

Mind the gulfs: An analysis of medication-related cognitive artifacts used by older adults with heart failure

Robin S. Mickelson^{1,2} & Richard J. Holden³

¹Vanderbilt School of Nursing, Vanderbilt University, Nashville, TN, USA

²The Center for Research and Innovation in Systems Safety (CRISS), Vanderbilt University Medical Center, Nashville, TN, USA

³Department of BioHealth Informatics, Indiana University School of Informatics and Computing, Indianapolis, IN, USA

Medication management is a patient health-related activity characterized by poor performance in older adults with chronic disease. Interventions focus on educating and motivating the patient with limited long-term effects. Cognitive artifacts facilitate cognitive tasks by making them easier, faster, and more effective and can potentially improve medication management performance. This study examined how older adult patients with heart failure use cognitive artifacts and how representational structure and physical properties facilitated or impeded medication-related tasks and processes. Interview, observation, medical record, and photographic data of and about older patients with heart failure (N = 30) and their informal caregivers (N=14) were content analyzed for cross-cutting themes about patient goals, representations, and actions. Results illustrated patient artifacts designed from a clinical rather than patient perspective, disparate internal and external representations threatening safety, and incomplete information exchange between patients and clinicians. Implications for design were the need for bridging artifacts, automatic information transfer, and cognitive artifacts designed from the perspective of the patient.

The health-related activities of patients (patient work) are a growing focus in research and practice of the healthcare focused human factors and ergonomics (HFE) community (Holden et al., 2013; Holden et al., 2015; Valdez et al., 2014). This is due in part to the U.S. healthcare model where payment is based on the effectiveness of care, dependent on patient behavior, and judged by patient outcomes (Hershberger & Bricker, 2014; Scott et al., 2011). This model depends not only on effective treatment decisions, but effective implementation of treatment by the patient.

Considering reported medication adherence rates of 40% to 60% in older adults with heart failure, medication-related treatment implementation is far from perfect (Moser & Watkins, 2008; van der Wal & Jaarsma, 2008). Typical interventions to improve medication-taking performance focus on educating and motivating the patient and report limited long-term success (Demonceau et al., 2013). Two avenues, not mutually exclusive are possible to improve medication-taking performance: an individual-centered focus on education, motivation, and improving skills; and a systems-centered focus on the support of work processes through the *design and use of cognitive artifacts* (Norman, 1991). Cognitive artifacts are a promising solution to the difficult problem of medication non-adherence. This study explores the cognitive artifacts currently used by older adults with heart failure to manage their medications.

Cognitive artifacts

Humans have limited memory and information processing capacities and cognitive artifacts can facilitate cognitive tasks by making them easier (decrease workload), faster (efficient),

and more successful (effective) (Heersmink, 2014). Cognitive artifacts are artificial objects created to improve cognitive task performance by displaying or operating upon information through representations (Norman, 1991). The power of an artifact to improve performance depends on how well it fits the user, their goals, and the context of use by enabling action, higher order thinking, and interpretations (Norman, 1993). Cognitive artifacts can assist with *acting upon the real world* (execution) and *representing the real world* (evaluation) (Norman, 1993). Effective cognitive artifacts can bridge the barriers or “gulfs” of execution and evaluation that impede performance (Norman, 2002). Performance problems occur when the means to execute or evaluate actions are unclear, interfering with a goal attainment. As an integral part of the work system, cognitive artifacts change the nature of the task itself (Norman, 1993). A cognitive task is altered by the physical properties of the cognitive artifact’s representation (Zhang & Norman, 1994).

Representations play a pivotal role in a distributed cognitive system. Distributed cognition is a theoretical approach often applied to the study of cognitive artifacts (Nemeth, 2003; Nemeth et al., 2004). Within a distributed cognitive system, tasks are distributed across internal (in the mind) and external (cognitive artifacts) representations resulting in shared knowledge that cannot be known by any single individual (Hollan et al., 2000; Hutchins, 1995, 1995b). Researchers have described cognitive artifacts as mediators of collaborative systems (Xiao, 2005) that shape cognition and collaboration (Woods, 1998). Cognitive artifacts influence what needs to be done by distributing tasks across time,

people, and place; and changing the action required to do an activity (Zhang & Norman, 1994).

Medication management in older adults

Corbin and Strauss (1985) described patient work as a fragile *emergent* balance of time and effort between illness work, everyday life work, and biographical work. Structural elements (people, task, tools, context) interact to shape process and performance (Corbin & Strauss, 1985; Holden et al., 2013; Valdez et al., 2014). Patient work is *collaborative and distributed* and necessarily includes the work performed by others, and the temporal and spatial flow of activities (Corbin & Strauss, 1985; Holden et al., 2015; Mickelson & Holden, 2013; Palen & Aaløkke, 2006). Last, patient work is *situated* within a social, environmental, and organizational context (Corbin & Strauss, 1985; Holden et al., 2015). Therefore, the cognitive work of medication management involves distributed, collaborative, goal-directed processes whose outcomes (medication adherence) are dynamic and shaped by interactions with life activities and context.

Older adults with heart failure describe medication management as “hard thinking work” requiring the help of many people to accomplish (Granger et al., 2009). Common reasons reported by older adults for not taking medications are cognitive in nature: forgetfulness, frequent medication changes, a complex regimen, daytime sleepiness, and routine disruptions (Hayes et al., 2009). Evidence suggests that cognitive functions (e.g. working memory processes, attention, connecting event to a context, task switching, encoding new information) decline with age (Craik & Salthouse, 2008; Park et al., 2001; Zacks et al., 2000). Therefore, education and skill enhancement strategies alone may not be effective in significantly improving medication management performance in older adults. Cognitive artifacts may provide the external cognitive support needed to improve medication management performance in this population.

Cognitive artifacts used in medication management

Prior studies support the view of medication management as complex, distributed, and a goal-directed group of patient activities characterized by a lack of effective patient tools. Klein and Meininger (2004) reported the self-management of medications as a challenging control task with few available tools to assist patients. Haverhals et al. (2011) found patients needed help to obtain reliable information and coordinating information from several providers. Siek et al. (2011) reported that patients wanted autonomy in managing their medication regimens and needed more information sources when faced with unusual events. Palen and Aaløkke (2006) determined medication adherence technology must support distributed tasks, computation (such as tracking), and patient administration and control. These studies identified unmet medication management support requirements but did not address cognitive artifacts in use. An analysis of patient artifacts can help make patient hidden work visible (Suchman, 1995), and give insights into the work the artifacts were designed to support (Nemeth et al., 2006). The objective of this analysis was to describe the cognitive artifacts used by older adults with heart failure for medication management,

their function, distribution characteristics, and effectiveness in bridging the gaps of execution and evaluation.

METHOD

We conducted an analysis of data from 30 patients, and 14 informal caregivers enrolled in a larger study of heart failure self-care. Data collection methods used in the larger study are reported in detail elsewhere (Holden et al., 2015).

Participants

Patient participants were ≥ 65 years old, lived within a 200-mile radius of Nashville, Tennessee, and received continuing outpatient care in a cardiology clinic specializing in heart failure. The mean age of participants was 74 years old (SD=6.5, range 65-86); 57% (17/30) were male; 60% (18/30) were White, non-Hispanic; and 33% (10/30) were Black/African American. Of those providing answers, 33% completed 12 years of formal education (30% completed <12 years); 53% were married (23% widowed); 97% were not working or retired; 75% had an annual household income of \leq \$50,000 (25% \leq \$15,000). All had Medicare (87% had ≥ 1 additional insurance plan). Patients had heart failure severity ratings by New York Heart Association (NYHA) functional classification of II or “mild” (37%), III or “mild/moderate” (60%), if known. The study excluded NYHA classes I and IV.

Procedure

Researchers collected data in 2012-2013 and included clinic visit observations, short (30-minute) interviews, and follow-up (90-minute) interviews. Researchers extracted photos of cognitive artifacts from in-home and in-clinic video recordings. Electronic medical records, and self-administered standardized surveys (100% response rate) provided additional confirmatory data.

Analysis

Researchers imported transcribed interviews and observation data (N=30) into NVivo 10 qualitative data analysis software for descriptive content analysis and iterative category development (Miles et al., 2013). First researchers identified broad passages of data mentioning a cognitive artifact used in medication self-management defined as the patient and caregiver processes by which prescribed medications are administered in a manner optimal for achieving treatment goals. Next, author RSM assigned thematic codes to structurally coded passages related to the artifact’s function including planning, sensemaking, organizing, tracking, problem-solving, communicating and coordinating and executing (Corbin & Strauss, 1985; Lorig & Holman, 2003). Also, passages were coded that related to task and information distribution characteristics (Hutchin, 1995), and impact of the artifact on the gulfs of evaluation and execution (Norman, 1993). The third pass involved data-driven, discussion-based thematic and category development (Miles et al., 2013). The senior researcher, RJH, facilitated analytic convergence (Berends & Johnston, 2005). Researchers used passages and still photographs to clarify the content and analytic themes (Bell, 2001).

RESULTS

Patients and their caregivers used multiple cognitive artifacts for detecting problems, communicating and collaborating with clinicians, sensemaking, tracking and the execution of medication administration. Some cognitive artifacts were multifunctional. The design of patient artifacts centered on the clinician perspective of patient work and patients modified artifacts to fit their needs. Table 1 summarizes the functional purpose and prevalence of cognitive artifacts used by participating older adults with heart failure. When reporting quotes, we provide sub-scripted patient identifiers using an AGE/SEX/RACE format, with race designations of White (Wh), Black (Bl), and Mixed (Mix).

Table 1. Cognitive artifact functions used by older adults with heart failure

Functions	Artifact/Prevalence (%)
Problem detection	Blood pressure (BP) cuff (70%), used daily (60%) Scale (97%), used daily (77%) Pulse oximeter (10%)
Communication & Collaboration	Health telemetry (3%) Appointment books, calendars, notes (17%) Prescription (Rx) bottles (3%)* Medication lists (20%)* Medication list + Rx bottles (17%)* No artifact, reliance on memory (60%)*
Sensemaking	Rx inserts (10%) Books, brochures (27%) Internet (33%) Television advertisements (17%)
Execution, Administration	Rx bottles only (3%) Pill Organizer (73%) Rx bottles + medication list (17%) Paper bags, toiletry bags (7%) Small portable containers (7%) Cellphone reminders (7%)
Tracking	Paper logs, weight (43%) & BP (37%), brought to appointment (20%)*
Multifunction	Left atrial pressure monitor (7%) Patient portal/personal health records (27%)

* cognitive artifact brought to the clinic appointment

Distribution of tasks and information

Effective cognitive artifacts facilitate task distribution and knowledge building between members (Hollan et al., 2000; Hutchins, 1995, 1995b). Several cognitive artifacts *distributed tasks across time* to reduce task burden. Pillboxes distributed the effort of reading labels and opening prescription (Rx) bottles from a several times per day task to a once a week task reducing the patient's workload. One patient explained, "trying to open half a dozen containers twice a day, is impossible."^{81/M/Wh} However, an unintended consequence of pillbox use was the separation of medications from identifying

information printed on the Rx bottle label. In a pillbox, medications were identifiable by time and appearance alone. Medication appearance gave no clues as to the name, dose, or directions for administration of the medication. Many medications were similar in appearance and patients recounted administration errors after confusing medications based on appearance. A patient described an episode where his blood pressure (BP) fell after he confused two medications, "Its football shaped just like the Coreg, only a little bit smaller, and the only thing I could think of that could possibly have caused that was I screwed up the pills."^{66/M/Wh}

Patients made notes to remind themselves to communicate information to clinicians. Patients sometimes misplaced or forgot these notes and had to rely on memory to convey important information, "I know I left me a note on one of these papers, is a note in there that said for me not to take the Dioxin (sic)."^{68/F/Wh}

Self-made artifacts conveyed a need for patients to track medication history. Clinicians commonly asked patients about past medications and patients relied primarily on memory for this information. A caregiver struggled to remember the name of a medication his wife had taken in the past, "it was just a little pill."^{74/F/Wh} One patient kept a list of problematic medications, "I've got another list that, that had medications I take and that did have side effects and that weeded out a bunch of stuff."^{66/M/Bl} Another patient made a chart that listed all the medications he had ever taken, the date the clinician discontinued the medication (if so), the name of the prescribing provider, and when the next refill was due.

Daily weight and blood pressure (BP) logs distributed the task of tracking and evaluating the patient's condition to include the time between clinic visits. Logs gave the clinician additional data points on which to base evaluations and allowed patients visual feedback and the ability to follow trends. These artifacts were adaptable to tracking additional information. One patient documented when she took an extra diuretic on her log, "You see how my weight constantly kept going down... You can see here where I went up a little bit and took those pills and dropped."^{68/F/Wh}

Cognitive artifacts also distributed tasks across people. Paper weight and BP logs facilitated shared responsibility for evaluating, tracking, and communicating information. However, less than half of patients documented weight (43%) and BP (37%) and 20% of patients remembered to bring the logs to appointments and relied on memory. Paper medication lists and Rx bottles brought to clinic visits by the patient facilitated the task of medication reconciliation. However, 60% of patients did not bring Rx bottles or lists to clinic visits leading to uncertainty about what medications the patient was or should be taking. Patients' externally represented medications based on a direct experience of appearance (size, shape, color). Clinicians' external representations were textual and indirect, by name, dose frequency and intended actions and effects. Without the aid of cognitive artifacts, communicating across these differing representations was difficult.

Some cognitive artifacts *distributed information across places*. Wireless communication devices automatically sent weight and BP measures to clinicians with little patient effort.

The clinician could respond in real time and change medications as needed. One patient commented, “*if I gain five pounds, I get a phone call, and she and the Nurse Practitioner of this organization compare notes and call me and give me a tongue lashing.*”^{80/M/Bl} The web-based patient portal used by some patients (27%) allowed them to send messages to clinicians; track appointments, laboratory and test results; and access clinical summaries, problem lists, and current medication lists.

Some (7%) patients used portable medication containers when they were out for the day. Otherwise, patients delayed or skipped medications when they were away from home.

Gulfs of execution and evaluation

Patients experienced *difficulty with execution* relating to the physical characteristics of artifacts. One patient could not see or read the labels on the Rx bottles. He invented a system where he marked to tops of the bottles with abbreviations (M for the morning, N for noon, B for bedtime) and number of tablets to administer. Some patients had difficulty standing on the scale before it timed-out and shut off, “*I’m too slow to, to make it does what it’s supposed to do.*”^{86/F/Bl} and others could not see scale numbers, “*They were accurate. I just couldn’t see ‘em.*”^{80/M/Wh} Patients also had difficulty opening Rx containers.

Equipment and skills were needed to use technology. Twenty-seven percent of patients used the patient portal and others were unaware the portal existed (13%), did not own a computer (27%), and did not like to use a computer or felt they did not have the necessary skills (13%). One patient did not have a phone jack to communicate electrocardiogram information to her clinician, “*I don’t have an actual jack for the phone so therefore I can’t just you know plug it in.*”^{65/F/Bl}

Patients did not always understand the purpose of cognitive artifacts, which interfered with appropriate use. One patient felt burdened having to record his weight and BP, “*taking my blood pressure, taking my weight, and sugar count, so forth ‘til I feel like a secretary.*”^{80/M/Wh} Another patient did not record his weight, “*I know my weight,*” not acknowledging the need to communicate this information to the clinician. Without approval from his clinician, a patient decided when to take an extra diuretic dose based on a pulse oximeter value of 96% oxygenation. This patient said, “*the doctor won’t tell you to buy one of these, but I used it as a trigger, you know.*”^{84/M/Wh} During a clinic visit the doctor told him, “*we don’t get concerned until it’s below 88%.*”^{MD of 84/M/Wh}

Patients had *difficulty with evaluation* of information generated by cognitive artifacts. Patients did not always have the knowledge to interpret weight, BP, and oxygen saturation values and either did not act or acted incorrectly to unusual values. One patient’s wife explained, “*They said to check it, and if it’s a certain level then it’s okay. But then when it’s not, you know you know write it down.*”^{wife of 70/M/Wh} She decided documenting an unusual value without notifying the clinician was the appropriate action.

Cognitive artifacts also *facilitated execution and evaluation*. Implantable cardiac monitoring devices gave patients automatic feedback on the dose of medications based

on biometrics. Daily wireless transmission of weight, BP, and oxygen saturation values to clinicians allowed patient access to expert feedback and interpretation of these data, and immediate medication changes based on real-time values.

DISCUSSION

This analysis, guided by a distributed cognition and barriers to action framework, revealed striking gaps and potential opportunities for the use of cognitive artifacts for medication management by older adults with heart failure.

A distributed cognition framework is often applied to team performance. Collaborative teams coordinate information and knowledge using shared artifacts such as communal displays to mediate collaborative work (Xiao, 2004). Patients and clinicians in this study did not use collaborative artifacts to enable shared understanding. This resulted in an incomplete understanding of information. There was a lack of *bridging* artifacts to combine disparate representations and knowledge to facilitate shared understanding.

In addition to a reliance on incomplete information, skill levels of patients were variable. We cannot assume all patients can perform health tasks unaided. One solution is the automatic transmission of health data or “automated hovering” (Asch et al., 2012). With the use of remote monitoring or telehealth technology, patients no longer are required to document and evaluate data without assistance. They can receive timely feedback from clinicians as needed, directing them to take appropriate actions. Studies suggest that remote monitoring can decrease mortality and hospitalization rates in patients with heart failure (Dierckx et al., 2014).

There are several concerns about automatic transmission of patient data. There is a potential decline in patient engagement when patients no longer participate in the evaluative process. The lack of participation may create an overdependence on automation and make patients passive recipients of care. Automation may also interfere with patient autonomy. Studies report patients desire autonomy in managing their medications (Palen & Aaløkke, 2006; Siek et al., 2011). Other studies report technology facilitates patient engagement in self-care (Ricciardi et al., 2013). It is clear there is a delicate balance between automation and patient participation and shared responsibility that must be maintained in cognitive artifacts designed for patients.

Current cognitive artifacts do not optimally support *patient* work. The clinical perspective was the basis for the design of BP cuffs, pulse oximeters, logs and patient medication lists. Palen and Aaløkke (2006) reported medication management technologies were based on the provider view of patient work. Forsythe (1996) described an information tool for migraine headache patients based on a physician perspective and a developer’s assumptions. The resultant technology was not useful or usable for the intended patients. Artifacts designed for by and for clinicians may not support the work of patients. Studies report patients desire more information about their medications (Haverhals et al., 2011; Siek et al., 2011). Patients adapted cognitive artifacts to add information they required, and these adaptations give insights into the unmet needs of patients important to the

development of new cognitive artifacts. More research is needed related to cognitive artifact use by patients. Patient adaptations and self-made tools can give valuable insights into unmet needs and guide the design and development of future tools. A limitation of this study was a lack of a cognitive impairment assessment. Future research could explore the effects of cognitive impairment on cognitive artifact use.

In conclusion, there is great potential for cognitive artifacts to improve the cognitive performance of patient medication management work. Cognitive artifacts can especially enable information and skills sharing between disparate individuals—patients, informal caregivers, and various clinicians—who must collaborate to achieve medication management goals.

References

- Asch, D. A., Muller, R. W., & Volpp, K. G. (2012). Automated hovering in health care—watching over the 5000 hours. *New England Journal of Medicine*, 367(1), 1-3.
- Bell, P. (2001). Content analysis of visual images. In T. van Leeuwen & C. Jewett (Eds.), *Handbook of Visual Analysis*, London, U.K.: Sage, 10-34.
- Berends, L., & Johnston, J. (2005). Using multiple coders to enhance qualitative analysis: The case of interviews with consumers of drug treatment. *Addiction Research & Theory*, 13(4), 373-381.
- Corbin, J., & Strauss, A. (1985). Managing chronic illness at home: Three lines of work. *Qualitative Sociology*, 8(3), 224-247.
- Craik, F. I., & Salthouse, T. A. (2008). *The Handbook of Aging and Cognition* (3rd ed.). New York, NY: Psychology Press.
- Demonceau, J., Ruppard, T., Kristanto, P., Hughes, D. A., Fargher, E., Kardas, P., . . . Urquhart, J. (2013). Identification and assessment of adherence-enhancing interventions in studies assessing medication adherence through electronically compiled drug dosing histories: A systematic literature review and meta-analysis. *Drugs*, 1-18.
- Dierckx, R., Pellicori, P., Cleland, J. G. F., & Clark, A. L. (2015). Telemonitoring in heart failure: Big Brother watching over you. *Heart Failure Reviews*, 20(1), 107-116.
- Forsythe, D. E. (1996). New bottles, old wine: Hidden cultural assumptions in a computerized explanation system for migraine sufferers. *Medical Anthropology Quarterly*, 10(4), 551--574.
- Granger, B., Sandelowski, M., Tahshjain, H., Swedberg, K., & Ekman, I. (2009). A qualitative descriptive study of the work of adherence to a chronic heart failure regimen: patient and physician perspectives. *The Journal of Cardiovascular Nursing*, 24(4), 308-315.
- Haverhals, L. M., Lee, C. A., Siek, K. A., Darr, C. A., Linnebur, S. A., Ruscin, J. M., & Ross, S. E. (2011). Older adults with multi-morbidity: medication management processes and design implications for personal health applications. *Journal of Medical Internet Research*, 13(2).
- Hayes, T. L., Larimer, N., Adami, A., & Kaye, J. A. (2009). Medication adherence in healthy elders small cognitive changes make a big difference. *Journal of Aging Health*, 21(4), 567-580.
- Heersmink, R. (2014). The metaphysics of cognitive artefacts. *Philosophical Explorations*(ahead-of-print), 1-16.
- Hershberger, P. J., & Bricker, D. A. (2014). Who determines physician effectiveness? *JAMA*, 312(24), 2613-2614.
- Holden, R. J., Carayon, P., Gurses, A. P., Hoonakker, P., Hundt, A. S., Ozok, A. A., & Rivera-Rodriguez, A. J. (2013). SEIPS 2.0: a human factors framework for studying and improving the work of healthcare professionals and patients. *Ergonomics*, 56(11), 1669-1686.
- Holden, R. J., Schubert, C. C., & Mickelson, R. S. (2015). The patient work system: An analysis of self-care performance barriers among elderly heart failure patients and their informal caregivers. *Applied Ergonomics*, 47, 133-150.
- Hollan, J., Hutchins, E., & Kirsh, D. (2000). Distributed cognition: toward a new foundation for human-computer interaction research. *ACM Transactions on Computer-Human Interaction (TOCHI)*, 7(2), 174-196.
- Hutchins, E. (1995). *Cognition in the Wild*. Cambridge MA: MIT press.
- Hutchins, E. (1995b). How a cockpit remembers its speed. *Cognitive Science*, 19, 265- 288.
- Klein, H. A., & Meininger, A. R. (2004). Self management of medication and diabetes: Cognitive control. *Systems, Man and Cybernetics, Part A: Systems and Humans, IEEE Transactions on*, 34(6), 718-725.
- Lorig, K. R., & Holman, H. R. (2003). Self-management education: history, definition, outcomes, and mechanisms. *Annals of behavioral medicine*, 26(1), 1-7.
- Mickelson, R., & Holden, R. (2013). *Assessing the distributed nature of home-based heart failure medication management in older adults*. Paper presented at the Proceedings of the Human Factors and Ergonomics Society Annual Meeting.
- Miles, M. B., Huberman, A. M., & Saldaña, J. (2013). *Qualitative data analysis: A methods sourcebook*: SAGE Publications, Incorporated.
- Moser, D. K., & Watkins, J. F. (2008). Conceptualizing self-care in heart failure: a life course model of patient characteristics. *Journal of Cardiovascular Nursing*, 23(3), 205-218.
- Nemeth, C. (2003). How cognitive artifacts support distributed cognition in acute care. Paper presented at the *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*,
- Nemeth, C., Cook, R. I., O'Connor, M., & Klock, P. A. (2004). Using cognitive artifacts to understand distributed cognition. *Systems, Man and Cybernetics, Part A: Systems and Humans, IEEE Transactions on*, 34(6), 726-735.
- Nemeth, C., O'Connor, M., Klock, P. A., & Cook, R. (2006). Discovering healthcare cognition: the use of cognitive artifacts to reveal cognitive work. *Organization Studies*, 27(7), 1011-1035.
- Norman, D. A. (1991). Cognitive artifacts. In J.M. Carroll (Ed.), *Designing Interaction*. New York, NY: Cambridge University Press.
- Norman, D. A. (1993). *Things that make us smart*: Reading, MA: Addison-Wesley.
- Norman, D. A. (2002). *The design of everyday things*: New York, NY: Basic books.
- Palen, L., & Aaløkke, S. (2006). Of pill boxes and piano benches: home-made methods for managing medication. Paper presented at the *Proceedings of the 20th anniversary conference on Computer Supported Cooperative Work*, New York, NY: ACM, 79-88.
- Park, D. C., Polk, T. A., Mikels, J. A., Taylor, S. F., & Marshuetz, C. (2001). Cerebral aging: integration of brain and behavioral models of cognitive function. *Dialogues in Clinical Neuroscience*, 3(3), 151.
- Sabatãe, E. (2003). *Adherence to Long-term Therapies: Evidence for Action*. Geneva, Switzerland: World Health Organization.
- Scott, A., Sivey, P., Ait Ouakrim, D., Willenberg, L., Naccarella, L., Furler, J., & Young, D. (2011). The effect of financial incentives on the quality of health care provided by primary care physicians. *Cochrane Database Systematic Reviews* (9).
- Siek, K. A., Khan, D. U., Ross, S. E., Haverhals, L. M., Meyers, J., & Cali, S. R. (2011). Designing a personal health application for older adults to manage medications: a comprehensive case study. *Journal of Medical Systems*, 35(5), 1099-1121.
- Suchman, L. (1995). Making work visible. *Communications of the ACM*, 38(9), 56.
- Valdez, R. S., Holden, R. J., Novak, L. L., & Veinot, T. C. (2014). Transforming consumer health informatics through a patient work framework: connecting patients to context. *Journal of the American Medical Informatics Association*, 22(1), 2-10.
- van der Wal, M. H., & Jaarsma, T. (2008). Adherence in heart failure in the elderly: problem and possible solutions. *International Journal of Cardiology*, 125(2), 203-208.
- Woods, D. D. (1998). Commentary Designs are hypotheses about how artifacts shape cognition and collaboration. *Ergonomics*, 41(2), 168-173.
- Xiao, Y. (2005). Artifacts and collaborative work in healthcare: methodological, theoretical, and technological implications of the tangible. *Journal of Biomedical Informatics*, 38(1), 26-33.
- Zacks, R. T., Hasher, L., & Li, K. Z. (2000). Human memory. In C. Fim & T.A. Salthouse (Eds.), *The Handbook of Aging and Cognition* (2nd ed., pp. 293-358). Mahwah, NJ: Lawrence Erlbaum Associates.
- Zhang, J., & Norman, D. A. (1994). Representations in distributed cognitive tasks. *Cognitive Science*, 18(1), 87-122.