

Multitasking Disorder From Right Temporoparietal Stroke

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Abstract: Acute behavioral syndromes after right hemisphere stroke (eg, hemi-inattention) resolve in most patients by 6 months. Less is known about the nature of chronic disorders after these lesions when the initial deficits are no longer apparent. We report the case of a woman who suffered a cerebral infarct in the right temporoparietal region and who, after the resolution of neglect, demonstrated a significant disorder of multitasking in her everyday life. Neuropsychologic tests failed to reveal the extent of disruption in her daily functioning. A journal of daily activities elucidates the nature of her deficits and demonstrates, from the patient's perspective, the impact of the lesion on her ability to multitask. Our findings are consistent with the concept of a right frontoparietal attentional axis that governs the ability to hold several tasks in working memory at the same time. We conclude that right hemisphere lesions can disrupt the cognitive system of multitasking through disruption of the attentional matrix.

Key Words: multitasking, stroke, right hemisphere, strategy application deficit

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Syndromes after acute right hemisphere stroke have traditionally included left-visual neglect, defects in visual search and spatial attention, constructional and dressing apraxia.^{1–3} Although there seems to be a predominance of abnormality in visually-guided behavior, other defects have included anosognosia,⁴ acute confusional syndrome,⁵ and hemi-attention to other stimulus dimensions such as sound and touch.⁶ Studies have also shown failure to perceive and express affect.⁷ These consequences of right-brain injury do not imply that the right hemisphere acts independently in these tasks, but rather that hemisphere-specific lesions are sufficient to produce several circumscribed classes of abnormalities.

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Right hemisphere syndromes can be profound at stroke onset. Symptoms persist in some patients, but up to 80% of these individuals improve significantly by 6 months.^{8–10} Resolution of initial visuo-spatial deficits, as demonstrated by relatively intact performances on tasks such as line bisection, letter cancellation, and drawing, however, can lead to the assumption that there is little long-term impact of right hemisphere lesions on activities of daily living. Nys et al¹¹ reported that among acute stroke prognostic factors, right hemisphere associated neglect and perceptual impairment were the most important predictors of poor long-term functional outcomes, even though 83% of their patients had no neglect at follow-up. For them, however, the nature of the persistent deficit was not clear.

We report the case of a woman who suffered a cerebral infarct in the right temporoparietal region and who, in the absence of gross hemineglect, visual imperception, or apraxia, became totally disabled from gainful employment. The neuropsychologic assessment almost 2 years after her event demonstrated abnormalities in organization and working memory, but her complaints far exceeded the magnitude of deficits documented by standardized testing, including no longer being able to multitask. Three years after her stroke, she was asked to keep a journal for 1 week and record instances in which her activities of her daily life had been altered to document further the effect of her stroke on her daily functioning. We use her journal entries to elucidate the nature of her deficits and to demonstrate, from a patient's perspective, the impact of a right hemisphere injury on the ability to multitask.

CASE REPORT

Clinical Description

S.R.P. was a 51-year-old right-handed, university-educated woman who was watching television in bed, had a headache, and fell to the floor. She was found by her husband about an hour later. She was later told that she was mumbling but she had no awareness that she was not speaking properly. She has no recollection from the time of her headache until Emergency Medical Services arrived, and she was brought to a local hospital. She was admitted and the next day a magnetic resonance imaging (MRI) of the brain showed an embolic stroke in the right temporal lobe. At discharge from the hospital, she was found to have mild residual clumsiness and awkwardness of her left hand and leg. At home, she was balancing her checkbook and found that she had trouble “getting it right.” She sat at a computer and tried to draft an e-mail message and

had trouble operating the system. On a follow-up neurologic examination at 2 weeks, she had mild persisting elements of left hemineglect, noted on letter cancellation and by visual extinction of the left side on double simultaneous stimulation. Further diagnostics revealed a hypercoagulable state from Factor II mutation and she was placed on Coumadin. Because of her left hemineglect syndrome, her driving skills were evaluated at a local rehabilitation facility, and she subsequently passed a driving test.

At the time of her stroke, she was a successful fund raiser for a large nonprofit organization. There was no reported evidence of functional decline or emotional disorder before her stroke. Because of her inability to handle finances, operate a computer or perform more than 1 task at a time while at home, she took a leave of absence at 10 months after her injury. At that point, her standard neurologic examination, including assessment of hemineglect, was normal except for dysesthesias in the left leg. At 16 months after her stroke, she was placed on permanent Social Security Disability.

Imaging

An MRI of the brain obtained 21 months after her stroke (Fig. 1) showed a chronic infarct in the right temporoparietal lobe and right insula. A tiny focus of signal abnormality was noted in the subcortical white matter of the right frontal lobe and there was calcification in the right basal ganglia.

Neuropsychologic Profile

She presented for neuropsychologic examination, 15 months after her stroke. She presented with a chief complaint of trouble organizing things, but denied any other significant problems related to language, visual perception, memory, or cognition. Neither she nor her family reported progression of her syndrome. She denied affective symptoms, psychosocial stressors, and had not undergone any significant changes in her life over the interval since her stroke.

The data from the evaluation are shown in Table 1. There was a 41-point difference between her overall verbal and performance IQ scores on the Wechsler Adult Intelligence Scale-III (WAIS-III, Verbal > Performance) that was highly significant, exceeding 2.5 standard deviations. Her verbal abilities were in the superior range but her working memory, perceptual organization and processing speed all bordered on the low average range. While her immediate and general memory (WMS-III) were also superior, with no difference in her memory function between auditory and visual material, her

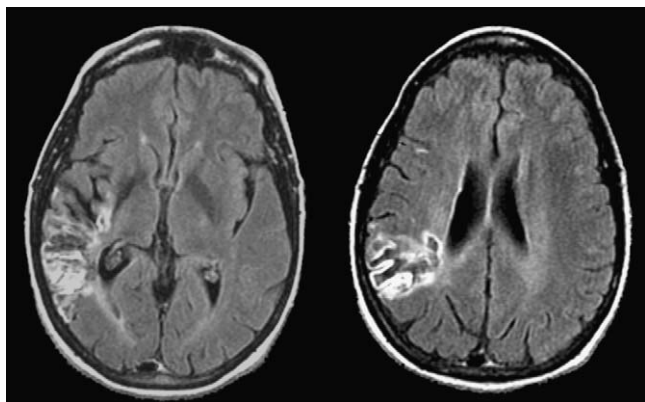


FIGURE 1. MR FLAIR axial images depicting the right hemisphere ischemic stroke.

TABLE 1. Results of Neuropsychologic Examination

	Score or (Percentile)
Intelligence Testing	
WAIS-III	
Verbal Scale	
Vocabulary	(95)
Similarities	(99)
Arithmetic	(37)
Digit Span	(75)
Information	(98)
Comprehension	(99)
Letter-Number Sequencing	(37)
Verbal IQ	130
Performance Scale	
Picture Completion	(25)
Coding	(25)
Block Design	(16)
Matrix Reasoning	(63)
Picture Arrangement	(25)
Symbol Search	(37)
Performance IQ	89
Verbal Comprehension Index	(99)
Perceptual Organization	(27)
Working Memory	(27)
Perceptual Speed Index	(27)
Language	
Boston Diagnostic Aphasia Examination	
Left-Right Orientation	2/2
Commands	15/15
Complex Ideational Material	12/12
Animal Naming (1 min)	(49)
Repeating Phrases	16/16
Oral Sentence Reading	10/10
Reading (Comprehension) for Sentence and Paragraphs	10/10
Narrative Writing	5/5
Boston Naming Test	60/60
Controlled Oral Word Association Test (FAS)	(62)
Wide Range Achievement Test—Revised	
Reading	(93)
Arithmetic	(50)
Memory	
Wechsler Memory Scale-III	
Auditory Memory	(98)
Visual Immediate Memory	(96)
Immediate Memory	(99)
Auditory Delayed	(98)
Visual Delayed	(97)
Auditory Recognition (Delayed)	(84)
General Memory	(99)
Working Memory	(39)
Visual-Spatial	
Rey Complex Figure Test	36/36
Letter Cancellation	
Left Field	30/30
Right Field	30/30
Judgment of Line Orientation	28/30
Executive Function	
Trail Making Test	
Part A	(43)
Part B	(15)
Wisconsin Card Sorting Test	(1 Category; not completed)
Sensorimotor	
Stereognosis	
Right Hand	4/4
Left Hand	3/4
Graphesthesia	
Right Hand	4/4

TABLE 1. (continued)

	Score or (Percentile)
Left Hand	3/4
Ideomotor Praxis (Correct out of 4 gestures)	4/4
Purdue Pegboard	30 s/60 s
Right Hand	14/27
Left Hand	12/22
Both Hands	9/17

working memory on this instrument was only at the 39th percentile. She demonstrated some degree of dysfunction on tests of executive function, such as on Trail Making Part B; unfortunately, the Wisconsin Card Sorting Test was prematurely stopped due to patient distress after 44 continuous incorrect responses. Subtests from the Boston Diagnostic Aphasia Examination showed most language functions in the normal range. Both phonemic and semantic fluency, however, were in the average range and were below expected levels given her superior verbal IQ. Her written arithmetic was only at the 50th percentile, certainly representing a decline in an individual who had formerly worked with large sums and budgets. On all standardized tests of visuo-spatial functions her performance was intact, as exemplified by her copy of the Rey Complex Figure (Fig. 2). On tests of higher sensory and motor function, her ideomotor praxis was normal; graphesthesia, stereognosis, and fine motor skills were mildly impaired on the left. In summary, a comprehensive neuropsychologic examination showed superior IQ and memory, intact language and visuo-spatial skills with relative dysfunction in working memory, processing speed, verbal fluency, set shifting, and mild left-sided sensory, and motor impairment.

Given that the neuropsychologic examination to date had not elicited the organizational dysfunction she reported, and in an effort to uncover a strategy application disorder of multitasking consistent with her reports, an additional assessment focused on the executive functions described by Burgess, using the Behavioral Assessment of Dysexecutive Syndrome (BADS) battery. Of particular interest was performance on the Modified Six Elements Test, a task designed to measure the ability to plan, organize, and monitor behavior; capturing features of multitasking by requiring recall and execution of intended acts at a future time point. All subtests from the BADS were administered, each scored on a scale of 0 (worst) to 4 (best). S.R.P.'s

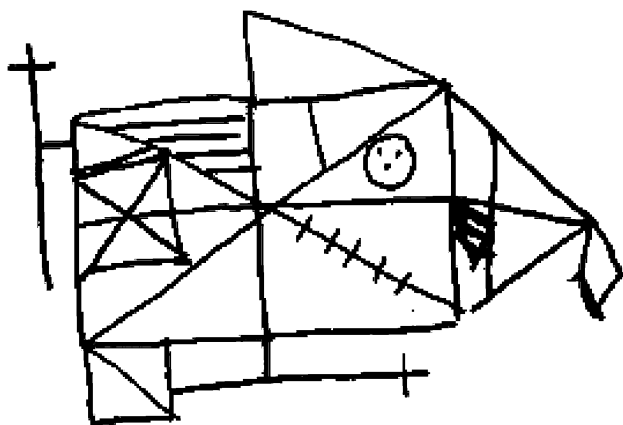


FIGURE 2. The patient's copy of the Rey Complex Figure.

total age-corrected standardized score on the BADS battery was in the low average range (SS = 88). Her performance on the Modified Six Elements Test, however, yielded a perfect score of 4. S.R.P.'s performance was scored at 4 on additional subtests: the Action Program test, requiring the development of a problem-solving action plan; and the Rule Shift Card test, assessing the ability to shift from one rule to another. Her poorest performances were on the Temporal Judgment test measuring estimation abilities, the Zoo Map test measuring spontaneous contingency planning, and the Key Search test assessing the ability to develop effective and efficient action plans. Although her performance on the BADS battery was below that expected for her intellectual level and assumed prior abilities, her low average performance nevertheless did not reflect the nature or extent of executive impairment reported in her everyday life.

Activities of Daily Living

To demonstrate the impact of her stroke in her everyday life, we then asked our patient to record in a journal each day over a period of 1 week specific examples of her inability to function. Illustrative selections from the diary follow. The only modifications in the text below are substitutions of generic names for brand names of medications, generic stores types for specific store names, punctuation at the ends of phrases and sentences when not provided, and words for symbols, such as "#."

Day 1

7:00 AM. Go to cabinet, remove 4 Bottles of pills. Lay out 3 different colored pills plus 6 gabapentin pills (3 for morning dose, 3 for afternoon dose to be taken later). Thought about something else, take 3 for morning and additional 3 for afternoon!!

12:00 noon. Drive to drug store to buy items. Gather items, stand in line to purchase. Present discount card, sign credit card slip, thank clerk, leave store without credit card, clerk runs after me into parking lot with card.

1:00 PM. Drive to health club. (Know that I have an appointment for hair cut at 2:45, 10 m drive from health club.) Work out in gym, lose track of time, realize that I am running late. Quickly take shower, get dressed, gather belongings. Rush to snack bar to buy drink. Quickly look in wallet for 5 dollar bill. Hand server \$20 bill. Leave without receiving any change. Rush out of health club, holding electronic entrance card to garage, drink, and gym bag.

6:00 PM. Realize that I never received change from \$20 bill.

Day 2

8:35 AM. Cooking. Begin recipe, forgot to use proper mixing bowls. Took eggs out of refrigerator, place them on counter. Husband calls, I cannot remember where I put the eggs. Cut bag of cocoa powder, put it aside behind other ingredients, did not remember where I put it. Four-step recipe, read it 3 times, had to go back to it 4 times just to complete the process.

9:45 AM. Drive to Main Street of town. Park in parking lot. Went to flower store to buy plant for daughter-in-law (thinking about her health). Bought plant, carried it out of store, walked to car, then placed it on front seat. Called husband on cell phone. Left car, continued walking. On way to store to buy food, met someone... and had brief conversation. Crossed street, intending to go to one store, started walking in wrong direction. Recrossed street.

5:00 PM. Working on paying a stack of 8 bills. Forgot to record amounts of 3 checks, which I had placed in envelopes, sealed and stamped. Had to reopen envelopes (had filed original bills away). Husband asked question, twice subtracted instead of added. Reverse numbers when writing check amounts/account numbers on checks. Opened refrigerator to take out something, left door open, went back to paying bills.

6:00 PM. Placed meat on BBQ grill. Answered phone, forgot that I left things cooking on grill.

9:00 PM. Watching TV, was about to take medication, spoke with husband, forgot to take medication.

Day 3

12:00 noon. Drive to health club for appointment with personal trainer. After doing some cardio training, trainer proceeds to show me a series of 4 exercises, some with weights, others with machines. He demonstrates each one, I repeat each one after he does. I cannot remember 2 out of 4 exercises.

1:00 PM. I take shower (one in long row of showers with curtains), gather toiletries outside shower, exit and lose my orientation (not turning proper way to return to locker room).

1:30 PM. Get dressed, put dirty clothes in gym bag on floor outside my locker, intending to return to get it after using restroom. Leave my gym bag on floor, exit health club, go to parking garage holding electronic entrance card and keys in hand, enter garage using card, walk to car, open car door, enter car, drive out of garage, realize I left gym bag on floor in locker room.

5:30 PM. While speaking with son, intend to take coffee cup out of dishwasher, take bowl out instead.

6:00 PM. Cooked dinner, took it out of oven, placed on table, ate meal. Four hours later, husband realized I had never turned off oven.

Day 4

8:00 AM. Decided to set up new snuggli front baby carrier for baby granddaughter. Took carrier out of package. Had written directions and diagram. Could not figure out how to make it work (how to place it on my body and put it together so that straps and snaps were fastened properly).

9:00 AM. Planned all week to go swimming, worked schedule around it. Night before, packed gym bag (except for bathing suit). While cooking remembered I needed to get bathing suit upstairs. Went upstairs to get bathing suit, phone rang and answered it.

9:15 AM. Drove to health club, went to locker room. Place gym bag in locker. Went to gym to work out. Finished work out, go back to locker room realized I forgot to pack bathing suit!

12:30 PM. Again, standing in front of refrigerator shelves, deciding what to take, person standing next to me asks me to move out of their way. Forgot to buy main staple, which I buy every time I shop there.

4:00 PM. Prepare casserole. Place in oven. Set oven timer. Speaking on cell phone near kitchen. Timer goes off. I continue conversation; do not take food out of oven.

Day 5

9:00 AM. Start paying bills. Going through mail. Go to refrigerator, see yogurt, cucumbers, take them out. Make soup, leave onions on counter (forgot to put them in soup). Begin putting things away, start cleaning outside of refrigerator. Go back to reading mail. Take out labeling tape, place in freezer by mistake, find it 2 hours later.

11:00 AM. At pharmacy, place basket on my arm, gather items, wait in line, purchase items. Clerk puts items in bags. I almost leave without signing credit card slip. Sign slip. Walked out of store into parking lot with basket with bags on my arm.

12:00 noon. Go to health club. Work out, swim. Take shower, leave shampoo which I had just bought in drug store in shower.

4:00 PM. Realize I left wet bathing suit in car.

Day 6

8:00 AM. Reading newspaper, article continued on another page, went to turn to pages, realized I forgot page number (happened twice in a row).

12:00 noon. Prepare to set table for lunch. Husband and sons milling about kitchen. Go back 3 times to closet to get napkins.

Day 7

8:00 AM. Take 1 pill w/8 oz water. Waited for 1 hour. Began reading. Set aside 3 pills to take for morning and 3 pills to take with me for mid-day. Leave house, forgetting to take both sets of pills. Went downstairs 3 separate times to get one thing. Each time, got distracted, going to computer, or refrigerator.

3:00 PM. Go to drugstore to pick up prescriptions and other items. Use debit card to pay (remember I need to get cash back). Receive packages with receipt and cash from clerk, put cash in wallet, place packages in shopping cart. Begin walking away without taking packages.

4:00 PM. Open front door with keys. Carry packages into house. Son finds keys left in door 2 hours later.

DISCUSSION

The patient's journal describes how components of everyday multitasking have been impacted by her right hemisphere injury. This individual, once a highly organized executive juggling multiple events and budgets, describes a continual state of disorganization while functioning in her home and community. In her attempts to perform the simplest of daily activities, such as managing medications, preparing food, shopping for groceries and staples, exercising at the gym, and paying bills, she demonstrates significant inattention, disorganization, absentmindedness, poor planning, and an inability to stay on task. From the time of her stroke, she has been unable to intersperse tasks for time-efficiency, thrown-off by interruptions, and without performance feedback or some means of cueing, she is unable to maintain her goal-orientation. In particular, her ability to return to a prior, interrupted task is impaired. Although she reported that she had trouble "remembering" to do things, her superior performances in immediate and general (delayed-recall) memory on the Wechsler Memory Scale-III showed that she did not suffer from an amnesic syndrome, per se. What emerges is her inability to juggle multiple, albeit simple, tasks simultaneously. Previous studies demonstrate that even a small ischemic infarct can have a sudden and profound effect on behavior in the absence of dementia.^{12,13} The absence of reported prestroke intellectual or emotional disorders and the stable, nonprogressive nature of her deficits suggest that her syndrome was related to her right hemisphere stroke.

Multitasking has been described as an activity that is central to functioning in everyday life. Burgess¹⁴ further defined multitasking as the ability to perform concurrent tasks, or jobs by interleaving, with 8 characteristic features: There are many tasks to be completed; performance of tasks must be interleaved for time efficiency; only one task can be performed at a time; unexpected interruptions and outcomes will take place; the time to return to a concurrent in-progress task is not signaled; tasks vary in priority, difficulty, and time required; adequate performance is self-determined; and there is no immediate performance feedback. Effective multitasking therefore requires intact working memory, the ability to analyze and prioritize continuously, the ability to function without feedback, signals, or warnings, and the capacity to concurrently self-monitor. A dysfunction in multitasking leads to a “strategy application disorder,” manifested in real-life complex situations.¹⁵ This dysfunction is typically described in patients with bilateral frontal lobe injury, but the impact of damage to other regions in the attentional matrix is less well understood.¹⁴ Thus the precise nature and extent of possible long-term, multitasking deficits after isolated right, nonfrontal cerebral injury are not yet characterized.

Despite the descriptive similarities between our case and those portrayed in the literature, there was virtually no image-verified evidence of frontal lobe infarction in our patient. Functional MRI studies have demonstrated networks of cognitive functions that may be involved during multitasking: working memory and attentional shifting. LaBar et al¹⁶ employed functional MRI to investigate working memory and spatial attention in healthy adult volunteers. Using tasks that minimized overlap of cognitive features, conjoint activation revealed overlap of activation at several frontoparietal sites, with every subject showing activation in the right intraparietal sulcus. In a meta-analysis of functional MRI studies, Wager et al¹⁷ examined the attention shifting process in working memory, finding a common set of distinct brain regions that were reliably activated in attention-switching studies of various types. Among those were bilateral posterior parietal and anterior insula regions. Additional evidence from electroencephalogram data has also demonstrated that the right hemisphere may hold greater importance than the left in mediating attention.¹⁸ We, therefore, propose that there may be higher-level integrative functions subserved by the right hemisphere than previously supposed in the clinical literature, and that right hemisphere lesions can disrupt the cognitive system of multitasking through disruption of the attentional matrix. Given the existing literature on the role of the right hemisphere in regulating attentional functions, we propose that comparative lesions in the left hemisphere would likely induce a lesser syndrome than described in this case, but this hypothesis has yet to be explored.

S.R.P. consistently reported problems in working memory and attention. Her neurologic and neurocognitive examinations indicated a disruption of attention. Mesulam¹⁹ has described “attention” as a generic process

that serves as critical input for choice behavior, which consists of domain-specific and domain-independent modulations. Within right hemisphere function, for example, spatial neglect reflects a domain-specific abnormality in the attentional matrix mediated by the posterior parietal lobe. Domain-independent functions are controlled by a bottom-up process via the ascending reticular activating system and a top-down system comprised of the parietal, limbic, and prefrontal regions. The ascending reticular activating system exerts a domain-independent global influence on attention that is not specific to any sensory modality or cognitive domain. Disruptions in this generic process of attention can impact allocation of attentional resources during tasks that require selective attention and working memory, which are essential to the ability to “multitask.”

The ability to function well on structured neuropsychologic tests has been attributed to the ability of predictable environmental cues that elicit appropriate behavior patterns whereas day-to-day functioning is much less structured, relying on both external cues and on strategies that are self-generated.²⁰ Deficits in these activities of daily living after brain injury have been attributed to a lack of internal supervisory control. It is not so much that these individuals cannot perform individual tasks, but rather it is the planning, timing, and integration with other tasks that seems so problematic. Thus, Shallice and Burgess¹⁵ proposed the notion that the inability to function in these unstructured situations pertains to a strategy application deficit. It is therefore not surprising that some patients with neurologic injury seem to perform well on IQ tests, measures of language, memory and perception, and even on tests of executive skills.^{15,21–26}

Traditional tests of neuropsychologic functioning fail to reveal abnormalities in multitasking owing to the nature of the assessment process. Many of the characteristics of multitasking (such as juggling multiple tasks, interleaving tasks, overcoming unexpected interruptions and outcomes, and the need to continually prioritize) are not the usual targets of a neuropsychologic assessment battery. The strategy for the task is typically provided before test administration. Moreover, the subject is placed in a “task-focused” environment without unexpected interruptions before a task is completed. Although the patient may be required to make judgments about the material, they are generally not required to organize or prioritize several tasks at the same time. Thus, neuropsychologic testing paradigms do not reveal the multitasking disorders elicited in everyday life.

Several years after suffering a large ischemic stroke in the right temporoparietal region, our patient is totally disabled under US Social Security criteria for not being able to function in the workplace.²⁷ Her scores on formal neuropsychologic examination, however, showed neither explicit signs of a “right hemisphere syndrome,” nor a pattern suggestive of a focal cognitive deficit. In general, the neuropsychologic test data failed to characterize the magnitude to which her life had been disrupted by her

stroke. Her performance on the BADS battery was only marginally affected by her lesion suggests that there are characteristics of multitasking and executive function that overlap but that there are behavioral features of the former that may be dissociable from frontal lobe control. We propose that a strategy application deficit can occur from chronic injury in the right hemisphere, but for different reasons than after frontal injury, and that an inability to engage in multitasking may therefore occur after injury anywhere along the right-frontoparietal attentional axis. Future research needs to refine the parietal contribution to working memory and to clarify further the interaction between parietal and frontal systems to function in everyday-life situations.

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