problem on two dimensional surfaces, while TOH required to solve the problem by physically shifting and moving disks working on three dimensions. Thus it is possible to claim that using technological devices, which usually involves processing the information presented in two dimensional surfaces, transfers to the pen and paper procedure but inhibits the tasks in three dimensions. However, this explanation is in probable because TOH has a direct relationship with the number of disk movements and the technology use positively predicted both RT and the number of movements. Furthermore, this also could be a mere transfer from the daily pen use. Since pen and pencil use hours indicated a significant positive correlation with the technology use, it is possible that the technology use serves as a mediator for pen and pencil use to be related with the reaction times. The fact that only reaction times but not the scores were related with aging and the technology use was suppressing the age factor for the speed in the TOH task, at least suggests that technology use may be somewhat beneficial for faster physical movements. To support this point, the previous research has suggested that as the number of disks increased in the TOH puzzle, the individual difference in perceptual processing speed explained lesser amount of variability in the reaction time (Sorel & Pennequin, 2006).

It is also worth to note that there were no moderation effects. The study originally postulated that there may be generation specific effects due to the difference in the life experience. However, there were no moderations by age or technology use indicating that any of the tasks were not predicted by depending on the condition of each other. Thus, for this current study, it can be concluded that technology use seems to inhibit the transfer of subgoals formation and transfers the visual search ability on information finding task regardless of aging.

In an attempt to observe the effects of technology use and to eliminate the aging effects, the current study used everyday problems that were in relevant contexts to the older adults. OTDL task was created for older adults to measure their ability to perform tasks in daily lives. Map task was adopted from the previous study of Salthouse and Siedlecki (2007) that examined the generational effects of route efficiency, thus the given map of zoo was considered relevant for any generations. Although there were positive correlations in reaction times, when the technology was taken account, age was not a predictor for reaction times in everyday problems. Moreover, age did not predict the performances of these everyday tasks confirming that these everyday problems successfully provided the relevant contexts across generations enabling to assess the effects of technology use on problem solving.

Salthouse and Siedlecki (2007) claimed the zoo map to be a strong battery to assess route efficiency, however, their study showed small differences between the optimal route and the actual route. Following their suggestions, the current study had the increased number of exhibits to visit in order to add more complexity to the task. Nonetheless, the result yielded even smaller differences from their study thus it may be a subject of ceiling effect. This may also explain the reason why that there were no relationships with technology use or age and the route inefficiency. In addition, Allain et al. (2005) also utilized this zoo map task to examine the generational effects of planning and execution of the plan. They found that planning was more difficult for older adults indicated by more route inefficiency while the execution of the plan was more difficult only among older participants. In the current study, there was no age factor playing a role in the route inefficiency with account of technology use. There are two possible explanations; the first is due to the ceiling effects for the previously stated reason, second explanation lies in the moderation effects of technology and age. It may be that aging is associated with lower ability to formulate a plan however, technology use that is negatively correlated with age, had been shown that to inhibit subgoal formation, also played a role in plan formulation thus ceasing the age to be a factor to predict the route inefficiency.

The confounding effects for using pen and paper procedure were anticipated due to the fact age and technology use were assumed to negatively correlate thus pen preference and pen use hours were included in the survey. As opposed to the previous assumption, the younger generation used more pen and pencil in terms of hours, and no pen use preference was prevalent by age. Therefore, the current procedure, pen and papers, did not interfere the participants' performances.

Limitations

One of the foremost limitations of this current study was a small sample size and the sampling bias. Small sample size, although expected in aging researches, contributed to the sampling bias. Such smaller sample size is not adequate to detect interaction effects in regression models. There were no interaction was found in the present study, the increase number of participants may lead to detect the interaction effects of age and the technology use. As for the sampling bias, the researcher collected the data from one location for older participants at the local retirement home. Therefore it can be assumed that the older participants in the current study may reflect certain SES or other characteristics to choose the certain retirement community that may interfere with their ability to solve problems or technology use. In addition, the participation for older participants were completely voluntarily, thus people who have participated in study may share certain characteristics such that they are more progressive in general thus they may have been willing to adopt new technology as well. Also, it could be that people who are more confident about their daily functioning may be more willing to participate. Although self-report efficacy and the performance level of actual everyday task do not always correlate (Vaughan & Giovanello, 2010), it is possible that the data only represents those who are highly functioning in each age. In future study, it is necessary to eliminate such sampling bias and the increase in sample size is suggested.

Other limitation is a high collinearity between age and technology use (r = -.69). High collinearity usually provides less sensible measures of predictions and yields to high standard errors in regression models. In the current study, OTDL score was found to be explained by age and technology use, however, their unique contribution could not be found due to such high collinearity. One of the solutions and another limitation of this study is that this study used cross sectional design. Although this study provided some insights to the relationships between technology use, age and everyday problem solving the causal effect conclusion cannot be drawn from the current study. Moreover, aging studies suggest that individual difference in cognition in later adulthood are much larger than younger generation (Redick, 2012), and the longitudinal studies among older adults suggests that, although the ability to solve everyday problems may not differ when represented as age groups, individual declining in executive functions over the time predict the level of everyday problem performance (Tucker-Drob, 2011). Further study could be designed by manipulating the introduction of new technology to solve given problems in order to draw a causal effects relationship of technology use, aging and a problem solving as well as exploring the longitudinal relationship of the three factors.

The reliability of technology survey also needs to be discussed. Technology use variable was created by compositing survey responses which lead to have relatively low reliability (Chronbach's $\alpha = 0.66$). When TAM survey for GPS, Smartphones and tablets were included the reliability significantly increased and showed high reliability. However, for this study TAM responses for these devices were excluded due to the substantial missing responses. Missing responses, consequently not owning a device, do not indicate lower perceived usefulness and easiness. Other factors such as SES, education level, residence location (urban or rural) could affect one's decision to adopt a technological device (Marcellini, Mollenkopf, & Ruoppila, 2005). One exception was made for one participant who did not own a computer but the participant had an instant access to the computers on the university's campus. For the future study, regardless of ownership of the device, the participants may fill out the TAM survey and information about each device may be included in the survey to learn about certain devices (such as tablets and Smartphones) in case the participants are not familiar with or do not know about the devices.

For the current survey, the amount of technology use included the measurement of self-reported time that they engage in using each device. The self-report hours revealed that younger participants were much more likely to report any hours longer than older participants. Furthermore, often times, sum of raw hours for all the devices and pen and pencil use exceeded 24 hours. This may suggests that there may be a difference in perception of time or some other motivational factors playing a role to report such long hours. One reason may be the technology acceptance. Depending on the attitudes towards technology, one may estimate the hours lower or higher. Time is also individuals' subjective experiences. The recent study suggests that depending on the one's mindset (abstract or concrete) and the features of the presentation material (low detail or high detail) could interactively affect time perception (Hansen & Trope, 2012). Thus depending on how people use each device, the perception of time, subsequently the reporting time, may be different. The modification of survey questions could account for more precise estimates of their time spent with each device.

Implications

The present study sheds light on the relationship between technology use, age and problem solving for the first time. The presence and inhibition of analogical transfer was observed attributing to the technology use depending on the problem type. While the ability to visually search items transferred to the everyday problem solving, general problem solving ability, in particular, the formation of subgoals was interfered by technology use. More importantly, when technology use was accounted in the model, age was not a factor related with the ability to solve general problems. This finding challenges the studies that have suggested the aging and the declining ability to solve problems (Sorel & Pennequin, 2008; Viskontas et al., 2004; Thomas & Hasher, 2012). Many studies assessing generational effects on problem solving occur in laboratory settings and utilize computer based program without accounting individuals' use of technology.

There are many remaining questions for future research regarding the effects of technology use. In line with the limitation of the current study, it is imperative to investigate the causal effect model of technology use, aging and problem solving as well as the longitudinal study to account for the individual differences. Although technology use seemed to suppress the aging effect on the speed to move disks in TOH, it is yet unclear the relationship between technology use and aging as to what specific domains of functions of age related factor to cause the difference in the reaction time. Furthermore, the tasks in the present study reflect the executive functions, and these tasks have been extensively examined in neuropsychological terms. It would be compelling to further explore such neuropsychological testing as a function of technology use along with aging could reveal in depth understandings of general technology use and aging.

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Appendix A

Technology Acceptance Survey --Modified

How old are you?

____

What is your gender?

- ❍ Male
- ❍ Female

What is the highest level of education you have completed?

- ❑ Less than High School
- ❑ High School / GED
- ❑ Some College
- ❑ 2-year College Degree
- ❑ 4-year College Degree
- ❑ Master’s Degree
- ❑ Doctoral Degree
- ❑ Professional Degree (JD, MD)

What is your ethnic background?

- ❑ White
- ❑ Native American
- ❑ Hispanic/ Latino
- ❑ African American
- ❑ Asian
- ❑ Do not choose to indicate
- ❑ Other

Please tell us how you use technologies every day. Please check in the box where it applies.

I use technologies for,

	Cell Phones	Desktop or Laptop Computers	Tablet Computers (e.g. Ipad, Galaxy Note etc.)	Smartphone (e.g. iPhone, Android, Windows phone)
Online searching (looking up things I want to know)				
Finding resources				
Emails				
Social Networking Sites (SNS) like Facebook, MySpace, Linkedin				
Playing games online or offline				
Watching video clips and movie clips on the internet (e.g. Youtube, Hulu etc.)				
Offline activities such as making documents, creating spread sheets				

How many hours do you use each technology in a day? Please write the number of hours in the boxes below.

	Cell Phones	Desktop or Laptop Computers	Tablet Computers	Smartphone
For online information search (e.g. web surfing, Wikipedia)	hours	hours	hours	hours
For personal communication (e.g. email, SNS, etc.)	hours	hours	hours	hours

Do you prefer to write things down with pens and pencils rather than typing?

- Yes
- No

How much time do you use pencils and pens everyday?

__________ hours

If you own <u>desktop or laptop computers</u>, please answer this question

To what extent do you agree to the following statements regarding your personal computer use?

	Strongly Disagree	disagree	Agree	Strongly Agree
I use computers to improve my daily performance of tasks	❍	❍	❍	❍
Using computers enables me to accomplish daily tasks more quickly	❍	❍	❍	❍
Using computers increases my daily productivity	❍	❍	❍	❍
I understand what computers can do and how I can use them	❍	❍	❍	❍
It would be easy for me to become skillful at using computers	❍	❍	❍	❍
I find computers easy to use	❍	❍	❍	❍
Learning to operate computers is easy for me	❍	❍	❍	❍

If you have <u>tablet computers</u>, please answer the questions below

To what extent do you agree to the following statements regarding your tablet computer use?

	Strongly Disagree	Disagree	Agree	Strongly Agree
I use tablet computers to improve my daily performance of tasks	❍	❍	❍	❍
Using tablet computers enables me to accomplish daily tasks more quickly	❍	❍	❍	❍
Using tablet computers increases my daily productivity	❍	❍	❍	❍
I understand what tablet computers can do and how I can use them	❍	❍	❍	❍
It would be easy for me to become skillful at using tablet computers	❍	❍	❍	❍
I find tablet computers easy to use	❍	❍	❍	❍
Learning to operate tablet computers is easy for me	❍	❍	❍	❍

If you have <u>Smartphones</u>, please answer the following questions.

To what extent do you agree to the following statements regarding your Smartphones?

	Strongly Disagree	Disagree	Agree	Strongly Agree
I use Smartphones to improve my daily performance of tasks	❍	❍	❍	❍
Using Smartphones enables me to accomplish daily tasks more quickly	❍	❍	❍	❍
Using Smartphones increases my daily productivity	❍	❍	❍	❍
I understand what Smartphones can do and how I can use it	❍	❍	❍	❍
It would be easy for me to become skillful at using Smartphones	❍	❍	❍	❍
I find Smartphones easy to use	❍	❍	❍	❍
Learning to operate Smartphones is easy for me	❍	❍	❍	❍

Following questions are about GPS navigation devices. If you own GPS devices, or use navigation programs on your Smartphones, tablet computers, please select all that apply.

I use GPS

- ❍ for finding the route to the destination that I have never been
- ❍ for finding the route to the destination that I have been before but don't remember exactly
- ❍ everytime I drive
- ❍ I own GPS devices or navigation system installed on my devices but never used it
- ❍ I do not have GPS or navigation program

How often do you use GPS?

- ❍ Never
- ❍ Less than Once a Month
- ❍ Once a Month
- ❍ 2-3 Times a Month
- ❍ Once a Week
- ❍ 2-3 Times a Week
- ❍ Daily

To what extent do you agree to the following statements regarding your GPS use?

	Strongly Disagree	Disagree	Agree	Strongly Agree
I use GPS devices to improve my daily performance of tasks	❍	❍	❍	❍
Using GPS devices enables me to accomplish daily tasks more quickly	❍	❍	❍	❍
Using GPS devices increases my daily productivity	❍	❍	❍	❍
I understand what GPS devices can do and how I can use them	❍	❍	❍	❍
It would be easy for me to become skillful at using GPS devices	❍	❍	❍	❍
I find GPS devices easy to use	❍	❍	❍	❍
Learning to operate GPS devices is easy for me	❍	❍	❍	❍

Appendix B

SANTA BARBARA SENSE-OF-DIRECTION SCALE- MODIFIED

This questionnaire consists of several statements about your spatial and navigational abilities, preferences, and experiences. After each statement, you should circle a number to indicate your level of agreement with the statement.

	Strongly Agree	Agree	Disagree	Strongly Disagree
I am very good at giving directions	❍	❍	❍	❍
I have a poor memory for where I left things	❍	❍	❍	❍
I am very good at judging distances	❍	❍	❍	❍
My "sense of direction" is very good	❍	❍	❍	❍
I tend to think of my environment in terms of cardinal directions (N, S, E, W).	❍	❍	❍	❍
I very easily get lost in a new city	❍	❍	❍	❍
I enjoy reading maps	❍	❍	❍	❍
I have trouble understanding directions	❍	❍	❍	❍
I am very good at reading maps	❍	❍	❍	❍
I don't remember routes very well while riding as a passenger in a car	❍	❍	❍	❍
I don't enjoy giving directions	❍	❍	❍	❍
It's not important to me to know where I am	❍	❍	❍	❍
I usually let someone else do the navigational planning for long trips	❍	❍	❍	❍
I can usually remember a new route after I have traveled it only once	❍	❍	❍	❍
I don't have a very good 'mental map" of my environment	❍	❍	❍	❍

Appendix C

Modified OTDL-R Instruction

Task 1

What number would you dial if you would like to find out about subsidized housing for older adults? You may use a pencil eraser to find the number on this page.

Task 2

What number would you dial if you wanted to have one of your prescription filled at a hospital pharmacy? You may use a pencil eraser to find the number on this page.

Task 3

If you make a long-distance call on a Sunday night from 10:30pm until 11:00om, which long-distance charge applies? You may use a pencil eraser to find the location on this page.

Appendix D

Materials for Modified OTDL-R

Task 1

INFORMATION PAGES

COMMUNITY PAGES

Senior Resources

The Senior Citizen Resources page is designed to assist seniors in identifying available resources. Inclusion of an organization does not imply endorsement. Any omissions are unintentional and do not reflect the value of that agency. Due to the changing nature of this information, all services may not be listed. At the time of publication, all phone numbers were correct. For further information call Senior Information and Assistance Center (SIAC): 471-2096.

Adult Day Care
SIAC 471-2096

Congregate Meals
Golden Circle Nutrition Program Sites 578-1048
Salvation Army Sites 636-3891

Weekend Meals
Downtown Center 578-6644
Soup Kitchen ...475-7314
Lord's Dinner at Sacred Heart..633-8711
Shove Chapel ...389-6641
United Way 262-9723
Weekend Feast 473-8574

Emergency-911
Adult Protective Services 444-5775
Child Protective Services 475-9593
Center for Domestic Violence 633-3819
Senior Victim Assistance Team 444-7438
Suicide Prevention Hotline 596-5433

Employment
Forty Plus 475-3771
Senior Employment Program 635-3579
Contact SIAC 471-2096
Professional Employment Service 633-9731

Health/Clinics/ Wellness Program Clinics
Health Dept. Senior Wellness 578-3199
S.E.T. Wellness Clinic 776-5476
County Public Health 687-1404

Dental and Physical Referral
Dental Society ..598-5161
County Medical Society 591-2424
Memorial Hospital Healthlink 475-5555
Health Resource Center 776-5555

Geriatric Case Management
Contact SIAC...471-2096

Hospice
Contact SIAC...471-2096
Senior Insurance Assistance 635-4891
Medicare (800) 638-6833
Medicaid 444-8002

Home Delivered Meals
Meals on Wheels 632-1521

Home Health Care
See the *Yellow Pages* under Home Health Care
Contact SIAC ..471-2096

Home Weatherization/ Utilities
Energy Resource Center 591-0772
LEAP (Low Income Energy Assistance Program) 444-8050

Housing
For information on Assisted Living, Board & Care, Nursing Homes, Retirement and Subsidized Housing contact SIAC 471-2096

Legal
County Bar Association 473-9700
Senior Legal Services 471-0380

Nutrition Food Assistance
Care & Share 528-6767
Food Stamps 687-3335
County Food

Social Security
.... (800) 772-7080

Ombudsman
Resident Advocate in Long Term Care Facilities 471-7080

Task 2


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REPAIR SERVICES
America's Repair Specialists
Emergency Service And Replacement Available
We repair all major brand name heating & cooling units
Satisfaction guaranteed or your money back
Call 24 Hours a Day, 7 Days A Week
For In-Home Service Call 1-888-555-7247
Parts By Phone Delivered Direct To You
1-888-555-6013
Sales 1-888-555-7500
Call For Free In Home Replacement Estimate


ZIP-ZIP
ONE HOUR CLEANERS
FULL SERVICE DRY CLEANING
*Alterations
*Laundry
*Drapes
*Silks
*Suedes/Leathers
*Bedspreads
*Wedding Gowns
*Feather Pillows
*Shoe Repair
*Sleeping Bags
ONE HOUR SERVICE
8 AM TO 2 PM MON-FRI
8 AM TO 12 NOON SAT
SAME DAY SERVICE
IN BY 10 AM OUT BY 4 PM MON-FRI
LASALLE
ACADEMY
BLVD.
PALMER
PARK
596-3646
1608 N. Academy Blvd.
SD
SENIOR DISCOUNTS
UNION BLVD.
ACADEMY BLVD.
592-9314
5059 N. Academy Blvd.


PENROSE-ST FRANCIS PROFESSIONAL PHARMACIES
8 am - 6 pm Monday through Friday
9 am - 3 pm Saturday
COMPETITIVE PRICES
WE ACCEPT
·Workmen's Compensation
·Medicaid
·Major Pharmacy Cards
·Major Credit Cards
Penrose Hospital
3215 N Cascade Ave 776-5486
Penrose Community Clinic
3205 N Academy Blvd 776-3784
St. Francis Health Center
825 E Pikes Peak Ave 776-8371


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flowers and accessories
SINCE 1982
*Fresh Flowers & Plants
*Wedding Consultations
*Party Decorations
*Contemporary French Country Designs
*Personalized Permanent Arrangements
*Unique Gifts
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Task 3

CALLING LONG DISTANCE

CONTINENTAL U.S.

RATE DISCOUNTS AND APPLICATION PERIODS

Rates can vary depending on the long-distance company used

		MON. TUES. WED. THURS FRI.	SAT.	SUN.
8 A.M. – 5 P.M.	WEEK-DAY	**FULL RATE** Minimum Charge: 1 Minute		
5 P.M. – 11 P.M.	EVE-NING	**DISCOUNT FROM FULL RATE** Minimum Charge: 1 Minute		
11 P.M. – 8 A.M.	NIGHT & WEEK-END	**LARGEST DISCOUNT FROM FULL RATE** Minimum Charge: 1 Minute		

Charges are based upon rates in effect at the time of connection at the calling point (origin of call). Charges for rates originating in one rate period and ending in another rate period will reflect the two different rates.

LOWEST RATES
DIRECT DISTANCE DIALING

Direct Distance Dialing means calls are placed without operator assistance from a residence or business phone.

Direct Distance Dialing initial rate period is one minute any time of day or night. You pay only for the minutes you talk.

Additional savings apply if you dial direct furing the "discount" time periods indicated on the chart above.

HIGHEST RATES
OPERATOR-ASSISTED/ONE MINUTE RATES

Operator-Assisted calls are those requiring the assistance of an operator to complete the call. These include person-to-person, coin, collect, calling card, billed to third number, hotel guest, time and charge calls.

The initial period for all Operator-Assisted calls is one minute. An operator assistance charge is applied in addition to the direct-dial rate. Discounts apply to initial and additional minute rates, but not to Operator-Assisted charges.

If a call requires two types of Operator Assistance (person-to-person credit card), the higher of the two Operator-Assisted charges will apply.

Holiday Rates

On these legal holidays: New Year's Day, July 4th, Labor Day, Thanksgiving Day, Christmas Day, the evening long-distance rate applies all day on direct distance dialed calls (DDD) unless a lower rate would normally apply (nights & weekends). The evening rates also apply on Martin Luther King Jr. Day, President's Day, Memorial Day, Columbus Day Veteran's Day, excluding calls originating and terminating within Florida.

Long Distance Charges

All long distance charges originating from a subscriber's telephone service are the responsibility of the subscriber to whom the service is listed, regardless of who places the call.

Appendix E

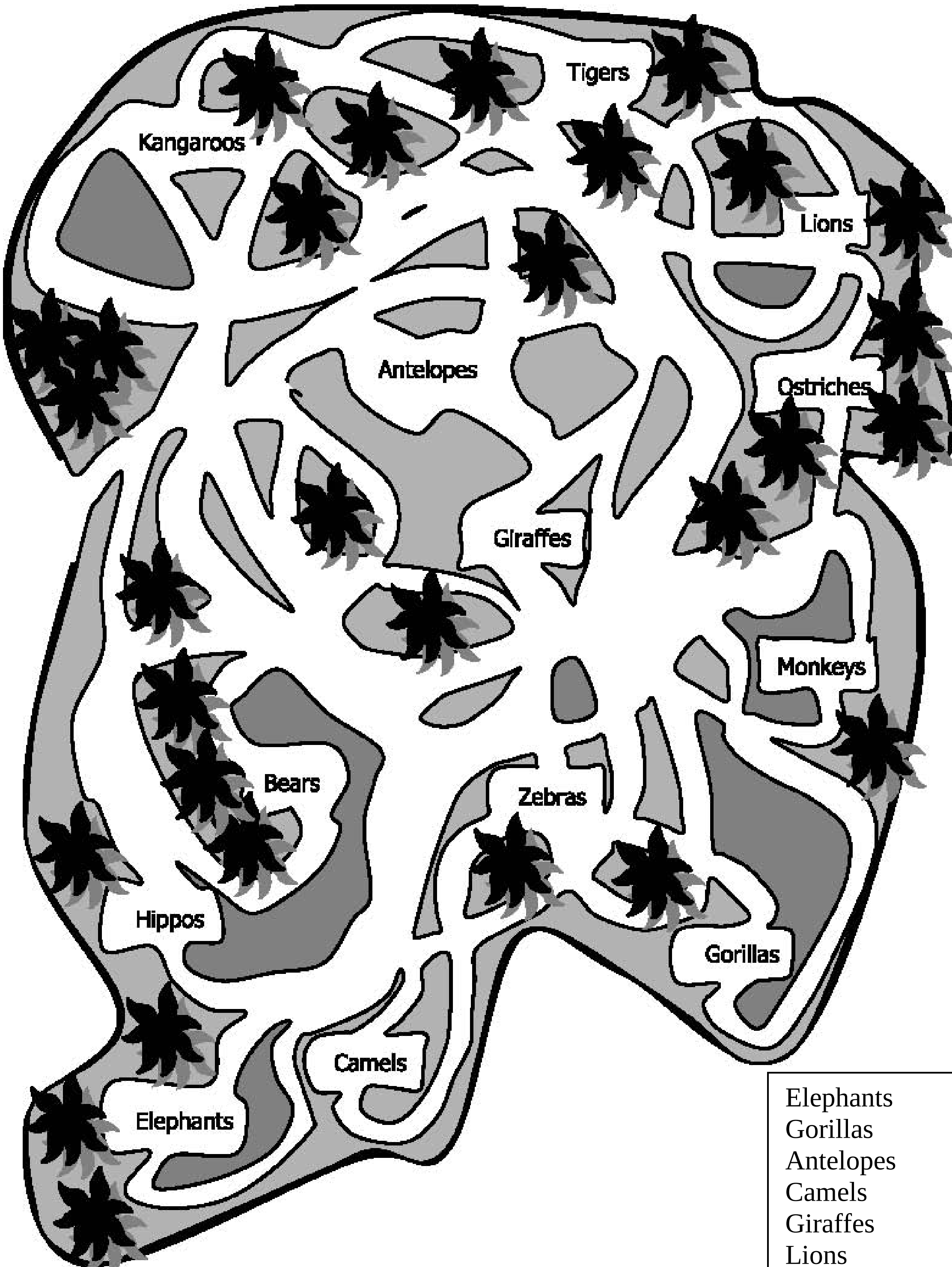
Modified Scoring Criteria for OTDL-R

Item #	Subject Behavior	Score	Comments
C1	SUBJECT FINDS/POINTS TO/EXAMINES HOUSING SECTION YES NO	 1 0	This step has to come first.
C1a	PROMPT GIVEN YES NO	 1 2	See Prompt Rule
C2	SUBJECT CALLS OUT "471-2096" YES NO	 1 0	The participant has to **mark** this number; just saying the number does not suffice.
C2a	PROMPT GIVEN YES NO	 1 2	See Prompt Rule
C3	SUBJECT FINDS/POINTS TO/EXAMINES HOSPITAL PHARMACY ADVERTISEMENT YES NO	 1 0	This step has to come first.
C3a	PROMPT GIVEN YES NO	 1 2	See Prompt Rule
C4	SUBJECT CALLS OUT "776-5486" YES NO	 1 0	The participant has to **mark** this number; just saying the number does not suffice.
C4a	PROMPT GIVEN YES NO	 1 2	See Prompt Rule
C5	SUBJECT FINDS/POINTS TO/EXAMINES CORRECT ("Discount from Full Rate")TIME PERIOD ON THE RATE CHART YES NO	 1 0	This step has to come first.
C5a	PROMPT GIVEN YES NO	 1 2	See Prompt Rule

Item #	**Subject Behavior**	**Score**	**Comments**
C6	SUBJECT SAYS "The Discount from Full Rate Charge" YES NO	 1 0	The participant has to **mark** the rate name; just pointing does not suffice.
C6a	PROMPT GIVEN YES NO	 1 2	See Prompt Rule

Appendix F

A zoo map used for the map task



Elephants
Gorillas
Antelopes
Camels
Giraffes
Lions
Kangaroo