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A CODING SCHEME FOR USE IN THE DESIGN OF ELECTRONIC CONSUMER PRODUCTS FOR OLDER ADULTS

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1. Introduction

Older peoples' access to digital technology has become a central issue for interdisciplinary research concerned with the design and development of dependable technology-based products such as domestic consumer appliances. Dewsbury et al. [2010] provide a working definition of successful dependable technology-based products, describing the consequences of their use as the attainment of independence, autonomy and wellbeing to facilitate and support independent living activities. Clay and Barral [2013] argue that research studies have not yet attained an adequate understanding of ageing processes as life course developments and their implications for the design of dependable technology-based appliances. Lim et al. [2012], reporting on a study of the challenge of designing for diversity in older users, conclude that to sustain technology usage in older people a range of approaches, techniques and methodologies needs to be considered. This aligns with observations by Ateca-Amestoy and Ugidos [2013] that user behaviours are multidimensional and encompasses complex combinations of challenges, skills, achievement thresholds, concentration and working memory.

The aim of the research reported in this paper is to explore approaches for supporting independent living through the design of operational user interfaces for domestic information-processing appliances. Learning from pilot studies using the scheme introduced in this paper indicate that a key design opportunity lies in creating interfaces that mirror the real-life activities and processes that users are carrying out. The research seeks to understand cognitive and interaction reasons for usability challenges that older adults' experience through an improved understanding of the design of user interfaces on domestic information appliances such as washing machines and microwave ovens. A coding scheme for use in the design and development of electronic consumer products relates to both psychological and a physiological characteristic of ageing is proposed for use in the design of improved operational user interfaces for domestic information-processing appliances.

Bodker [1996] identifies processing interruptions and visual distractions known as interaction breakdowns and focus-shifts as key factors in older users' inability to operate such interfaces. This research is exploring the use of design to minimise interaction breakdowns and focus-shifts in the use of technology-based appliances by older adults with age related cognitive decline carrying our independent living activities such as washing clothes or preparing a simple meal. A coding scheme is introduced to support the analysis of both cognitive and physical characteristics of the interactions between older users and domestic information-processing appliances. The scheme has been validated through a series of pilot studies that resulted in quantifiable descriptions of user interactions and product behaviours, and their relationship to the activity they were carrying out. The pilot analyses

highlighted different types of ageing-related cognitive changes, for example, loss of semantic memory, task knowledge and interaction, and their impact on effective and efficient use of the appliance.
This paper focuses on the development of a coding scheme to describe, analyse and quantify cognition characteristics of interaction between older adults and domestic information-processing appliances. Section 2 outlines theoretical dimensions of the research and looks at how older peoples' functional and information-processing capabilities relate to characteristics of interaction experienced by older operators using current domestic information-processing technology. The methodology used to develop the coding scheme is described in Section 3. Section 4 presents the experimental design. The coding scheme is presented in Section 5. Sections 6 & 7, present the results of the washing machine and microwave case study. Section 8 presents the implications for user interface design. Finally, in Section 9 conclusions are drawn.

2. Literature review

Clarkson [2003] argues that for the purpose of improving electronic consumer products designed to accommodate the needs and aspirations of people over 50 years old, analysis of population statistics, disposable income and free time, together with target market segmentation should be conducted to emphasise the importance of heterogeneity in ageing. This is supported by Coleman [2003] who proposes that in the future, domestic information-processing appliances will need to accommodate the needs and motivations of older people by supporting changing lifestyles and activities, thus capabilities. One view, expressed by Young et al. [2011] is that user interfaces on electronic consumer products could be better designed to support operating and constructing activities and actions required for successful user product interaction. A similar view is put forward by Keates and Clarkson [2003] who argue that most studies are concerned with activities of daily living and do not normally take into account the individuality of older adults' capabilities and abilities to conduct an operational procedure with an information-processing appliance. The work of Huppert [2003] concluded that the most significant aspects of information-processing in this context are perception, working memory, activity and actions. Huppert's [2003] findings corroborate the ideas from Goel and Pirolli [1989] that draw attention to information-processing systems and the wider range of cognitive elements encompassed in the user interface designs. Central to the cognitive architecture of appliance user interface design is an understanding of the users' problem solving actions and strategies associated with the task to be performed. Others have been considering the creation of product requirements based on information that has been elicited from users' interactions. This idea has been extended further by Thompson and Norton [2011] who suggest that excessive numbers of product features on all types of domestic information-processing appliance cause the most performance issues and problems.
One theory is that older people are highly likely to increase the rate and readiness to use compensatory strategies as a form of improvisation and intervention when performing everyday activities with domestic information-processing appliances Rose et al. [2010]. There is a view that variances in the experience, task knowledge and cognitive abilities affects older adults' ability to perform everyday activities Finucane [2010]. According to Mitchell et al. [2013] variances in the monitoring of visual format and task information provides an understanding of older adult's experience, task knowledge and cognitive abilities. A similar stance is taken by Huppert [2003] who agrees that transitory information presented in information-processing systems can cause problems. It has been argued Mitchell et al. [2010] that irrelevant transitory information is more likely to remain active in human information processing channels, thus affecting cognition and information-processing capabilities. So far, however, there has been little discussion about the way cognition and information-processing capabilities are affected by irrelevant transitory information. Most studies in information-processing and daily living activities have only paid attention to the effect of poor cognition and information-processing which manifests itself through rapid and continuous movement between product features such as text, labels, icons and symbols, and perceived corresponding controls and displays on the domestic information-processing appliance.
There is an argument that older adults' poor information-processing ability is attributed to an inability to determine and recover bounded units of information when performing activities of daily living with domestic information-processing appliances Old and Naveh-Benjamin [2012] and [2008]. User

interface characteristics and features show a disconnection between the visual image and its meaning in a real world context, more often than not having a negative effect on older operators, causing an inability to determine and recover discrete or bounded units of information. An alternative suggestion is that semantic association are not representative of older adults' visual ontology. Research to date has tended to focus on observations and the manifestation of information-processing problems rather than principles and methods for the development of natural cognitive processing systems to support older adults. Boman et al. [2012] concurs with this view suggesting that a requirement specification for older adults' functional and information-processing capabilities with consumer appliances used in daily living activities would be advantageous for digital inclusion, ageing research, theory and practice. However, there is no reliable evidence that current coding schemes for use in the design and development of domestic information-processing appliances provide a suitable method for quantifying the functional and information-processing capabilities and characteristic of interaction of older adults.

3. Research methodology

The coding scheme introduced in this paper is part of a wider research activity that is using the four stage research methodology illustrated in Figure 1. The methodology integrates Lincoln's [1985] Constructivist Inquiry with Theory Building from case study-based research [Eisenhardt 1989a,b] and Van de Ven's [2007] engaged scholarship diamond model of Action Research. The coding scheme introduced in this paper was developed as part of a wider methodology which involved four stages: define [research questions]; design and develop research instruments, conduct experiments; and analyse results and conclude. Figure 1 positions the development of the coding scheme and shows how it fits into the wider methodology. King's [2004] Template Analysis and Atman's [1999] coding scheme for design processes were integrated to help to explain the phenomenological aspects of the iterative research approach which moved from a single case to a cross-case analysis. Moreover, the inductive and deducted nature of King's template analysis was applied to the overall research methodology to further deconstruct and construct specific aspects of the descriptive and analytical data. For the purpose of theory building Bourgeois and Eisenhardt [1989] and Carlile's [2004] cycle of theory building in management research and Yin [2009] was used. This allowed for a more descriptive theory building approach to be adopted which instinctively created rich multifaceted qualitative data.

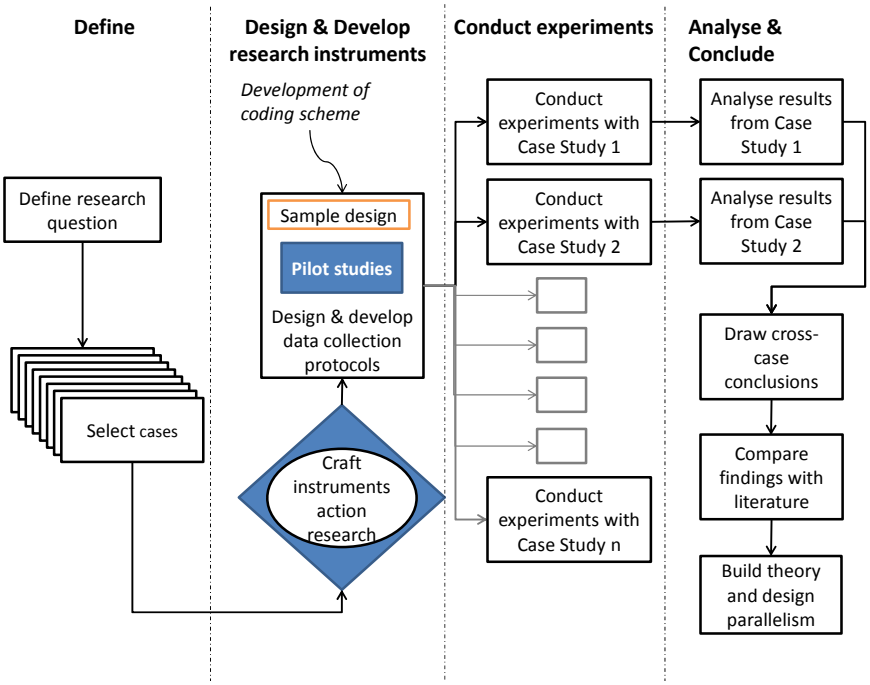

Figure 1. Overall research methodology

4. Experimental design

The experiments reported in this paper built on Bodker's [1996] approach to ethnographic study of activity theory and human computer interaction but analysed the information-processing and interaction of two older adults (women aged 55 and 68 years) operating two case study domestic information-processing appliances. Figure 2 shows the user interfaces of the washing machine (a) and microwave oven (b) that were used in the study. The 68 year-old used the microwave oven and the 55 year-old the washing machine. The information-processing task was conducted in an unfamiliar residential setting. During the task participants were given a specific task to complete (heat up a ready meal or wash white cotton clothing), an instruction manual for the machine they were being asked to programme and instructions off the ready meal packaging or labels on the garments to be washed. Each participant was asked to talk through what they were doing as they completed the task. Each participant was video-recorded. The video (including audio) footage was analysed using the coding scheme introduced in the next section.

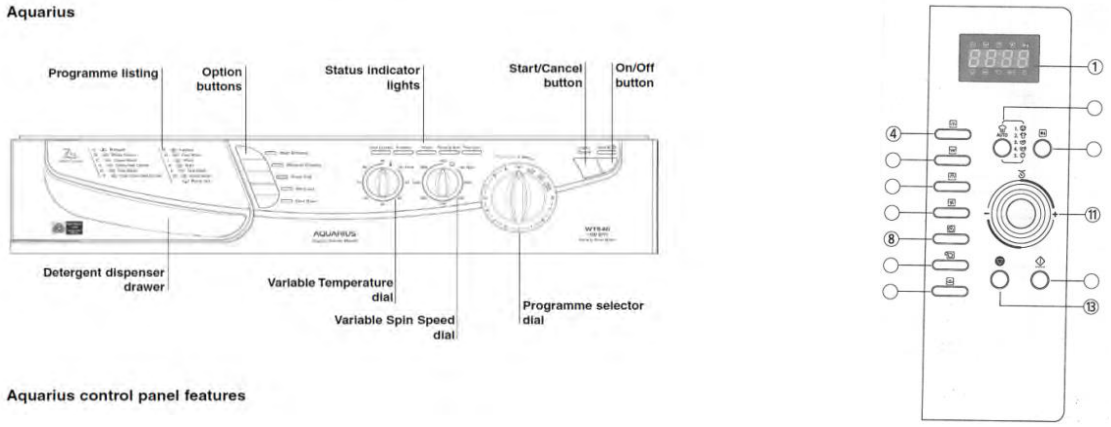

Figure 2. Control panel features on a washing and a microwave oven

5. The coding scheme

Atman et al. [1999] and Hughes et al's [2003] coding schemes were adapted. Analysis of verbal protocol behaviour Bodker [1996] and Patrick et al. [2004] increased the reliability of the outcome measures. Anderson and Krathwohl [2001] defined information-processing skills to measure the variability and variety of cognitive processing capabilities. The coding scheme used to analyse the experimental results is shown in Tables 1, 2 and 3. Three independent coding scheme protocols and verbal protocols are presented in Tables 1, 2 and 3. The coding scheme in Table 1 differentiates between two kinds of impediments to workflow: interruptions and distractions. Different kinds of operational event are highlighted in the scheme in Table 2. Relationships between these events and cognitive domains are given in the right-hand column of this table. The coding scheme in Table 3 describes the types of cognitive and processing skills used by operators in programming tasks.

Table 1. Coding scheme for protocol data impediments to workflow

Impediments to workflow	Characteristics of interaction	Bodker [1996]
Interaction Breakdown	Interruption and disruptions to workflow	Interaction breakdowns are caused by breakdowns in operational procedure and sequencing.
Interaction Focus Shift	Distractions to activities of workflow	Interaction Focus-Shifts are caused by a shift in the operator's attention resulting in operators focusing on alternative features and user interface characteristics

Table 2. Coding scheme for protocol data information acquisition behaviours

Operational procedure events	Operational event domain definition	Operational domains based on Anderson and Krathwohl [2001]
Searching for information	Presenting and defending opinions by making judgments about information and visual elements	Evaluating
Categorising information	Combining visual elements and information in new patterns or proposing alternative procedural solutions	Creating
Programming	Applying acquired knowledge, facts, techniques and rules to the user interface	Applying
Problem scoping	Demonstrating an understanding of facts and ideas relating to the procedural domain	Understanding
Checking content/equipment	Presenting and defending opinions by making judgments about task domain based on a set of criteria	Evaluating
Developing alternative solutions with m/c	Producing a plan or proposing a set of operations	Creating

Table 3. Coding scheme for verbal protocol data information-processing skills requirements

Cognitive events	Cognitive domain definition	Cognitive skills based on Anderson and Krathwohl [2001]
Identifying intentions	Identifying basic intentions and recalling facts	Remembering
Information gathering	Examining and breaking information into parts	Analysing
Information obtained	Translating and interpreting information	Understanding
Identifying user interface problems	Inferring and finding evidence of visual elements problems	Analysing
Resolving user interface problems	Translating and interpreting visual elements and information problems	Understanding
Identifying irrelevant user interface information obtained	Examining visual elements and information to identify causes and effect	Analysing
Identifying cognition problems	Breaking visual elements and information into parts by identifying causes and effect	Analysing
Cognition problem resolving	Compiling information together in different ways by combining visual elements and new knowledge	Creating
Concurrent verbalization supporting problem solving	Verbally verifying ideas to determine level of complexity of user interface	Evaluating

6. Results from the washing machine case study

Results of an analysis of the washing machine case study are presented in Tables 4 and 5. It can be seen that 27 tactile interactions with the washing machine were identified along with five episodes of interaction breakdowns nine of focus-shifts.

Table 4. Excerpts from Transcription of the Verbal Protocol Analysis and Tactile Interactions with the Washing Machine

Interaction points	Characterisation of interaction	Breakdown or focus-shift	Concurrent verbalisation	Processing skills taxonomy and related coding
1	*Handling*		White is very bad for my eyes.	Remembering
2	*Handling*		Mostly, I do things by touching not reading.	Remembering
3	*Handling*	breakdown	Switch the plug on and make sure it is on.	Analysing
4	Subject/Object			
5	Subject/Object	focus-shift	I want to wash it not boil it. It has a letter J, why?	Understanding
6	Subject/Object	breakdown	I have to come closer, I cannot see very well.	Applying
7	Subject/Object	focus-shift	Is that 40 for woolen? I'm confused.	Understanding
8	Subject/Object	focus-shift	The white cotton should be 95. It should be B?	Understanding
9	Subject/Object	focus-shift	…so much writing it should be more organized.	Understanding
10	S/O +Handling			
11	S/O +Handling			
12	S/O +Handling			
13	Subject/Object			
14	S/O +Handling	focus-shift	The design is so sophisticated.	Understanding
15	S/O +Handling	breakdown	I will leave it, I don't know how to programme it	Creating
16	*Handling*	breakdown	Reduced crease, rinse, what does that mean?	
17	Subject/Object			Evaluating
		breakdown	I am not sure where the liquid goes	
18	Handling	focus-shift	I think the powder should be on the other side	
19	Handling	focus-shift	I do not know if they are done.	Applying
		focus-shift	I still see off/on	
20	Handling			Evaluating
21	Handling			Evaluating
22	Subject/Object	focus-shift		Understanding
23	*Handling*		I still don't know what is happening?	
24	*Handling*			
25	*Handling*			
26	*Handling*			
27	Subject/Object			Understanding

Table 5. Excerpts from Transcription of the Verbal Protocol Analysis and Tactile Interactions with the Washing Machine Showing Time

Events	Time (min/sec)	Type of processing skills required [Anderson 2001]
Cognitive		
Identify intentions	03:00	Remembering
Information needed	03:20	Analysing
Information obtained	01:00	Analysing
Visual user interface problem identified	00:20	Analysing
Irrelevant information obtained	00:30	Evaluating
None visual user interface problem solved	00:20	Evaluating
Visual cognition problem identified	00:30	Remembering
Visual cognition problem solved	00:50	Evaluating
Verbal Problem solving	06:50	Evaluating
Operational Procedural		
Sorting	00:40	Evaluating
Uploading	00:30	
Programming	04:50	Creating
Washing	01:30	
Unloading and segmenting	02:20	Analysing
Sorting and Organising	01:30	Analysing
Breakdowns and focus-shifts	04.50	Creating

Strong evidence of user interface complexity was found when the operator programmed the washing machine. It can be seen that, for this operator, the parameters, characteristics and features on the displays and controls reduced the effective transmission and reception of information between the user

and machine. Concurrent verbalisation to support problem solving provided the evidence and reasons for user interface problems and issues. The data in Table 4 shows that the operator's motivations to control interaction breakdowns and focus-shifts were stimulated by symbolic semantic information. The excerpts from transcriptions presented in Table 5 shows how the operator cognitively explains and evaluates ways to eliminate and or control the interaction breakdowns and focus-shifts:

"Reduce, crease, rinse, what does that mean?"
"I want to wash it, not boil it! It has a letter J, why?
"Is that 40 for woollen? I'm confused"
"The white cotton should be 95. It should be B?"
"I still see off/on"
"I still don't know what is happening"

Both cognitive and operational procedural differences were identified. Furthermore, many reoccurring patterns of behaviour and interaction were presented. Noticeable findings included the following:

- symbolic semantic user interface characteristics, in the form of visual instructions and directions, caused the majority of the interaction breakdowns and focus-shifts
- text, words, lettering, symbols and icons were associated with significant numbers of interaction breakdowns and focus-shifts
- large amounts of time was spent using the cognitive processing skill of evaluating and remembering
- large amounts of time was spent using the operational procedural domain of applying.

Results indicate the older operator was motivated by symbolic semantic user interface components on the washing machine, thus searching for meaning from symbolic semantic user interface components was a key activity.

7. Results from the microware case study

A further qualitative study using the coding scheme, protocol and verbal protocol analysis was conducted with another older operator using a microwave oven. This demonstrates how the coding scheme can be used to highlight overlaps in the use of different cognitive domains and operational procedural events. Results of transcriptions of the verbal protocol analysis were analysed and presented in Figure 3.

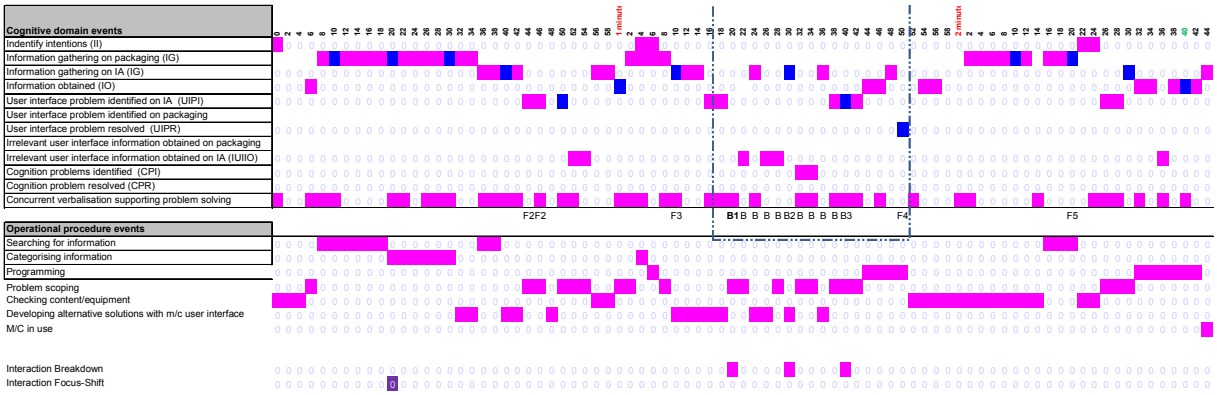

Figure 3. Trace of the microwave experiment at 2 second intervals

Figure 3 show the operator's cognitive and operational. Noticeable findings included the following:

- information gathering with the meal packaging was preferred to initiate the information processing task
- the user showed a reliance on the information on the meal packaging was evident
- user interface design on the appliance was not reviewed before the start of the activity
- user interface problems were noticed in advance of a series of interaction breakdowns

In the trace are:

- a large amount of time was spent identifying intentions

- a large amount of time was spent in overlapping transitions amongst cognitive skills and operational procedural domains
- a large amount of time was spent in cognitive and operational procedural events which differed in frequency and length
- developing alternative solutions followed a period of categorising information
- interaction breakdowns coincided with programming user interface problems were often followed by identification of cognition problems

Trends in the trace showed characteristics of interaction of the operator. The coding scheme helps to describe cognitive and operational procedural domains. In summary, noticeable findings were:

- a large amount of time was spent in overlapping transitions amongst cognitive skills and operational procedural domains
- a large amount of time was spent in cognitive processing categories such as evaluating and remembering.

8. Implications for user interface design

Cognitive and physical interaction issues were similar for both participants reported in this paper. Results suggest that irrelevant symbolic semantic characteristics and information remains active in the working memory of older people. This can be seen in concurrent verbalisation used to support problem solving. The coding scheme can be used to create both descriptive and analytical explanations of the cognitive and operational procedural events occurring in real-time interactions. Similar to the finding of Old and Naveh-Benjamin [2008] this study found that there are problems with older peoples' perception and cognitive capabilities when using domestic information-processing appliances. Inability to determine and recover semantic meaning from unbound units of visual information causes the most difficulties due to an unlikely operational sequence. This appears to be more apparent when faced with a lack of chronological operational sequencing which is apparent in the performance of everyday tasks in a real world context, but not evident in operational procedural events with domestic information-processing appliances. The study indicates that the characteristics of interaction of both older adults were affected negatively by symbolic semantic characteristics and features on current domestic information-processing appliances. Moreover, the exploratory styles of both operators can help to fabricate significant constructs for a further study. Further data is required to determine and improve methods to assess the weighting of symbolic semantic characteristics and features and its effects on older peoples' cognitive working memory.

The coding scheme provides a method to details relationship between domains and skills with units of time, providing a way to efficiently assess information-processing, thus having the potential to describe a user's performance. Of particular interest, to researchers concerned with conscious and unconscious cognition and interaction, also non-scientific researchers involved in observing the habits and thoughts of operators using problematic user interface designs and technology. Researchers in social science could use the coding scheme to define activities influencing the participants' natural approach to problem solving. The study reveals the importance of reflexivity in information-processing with domestic information-processing appliances suggested by Rose et al. [2010]. Personal reflexivity referring to operator's values and beliefs in work flow and epistemological reflexivity refers to operator's ability to identifying the foundations of knowledge and symbolic semantic reference found in concurrent verbalisation used to support problem solving. Similar to Atman [1998], this study measures how much time each operator spends in processing different types of activities involved in an information-processing task. In this study measures include impediments to workflow, cognitive skills and operational procedural domain events. However, in this study the researcher was unable to measures how much time each operator spends in overlapping transitions amongst cognitive skills and operational procedural domains. Overlapping transitions amongst cognitive skills and operational procedural was a key finding and warrants further study.

9. Conclusions

Results indicate symbolic semantic characteristics cause the majority of distractions and interruptions to workflow, namely, interaction breakdowns and focus-shifts. Results found overlapping transitions amongst cognitive skills and operational procedural were a key finding in interaction. The coding scheme aids the product design process by providing a better understanding of the complexity of cognition and interaction by reducing the information-processing into deconstructed component parts, accurately describing observations on the basis of a model containing logical elements and predictions of behaviours. In terms of design improvement opportunities, the research found that operators' information-processing strategies tended toward aligning a relationship with information source material such as meal packaging information, clothes labelling and the domestic information-processing appliance.

This paper has introduced a coding scheme for use in the design of domestic information-processing appliances that could be used to provide improved support for independent living. The paper focused on the use of the coding scheme to describe, analyse and quantify cognition and characteristics of interaction between two older adults using two different domestic information-processing appliances. Results indicated that symbolic semantic characteristics and features, in the form of visual instructions and directions, cause the majority of interruptions and distractions to workflow, namely, interaction breakdowns and focus-shifts. The coding scheme quantified the cognitive processing and operational procedural events experienced by the two older operators. The study found that operators 'exploratory styles were negatively affected by text, words, lettering, symbols and icons on user interface designs and these were associated with a significant number of interaction breakdowns and focus-shifts.

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