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Effects of a Cell Phone Conversation on Cognitive Processing Performances

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Abstract

Background: The ability to apportion cognitive resources to process multiple visual and auditory stimuli is essential for human communication in competing conditions.

Purpose: The purpose of the current research was to examine the effects of a cell phone conversation on a battery of cognitive tests, using both timing (RT) and accuracy (A′) as dependent measures.

Research Design: A repeated measures ANOVA was conducted.

Study Sample: Forty-two college-age (mean 22 yr) adult females with normal hearing and cognitive function participated in the study.

Data Collection and Analysis: In one condition (quiet), a standardized cognitive assessment battery was administered to participants in a quiet room. In the (cell phone) condition, subjects were formulating and responding to specific questions about their travel experiences during administration of the same cognitive assessment battery. The computer automatically records subject performance. Post-hoc pairwise comparisons were conducted using the Bonferroni approach. The alpha level was set at .05 for all data analysis. This method of analysis was repeated for each of the dependent measures, RT, and A′.

Results: The results revealed a consistent, significant effect on reaction time between the two conditions. The same analysis was also conducted to examine the effect of participation in a cell phone discussion on accuracy. As with RT, results revealed a consistent, significant affect on A′ between the two conditions.

Conclusions: Our study supports the notion that there are differential effects of auditory distracters across cognitive spheres. For simple automatic type visual cognitive tasks, the effect is minimal. However, as visual tasks increase in difficulty, the effect of the auditory distraction is magnified, particularly when the task requires extensive division of language resources.

Key Words: Attention, auditory distraction, CalCAP, cell phone, cognition, cognitive accuracy, cognitive reaction time, cognitive resource allocation, dual task, mobile phone, visual attention

Abbreviations: A′ = A prime; CalCAP = California Computerized Assessment Package; CRT = choice reaction time for single digits; FD = form discrimination; LD = lexical discrimination; RR = response reversal and rapid visual scanning; RT = reaction time; SPM = serial pattern matching; VSA = visual selective attention

Cognitive attention theory, as postulated by Kahneman (1973), described attention as a multidimensional system that allocates processing resources from a finite supply. The allocation distributes resources in accordance with the demands of a task at any given moment. Task demands can vary, sometimes requiring minimal resources, and in other situations the processing requirements are

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greatly increased. In fact, resource allocation is often necessary for simultaneous and/or competing stimuli. The ability to allot resources to process stimuli is essential to the success of virtually all animal life forms. Crickets, for example, are able to choose a particular song model when another, less attractive but still acceptable song model is played simultaneously (Pollack, 1986). Likewise, humans experience the "cocktail party problem" when attempting to listen to a single conversation despite the simultaneous presence of other voices (Cherry, 1953). The "allocation policy," as Kahneman called it, presumably was initially programmed by the biological forces of predator evasion and species propagation and has subsequently evolved, in humans, to assimilate to the ever-changing task demands of today's world.

Although simultaneous cognitive processing often occurs in daily activities, resource allocation can be a real challenge when a person performs two tasks where each requires close attention. The degree of concentration necessary to successfully complete activities relates to the level of processing required by the task itself falling anywhere from "automatic processing," requiring minimal resources to "controlled processing," which carries a high resource demand.

This two-level information processing model was first proposed by Schneider and Shiffrin (1977). They based their model on a group of experiments designed specifically to examine task parameters that influence information processing. They discovered three variables that, when manipulated, resulted in subjects adopting a different type of information processing. Those variables were (1) memory load, (2) the nature of the stimulus-to-response mapping, and (3) the amount of practice on the task.

Tasks that carried minimal or no memory load were predictable in occurrence or required little concentration (mapping the stimulus to a target) and were highly practiced, requiring Schneider and Shiffrin's (1977) "automatic" level of information processing. Automatic processing calls for relatively low or no demand from available resources and thus may occur with little "cost" to attention capacity.

At the other extreme are activities that require controlled processes. Those tasks carried a memory load (the target stimulus occurred at an unpredictable rate or required great concentration) and the task and/or the stimulus was novel (unrehearsed). According to Schneider and Shiffrin (1977), tasks requiring controlled information processing create a great demand on attention capacity.

Now, consider a common occurrence with thought given to its information processing demands. The attention required to drive to work varies with the task demands of the drive. When the drive is routine, there is little conscious effort, at times one might even reach his or her destination without remembering the journey. In such a scenario the driver is on "automatic pilot" requiring only automatic processing. However, if we consider the same drive, in heavy traffic and a raging blizzard, the demands of the task have been dramatically increased. Now the task requires controlled processing due to the unpredictable nature of road conditions and surrounding traffic. Given this example, one may conclude that allocation of cognitive resources is a dynamic process, continuously adapting to varying task demands.

According to Kahneman's (1973) theory, however, there is a limit to the capacity of attentional resources. For example, in the case of simultaneous processing when two cognition tasks require controlled processing, and there is an attempt to divert attention from one cognitive task to another, one may expect stimulus interference. Therefore, in addition to the type of attentive processing, it is important to consider the capacity of attentive resources that are available.

It has been proposed that working memory may provide an index of resource capacity. Working memory refers to the cognitive capacity for maintenance and manipulation of information. Working memory as proposed by Baddeley is subdivided into content-specific systems (2000). The interplay of these systems, the visuo-spatial sketchpad and the phonological loop, is thought to be regulated by a common mechanism for resource allocation, the central executive, which is based on the supervisory attentional system originally proposed by Norman and Shallice (1986). Other authors (Spelke et al, 1976; Allport, 1980) have questioned whether such supervisory systems are necessary components of cognitive models. To test the theory of the central executive system (CES), which is thought to coordinate concurrent processing, dual-task paradigms are commonly used. In a dual task experimental paradigm, two behavioral tasks, often with incongruent sensory and cognitive objectives, are performed simultaneously. The dual task paradigm has been widely used as an effective experimental tool to investigate executive control processes because the concurrent performance of two cognitive loaded tasks requires distribution of attentional resources to different simultaneous processes each with varying processing demands (Spelke et al, 1976; Alm and Nilsson, 1995; Briem and Hedman, 1995; Strayer and Johnston, 2001).

To illustrate this notion, researchers have found that working memory tasks (Alm and Nilsson, 1995; Briem and Hedman, 1995) and reasoning tasks (Goodman et al, 1999) disrupt driving performance with what appears to be increasingly more tragic pragmatic consequences. Alm and Nilsson investigated choice reaction time (RT) in 40 young and elderly drivers while operating a driving simulator in a car-following situation. During the driving simulation, a mobile telephone conversation task resulted in slower RTs. Participants did not compensate for their lengthened RT by increasing their distance from the car in front of them. Furthermore, processing workload, as measured by the National Aeronautics and Space Administration Task Load Index (NASA-TLX) increased during the mobile telephone task. These results suggest that accident risk can increase when a driver is using a mobile telephone in a car-following situation.

Further evidence of cognitive processing interference was found by Briem and Hedman, who investigated the effects of hands-free, mobile telephone use on driving performance during a pursuit-tracking task. In that study, 20 participants in two age groups (19–26 yr and 40–51 yr) participated, with five males and five females in each group. Participants drove for 20 min in each of three secondary task blocks with (1) a simple telephone conversation about a familiar topic, (2) a difficult telephone conversation, incorporating a test of working memory, and (3) car radio tuning and listening. The authors concluded that all communication tasks requiring mechanical manipulation resulted in significantly more errors than communication tasks without manipulation. Moreover, difficult telephone conversation tasks created more driving errors than simple conversation tasks. Other research supports and further explains these findings in that word processing may require central "capacity-limited" processing versus "capacity-free" peripheral visual and auditory simple detection tasks (Bonnel and Hafter, 1998).

Brown et al (1969) reported significant adverse affects on reasoning ability in 224 men given the task of judging whether to drive through gaps that might be larger or smaller than the car, and a dual telephone task of checking the accuracy of short sentences. Their results indicated that a telephone task had minimal effects on the more automated driving skills, but perception and decision-making abilities may have been critically impaired by the need to switch between visual and auditory modality inputs. Research by McCann et al (2000) supports this notion that speech processing is not as automatic as some activation models suggest.

Unless drastic regulation appears, dual task performance utilizing the cell phone will increase with more than 272 million cell phone subscribers in the United States as of February 26, 2009 (Cellular Telecommunications Industry Association, www.ctia.org). The most notable secondary task, with a devastating, often tragic cost, is driving. Recent estimates purport that 85% of cell phone owners use the phone while driving (Goodman et al, 1999). The distracting effects of phone conversation, whether handheld or hands-free cell phone use, on driving are considerable (Strayer and Johnston, 2001). Comparatively, Strayer and Johnston demonstrated that listening to radio or audio books did not impair driving performance.

While the detrimental effects of a cell/mobile phone task on driving have been well documented, those effects have focused primarily on reaction time and simple perceptual tasks. There are many other aspects of attention/cognition that might be affected by simultaneous cell phone use. With the recent increase of cell phone use and estimates of further expansion on the horizon, it is important to examine the potential impact that cell phone use has on other aspects of cognition.

The purpose of the current research, therefore, was to examine the effects of a cell phone conversation on a battery of cognitive tests, with both timing (RT) as well as accuracy as dependent measures. Primarily, we sought to replicate and extend earlier findings by determining the extent to which cell phone conversations interfered with performance on a variety of cognitive tasks. In addition, we wanted to examine the nature of the interference on cognition. That is, are certain domains of cognition affected selectively? Such information might have important safety implications for daily activities.

METHODS SUMMARY

Subjects

Forty-two college-age (mean 22 yr) adult females participated in the study. None of the participants reported a history of neurologic impairment, psychiatric disease, physical disability, or motor or sensory impairment that would prevent their full participation in the experimental tasks.

Instruments

The California Computerized Assessment Package (CalCAP) (Miller, 2002) is a standardized assessment of a number of cognitive domains including reaction time, memory, form discrimination, and sustained and divided attention. The CalCAP is primarily a test of information processing and reaction times (choice, simple, etc.) across several cognitive domains. Performance is measured across a number of subtests:

1. Simple reaction time (SRT)
2. Choice reaction time for single digits (CRT)
3. Serial pattern matching (SPM)
4. Lexical discrimination (LD)
5. Visual selective attention (VSA)
6. Response reversal and rapid visual scanning (RR)
7. Form discrimination (FD).

Across subtests, performance is measured and recorded for reaction time in milliseconds, accuracy, and A prime (A′). For a full description of these seven subtests, refer to Appendix 1.

Table 1. Reaction Time Results (msec)

	No Cell Phone		With Cell Phone	
Subtests	Mean	Standard Deviation	Mean	Standard Deviation
Simple Reaction	318	52	406	87
Choice Reaction	383	36	425	44
Sequential Reaction	480	79	563	110
Language Discrimination	497	57	599	73
Degraded Words with Distraction	462	51	518	73
Response Reversal (Words)	559	70	639	104
Form Discrimination	630	108	734	131

In addition to the CalCAP, subjects participated in a scripted conversation about travel (see Appendix 2). Travel was chosen because it is a common experience for most individuals. For their likelihood to elicit a sustained conversation rather than a brief utterance or one word response, questions were selected from a list of conversation starters for teachers of English as a second language (*The Internet TESL Journal,* www.iteslj.org).

METHODS

Prior to the experimental tasks, a hearing screening was conducted to ensure the integrity of hearing for each participant. Following the hearing screening, the cognition assessment battery was administered to each subject in two experimental conditions in counterbalanced order. Whenever possible, both tasks were administered in the same session. However, in a few cases (four subjects) the tasks were administered on separate days.

In one condition (quiet), one of two research assistants trained in the standardized administration of the CalCAP administered the battery to participants in a quiet room. In the other condition (cell phone), subjects were instructed that they would be receiving a phone call. Once the phone call was received and the scripted conversation was initiated by one of the assistants, the second research assistant administered the cognitive assessment battery. The content of the phone call consisted of a scripted conversation about travel described previously. Thus, in the cell phone condition, subjects were not just listening to but formulating and responding to specific questions about their travel experiences during administration of the cognitive assessment battery.

Analysis

A power analysis was conducted to ensure adequate power given our sample size. For a medium effect size with a sample of 40 subjects, the delta was 0.99. Thus, our sample size of 42 provides more than enough power to conduct the following analyses.

To examine the effects of participation in a cell phone conversation on cognitive tasks, a repeated measures ANOVA was conducted. Post-hoc pairwise comparisons were conducted using the Bonferroni approach. The alpha level was set at .05 for all data analysis. This method of analysis was repeated for each of the dependent measures, RT, and A′.

Results

Distraction Effect

A repeated measures analysis of variance was conducted with condition (quiet vs. cell phone) as the within-subject factor and CalCAP subtests as between-subject factors. The results revealed a consistent, significant effect on reaction time between the two conditions (Table 1)

The same analysis was also conducted to examine the effect of participation in a cell phone discussion on accuracy. As with RT, results revealed a consistent, significant effect on A′ between the two conditions (Table 2).

Discussion

The literature is clear regarding the detrimental effects of a cell/mobile phone task on driving ability and have been well documented (Goodman et al, 1999; Strayer and Johnston, 2001). The purpose of our research was to examine the effects of a cell phone conversation on a battery of cognitive tests, with both timing (RT) as well as accuracy as dependent measures. Primarily, we sought to replicate and extend earlier findings by determining the extent to which cell phone conversations interfered with cognition. Are certain domains of cognition affected in a dual task with cell phone more than others? It appears that the distraction of simultaneous cell phone conversation does indeed degrade a broad spectrum of cognitive and linguistic processing performances. We have clearly shown that the effects of distraction may be measured using reaction time and A′ as dependent measures. That is, this degradation of performance is evidenced in both reaction time and accuracy.

Our results support the two-process model of Schneider and Shiffrin (1977). This model accounts for the degree of concentration necessary to successfully complete activities related to the level of processing required by the task. The processing level required may range from "automatic processing," requiring minimal resources, to "controlled processing," which carries a high resource demand. The cognitive activities used in our study, such as visual selective

Table 2. Summary for A′

SS Source	df	MS	E(MS)	F	p
Within Subjects (Condition)	41,1	CRT 0.001071	0.00006411	16.71	<0.0001
		SPM 0.061340	0.00153700	39.91	
		LD 0.043430	0.00060780	71.45	
		VSA 0.007619	0.00030200	25.23	
		RR 0.020740	0.00062330	33.29	
		FD 0.020430	0.00075900	26.92	
Between Subjects (CalCAP subtest)	1,41	CRT 83.242	0.00007758	1,072,921.0	<0.0001
		SPM 78.165	0.001506	51,908.042	
		LD 78.269	0.0008396	93,646.412	
		VSA 81.499	0.0004073	200,087.12	
		RR 78.532	0.001563	50,234.811	
		FD 73.379	0.002550	28,778.953	

Note: df = degrees of freedom; E(MS) = error of mean square; MS = mean square; SS = sum of squares.

attention and visual scanning activities, may require more automatic processing. Similarly, the findings of Strayer and Johnson found that passive listening to the radio or an audio book had no significant impact on driving performance. Apparently these automatic processing abilities are evidenced in both auditory and visual cognitive domains. However, more complex tasks such as working memory, lexical, and form discrimination represent controlled processing cognition. These findings agree with previous findings of working memory tasks (Alm and Nilsson, 1995; Briem and Hedman, 1995), reasoning tasks (Goodman et al, 1999), and perception and decision-making tasks (Brown et al, 1969) that were shown to have a greater negative impact on dual task performance ability.

In conclusion, our study supports the notion that there are differential effects of auditory distracters across cognitive spheres. For simple, automatic-type, visual cognitive tasks, the effect is minimal. However, as the visual tasks increase in difficulty, the effect of the auditory distraction is magnified, particularly when the task demands presumed further division of language resources. This finding may have important implications for individuals who are neurologically disordered (i.e., parkinsonism, multiple sclerosis, etc.). More specifically, visual cognitive performance is indeed significantly degraded during simultaneous cell phone use. More research is warranted to investigate the extent of the effect auditory distraction has on cognitive processing in those with neurological impairment.

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Appendix 1. CalCAP® California Computerized Assessment Package

Standard Edition

Test Duration: 20–25 minutes. The Standard program drivers for the CALCAP program were developed by Eric N. Miller, Ph.D., and Paul Satz, Ph.D. The stimulus materials assess a broad range of cognitive functions, including brief, sustained, and divided attention, rapid visual scanning, form discrimination, and language skills:

1. *Simple Reaction Time.* Subjects are asked to press a key as soon as they see anything at all on the screen. This procedure provides a basal measure of reaction time. This task is given at the beginning, middle, and end of the computerized procedures to allow the examiner to assess fatigue effects.
2. *Choice Reaction Time for Single Digits.* Subjects are asked to press a key as soon as they see a specific number such as *7,* otherwise they are to do nothing. This procedure adds a simple element of memory to the task.
3. *Serial Pattern Matching (Sequential Reaction Time).* Subjects are asked to press a key only when they see two of the same number in sequence, for example, if they see the number *3* followed by a second occurrence of the number *3.* This procedure adds a more complex element of memory since the subject must keep in mind the last number that was seen.
4. *Lexical Discrimination.* Subjects are asked to press a key when they see a word that fits into a specific category such as animal names (*COW* or *HORSE*) but not when they see a word that fits into a category of nonanimals (such as *DESK* or *FOOD*). This procedure introduces an additional level of language skills by requiring meaningful differentiation between semantic categories. The task requires rapid language processing and should be sensitive to any disruption in language skills.
5. *Visual Selective Attention.* Subjects are asked to press a key as soon as they see a specific word such as *SEVEN* in the center of the screen. An additional set of the words are displayed around the periphery of the target stimulus located in the center of the screen. These distractors require that the subject focus his or her attention much more narrowly.
6. *Response Reversal and Rapid Visual Scanning.* This task is identical to task 5 described above, but the subject must ignore the stimuli presented in the middle of the screen while responding to target stimuli displayed around the periphery of the computer screen. This task taps into the subject's ability to change cognitive set from the previous task and requires more rapid visual scanning across the entire display screen.
7. *Form Discrimination.* Subjects are shown three geometric figures simultaneously and asked to press a key only when two of the figures are identical. This task requires rapid comparison of non-nameable forms and, because of the brief exposure time, may measure the subject's ability to retain an iconic memory of the figures.

Source: Miller, 2002.

Appendix 2. Cell Phone Script

The following questions were asked, utilizing the same order, in the cell phone condition of the investigation.

- Have you ever been abroad?
- Where have you been?
- Are you planning on going anywhere for your next vacation?
  - If so, where?
  - Who with?
  - How long will you stay?
- Could you live in another country for the rest of your life?
- Describe the most interesting person you met on one of your travels.
- Describe your best trip.
- Describe your worst trip.
- Did your class in high school go on a trip together?
  - If so, where did you go?
  - How long did you stay?
  - How did you get there?
- Do you prefer summer vacations or winter vacations?
- Do you prefer to travel alone or in a group? Why?
- Do you prefer to travel by train, bus, plane, or ship?
- Have you ever been in a difficult situation while traveling?
- Have you ever been on an airplane?
  - How many times?
  - What airlines have you flown with?
- Have you ever been to a foreign country?
- Have you ever gotten lost while traveling? If so, tell about it.

- Have you ever hitchhiked? If so, how many times?
- Have you ever taken a package tour?
- How do you spend your time when you are on holiday and the weather is bad?
- How many countries have you been to? How many states?
- How many times have you traveled abroad?
- How much luggage do you usually carry?
- If you traveled to South America, what countries would you like to visit? (Brazil, Argentina, Chile, Bolivia, Peru, Venezuela)
- If you went to ___(Insert a country name)__, what kind of souvenirs would you buy?
- If you were going on a camping trip for a week, what 10 things would you bring? Explain why.
- What are some countries that you would never visit? Why would you not visit them?
- What are some things that you always take with you on a trip?
- What countries would you like to visit? Why?
- What countries would you most like to visit?
- What countries would you not like to visit? Why?
- What country do you most want to visit?
  - Why?
  - Do you think you will ever go there?
- What do you need before you can travel to another country?
- What is the most interesting city to visit in your country?
- What is the most interesting souvenir that you have ever bought on one of your holidays?
- What languages can you speak?
- What place do you want to visit someday?
- What was the most interesting place you have ever visited?
- What's the most beautiful place you've ever been to?
- When was the last time you traveled?
- When you are on a long car journey do you play games or sing songs to occupy your time?
  - What kind of games?
  - What songs?
- Where are you going to go the next time you travel?
  - When are you going to go?
  - Who are you going to go with?
  - How long are you going to go for?
  - What are you going to do there?
  - What kinds of things do you think you will buy?
- Where did you go on your last vacation?
  - How did you go?
  - Who did you go with?
- Where did you spend your last vacation? Your summer vacation? Your Christmas vacation?
- Where will you go on your next vacation?
- Would you like to take a cruise? Where to? With who?
- Would you prefer to stay at a hotel/motel or camp while on vacation?
- Would you rather visit another country or travel within your own country?
- Do you find more fulfillment from your leisure activities including vacations than from your job?
- Do you think the type of vacation one takes reflects one's social status?
- What are popular tourist destinations in your country?
  - Have you been to any of them?
  - Which would you recommend if you could only recommend one? Why?
- Do you prefer active or relaxing holidays? Why?
- Which is better, a package tour or a tour you organize and book yourself?
- Why do you travel?
  - Why do people travel?
- Would you like to go back to that same place?
- Did you find anything of particular interest? / Did you get attracted to anything special?
- What are some benefits of travel?
  - Why do people travel?
- What is your favorite mode of travel?