ABSTRACT
Motivation – To prolong functional independence of elderly persons who experience cognitive decline in attention, perceptual encoding, memory and self-efficacy.

Research approach – Ability of older adults to use domestic appliances depends on their mental model of operation. This may depend on transfer of understanding from similar, more familiar technology. Leveraging established mental models creates affordances for operating new technology but may constrain the discovery of advanced functionality. Familiar mental models may also interfere with developing appropriate mental models or interaction behaviour.

Findings/Design – Designing appliances to extend cognitive abilities provides opportunity to prolong functional independence. Concepts from cognitive psychology, human factors, and gerontology are reviewed to explain age-related behaviour towards technology to support innovative product development of technologies for older adults with cognitive impairment.

Take away message – The understanding of declining cognitive abilities must drive the development of technologies that sustain the independence of persons who are cognitive impaired.

Keywords
Cognitive impairment, domestic appliances, elderly, human-machine system, mental model, working memory, gerontechnology

INTRODUCTION
As the aged population expands, incidences of mild cognitive impairment (MCI) will dramatically increase. While technology innovation has extended lifespan, there has been little effort in developing technologies that support cognitive decline (Alwin et al., 2008). Cognitive decline can weaken learning and skill acquisition associated with fluid intelligence, spatial ability, perceptual speed, and working memory. Disparity between extending lifespan and declining cognitive abilities highlights the need for research into developing technology to sustain independence during cognitive decline (Vaupel and Yashin, 1985). Personal independence depends on the ability of seniors to perform instrumental activities of daily living. Self-reliance depends on their capacity to use domestic appliances. Seniors may lack confidence in dealing with new devices: perplexity replacing familiarity. Their inability to adapt leads to increased dependency on family members, friends, and service providers. Where support is scant, seniors may be impelled to move into residential care.

APPLIANCES FOR SELF SUFFICIENCY
Developing new appliance technologies that compensate for declining abilities may be a means of sustaining self-sufficiency, thereby delaying admittance to residential care. Integrating behavioural science and engineering in a context of product design allows designers to create technologies for supporting and extending declining abilities. Competency in using a technology varies from novice to frequent user. Proficiency depends on capacities and capabilities of working and long-term memory and attentional resources. To help seniors to learn how to use new products that enter their life, instructional design should be crafted to their learning style.

COGNITIVE IMPAIRMENT
As executive control in working memory declines with age, so does functional status measured by instrumental activities of daily living. Performance concerns planning, organisation and flexibility, which are functions of executive control. Carlson et al. (1999) found that attention is critical for completion of many complex, everyday activities.

Impaired attention decreases the number of objects a person can attend in a display. This decrement puts elderly people at a significant disadvantage. Therefore, designers should limit the number of control devices in appliances. However, Ball et al. (1988) found that through practice, seniors may recover their ability to attend multiple objects during visual search. Therefore, introducing control devices progressively, as proficiency with the display increases, may not detract from attentional resources.

Recognition of a control device depends on the user’s perceptual system extracting the graphical primitives—shape, colour and orientation—followed by integrating features (Treisman and Gelade, 1980). Inefficient integration, based on age-related limitations in selective
attention detracts from encoding. As the number of features that users can integrate is limited, graphical objects should be distinctly different to each other and the background (Schieber, 2003).

Successful usage of appliances depends on users monitoring performance and activating controls in response to cues. To respond to a cue, they must disengage their attention from the current activity and move it to another display item (Posner et al., 1987). For example, a grandmother cooking a Christmas dinner for her extended family monitors multiple pots on a stovetop and a roast in the oven. She responds to cues from sight (bubbling, colour), sound and smell, intervening when necessary (heat adjustment, removal from stove, initiation of another subtask, e.g., plating of meal). This may overwhelm someone with MCI. This might be alleviated by including technology that guides behaviour. Guidance technology may benefit from mixed modalities (e.g., verbal and visual), because different cognitive abilities deteriorate at various rates (Hertzog, Cooper & Fisk, 1996).

Seniors in normal domestic environments must also use appliances under the intrusion of demands from other appliances (e.g., phones) and persons. Performance depends upon the competition of limited attentional resources and the modality of the input and processing codes (spatial or verbal). For concurrent tasks, performance may be influenced by confusion between task elements, cooperation between task processes and competition for task resources (Wickens, 1991).

Older adults have much greater difficulty performing tasks that require a large degree of self-initiated information processing for tasks that are not accompanied by environmental support (Craik, 1986). It may therefore be possible to improve interface interaction performance in older adults by integrating recognition and cued-recall based retrieval methods into appliance controls.

Cognitive load associated with learning is often very high for older adults with MCI due to difficulties attending displays, discerning device features, and processing information in working memory. As a result, it hinders their progressive development of well-formed mental models.

**DESIGNING APPLIANCES FOR COGNITIVE IMPAIRMENT**

Successful formation and use of mental models of domestic appliances depends on persons holding and working with information stored in memory (Johnson-Laird, Byrne & Schaeken, 1992). Clearly, persons with MCI are at a disadvantage. However, if they recognise the problems they are trying to solve fit into a familiar cognitive structure, they may be able to reduce the cognitive workload (Sweller, 1988).

Once formulated, mental models tend to remain static and resistant to change (Richardson and Ball, 2009), until changes to the functionality of the represented system in the real world requires information to be reprocessed in working memory. Richardson and Ball suggest that difficulty overcoming invalid mental models is due to limitations in the capacity of working memory. Inability to consider, assess and reprocess alternative action sequences in the formation of mental models is exacerbated by MCI.

Designers of appliances should perhaps exploit the users’ understanding of familiar technologies. Users could then transfer learned patterns of control, retrieved from long-term memory, between old and new technologies (Schieber, 2003). As well as exploiting known mental models, demands on working memory can be reduced through training. Van Gerven et al. (2002) provide experimental evidence that elderly persons benefit more from training through the study of worked examples than means-ends learning. Spending time on task-relevant operations reduces the number of mental operations during learning.

Conversely, control structures that seniors anticipate to be present may create cognitive barriers that restrain exploration of new functionality. Recognition of new functions requires time and effort. If users can control basic product functions, they may easily ignore additional features. They may even be resistant to suggestions to explore other features; this can stem from cognitive tunnelling (Moray, 1999) due to an inappropriate mental model. The consequence is an undeveloped mental model; the cost is partial use of the product. However, there are less tangible costs: perhaps, awareness of incapability and fear of doing something “wrong” may lead to a loss of self worth.

Interference may arise where there are similar functions in a new product and a familiar product. Locating and triggering controls depends on the similarity of the surface features between the old and the new.

One way to address attention and working memory related decrements is to place information in the environment (Zhang, 1997). Many older adults, who wish to remember to perform a task in the future, adopt external memory aids (Maylor, 1990), such as personal notes or intentional placement of objects. Older adults who do employ such techniques often outperform younger adults in tests of prospective memory (Schieber, 2003). By externalising information in the environment, sufferers of MCI have cues available to them that prime explicit memory. An externalised appliance interface can cue an operator in a variety of forms. For example, an operator must be cognisant of the goal of the operation, the current state of operation, what tasks were performed to lead up to the current state, and what tasks are necessary to continue navigating towards the goal. Any combination of these forms of cueing may assist an MCI affected older adult in control of a device. The challenge in designing externalised appliance interface control lies in defining the method of cueing and what singular or combined forms of cuing are most effective given the state of cognition of the user. In this regard, the process of externalising information requires care. Setting a
suitable degree of externalisation is difficult, as there is no reliable method for measuring cognitive impairment in older adults.

For each person suffering MCI, its form is singular. Therefore, quantifying the range of cognitive deficiencies and its advancement is problematic. Studies of cognitive ageing usually only capture a snapshot of performance at a single time by comparing inter-individual differences for different groups. This does not capture variation in declining abilities of persons within and between age groups.

Designers with access to cohort-specific statistical patterns in changing cognitive abilities will have a much stronger grasp on addressing cognitive ergonomics for this demographic. In addition, determining familiarity with certain forms of technology will provide insight into designing applicable internalised and/or externalised control methods that support latent predispositions (known control methods) whilst enabling encoding of extended functionality.

For seniors with MCI, learning how to control a new product is stressful. Cognitive distress arising from the feeling of a lack of control over stressors may contribute to the lowering in self-efficacy and thereby impair cognitive functioning (Bandura, 1989). A vicious cycle of stress arising from inability to control the product, lowering self-efficacy, and adding learning with consequential accentuation of stress. In a study of individuals learning to use computers, Compeau and Higgins (1995) found that encouragement of successful outcomes served to enhance self-efficacy and outcome expectations. For MCI affected older adults using new forms of technology, integrating some form of encouragement of successful action into an interface may positively affect learning by facilitating better encoding, easing the formation of new mental models, and ultimately streamlining control whilst enhancing user satisfaction.

**ADAPTIVE APPLIANCE CONTROL**

Perception, attention, and memory are related to primary and secondary mechanisms of cognitive control theory. Primary mechanisms include active behaviour in manipulating external forces. Secondary mechanisms include internal cognition, emotional constructs, and mental reframing mechanics for offsetting loss of control (Gitlin, 2003). Addressing an MCI affected system by using adaptive secondary mechanisms of control, creates opportunity to aid forms of cognitive impairment through a joint cognitive systems (Hollnagel, 2002) approach to design. The goal of this approach is to quantify deficiencies on either side of the system and create solutions that extend functional limitations in an effort to optimise efficiency.

Designers of appliances can provide externalised cues in the form of Gibson’s affordances through Ecological Interface Design techniques of Vicente (1999). Affordances in the interface compensate for cognitive deficiencies by transferring information from memory to the world. Existence of affordances depends on users locating the cues within their mental model. By exploiting an individual’s existing mental model, an affordance acts as externalised prospective memory. In effect, the cognitive system combines internalised and externalised memory: that in the head with that in the world.

A system of prompting that provides user-specific guidance when necessary, lessens or withdraws as users gain proficiency, and occasionally prompts users during lapses in performance, may assist users with varying levels of ability.

**FUNCTIONING IN THE WORLD**

Maintaining independence in the home is a priority for older adults. Lack of ability to perform independent activities of daily living will create dependence on family, friends, and service providers for assistance, possibly leading to premature admittance to care facilities. The likelihood of strain on social systems is great given the large cohort of baby boomers set to retire over the next few decades.

Developers of home appliances should be aware of the physical, sensory, and cognitive challenges facing a large contingent of the approaching elderly population. Without extending design briefs to encompass deficiencies in attention and memory of older adults with mild cognitive impairment, developers will face barriers to the use of their products. Training older adults to use new technology may extend their independence at home. Familiar mental models from past technologies may then be ‘recycled’ through training that uses familiar cognitive structures. Integrating attentional controls and extending capacity for working memory, in designing the interface and the interaction process of home appliances may further streamline learning and extension of mental models, thereby providing better capacity for planning and achieving goals. In addition, instructional assistance in the home environment without peer pressure or time constraints will support self-efficacy in older adults by reducing anxiety associated with personal awareness of cognitive decline whilst using technology. Encouragement of successful outcomes will also strengthen efficacy, further supporting willingness to learn functionality. Instructional delivery of appliance control must be flexible and adaptive for the variety of users, and due to the unpredictable nature of cognitive decline. Methods of instructional delivery can include varied combinations of audio, visual, or state recognition prompting techniques that increase or decrease based on a users level of mastery and/or cognitive capacity.

A major challenge to research into age-related cognitive decline is the formation of an integrated methodology for measuring intra-individual differences across time. These measurements can help researchers determine the modes for the delivery of stimuli and responses that are efficacy supportive and appropriate for specific levels of prompting for controlling attention and enhancing
working memory. Integrating internalised and externalised methods of control into specific levels of prompting and defining transitions between levels will also challenge researchers creating adaptive guidance control for designing home appliances.

REFERENCES


