12.0 INTRODUCTION

Results detailed in Chapter 11 imply that individuals are not consistent in applying the same behavioural style for every task they undertake. It is theorised that new search heuristics are generated when an individual is unable to assimilate information during the search process. Cognitive load is caused by the uncertainty that arises when an individual has to apply new heuristics, and when a mismatch in perceptions and actual experience causes existing heuristics to be abandoned. Predicting the utility of feedback judgements using Cognitive Load Theory is possible. This Chapter will investigate the six conjectures proposed in Section 10.1.

12.1 COGNITIVE LOAD AND INTERACTION WITH INFORMATION OBJECTS

Cognitive flexibility theory is a constructivist theory that was specifically formulated to investigate the use of interactive technology, e.g., hypertext. Spiro and Jehng (1990) were the initial pioneers of the theory. Cognitive flexibility theory is largely concerned with the transfer of knowledge and skills beyond their initial learning situation. The theory asserts that effective learning is context-dependent and learners must be given the opportunity to develop and integrate their own representations of information in order to properly learn/understand.

When using an IR system, a user needs to be able to spontaneously restructure knowledge as an information need develops. The dynamic nature of an information need means that if knowledge can be represented along multiple rather than single conceptual dimensions then the assembly of new schemata is aided. Therefore, an individual's investigation of an information need is likely to require a combination of exploratory and goal-directed behaviour. Goal-directed behaviour requires an individual to develop their own representations of information.

Evidence was found to suggest that the *pe=2* measure could be reliably used as suitable measure of an individual's goal-directed / exploratory behaviour. Goal-directed behaviour could be observed when participants decided to integrate concepts during answer construction.

Extraneous cognitive load influences an individual's ability to interact with information objects (*see* Chapter 7). However, no evidence was found that suggested goal-directed / exploratory behaviour could be attributed to the extraneous cognitive load imposed on an individual (*see* Section 11.10). The ability to be cognitively flexible did not seem to significantly affect the amount of cognitive load. Without further investigation it is difficult to suggest an explanation for this.

It has been discovered that task complexity (*see* Section 11.8) was responsible for extraneous cognitive load, and consequently, could be partially responsible for the way individuals interacted with information objects. Individuals who were able to spontaneously restructure knowledge in response to situational demands experienced less extraneous cognitive load. When an individual discovered concepts that turned out to be much more important than the ones they were contemplating at the beginning, task complexity increased.

Pask (1976a) discovered that individuals could be categorised as being 'holists' or 'serialists'. Holists adopt a global approach by examining relationships between a range of potentially relevant topics and building an overview. Serialists prefer to concentrate on one topic at a time. Consequently, serialists obtain an overview at a much later stage. Interestingly, Pask also found that serialists were most affected by uncertainty.

Participant who experienced high levels of extraneous cognitive load submitted a fewer number of relevance feedback passages and found it difficult to pre-determine task requirements. This could be observed when a participant identified a passage as initially not being useful but then used it later within the answer construction process. This behaviour indicated a reliance on serialist information processing, and the lack of a developed task overview. It was found that participants who in some way attempted to incorporate a passage into an answer construction experienced a lower level of extraneous cognitive load. This behaviour was indicative of an attempt to develop a task overview. This is a typical holistic strategy.

Pask (1976b) associated holist and serialist approaches to components of understanding. The holist strategy was related to 'comprehension learning', while the serialist strategy was related to 'operational learning'. These differences have implications for interaction. Entwistle (1981) suggested that a 'deep approach' involves evaluating the extent to which conclusions can be supported and integrated within an individual's knowledge, while a 'surface approach' is limited to learning specific facts that are often disconnected.

Witkin et al's (1977) well-established concept of field dependent/independent cognitive styles seems to be compatible with both Pask's and Entwistle's findings. Field-independent individuals incorporate new information into a framework. Field-dependent individuals tend to rely on and preserve the structure of information. Consequently, field-independent individuals are better at organising information, which is analogous to the holist/deep approach.

Exposure to threatening, contradictory, or complex information is likely to increase levels of anxiety. A domain expert, however, is more likely to use a schema-driven 'field-independent' approach to information seeking. Such an approach enables an expert to proceed because a well-developed schema encodes a series of problem states and associated moves without being driven by a need to reduce affective anxieties (*See* Section 11.7). However, no evidence was found that suggested that a domain expert experienced lower levels of cognitive load (*see* Section 11.10).

Expertise did not seem to significantly affect the amount of cognitive load. A possible explanation was that adopting a 'schema-driven field-independent approach' does not necessarily mean that a holistic approach to the assimilation of information can always be undertaken. Individuals were not consistent in applying the same behavioural style for every task they undertook. It is theorised that new search heuristics are generated when an individual is unable to assimilate information during the search process. Heuristics are investigated in Section 12.5.

12.2 COGNITIVE LOAD DURING RELEVANCE FEEDBACK

Cognitive load experienced during relevance feedback is the intrinsic and extraneous difficulty associated with providing useful / accurate feedback judgements during information seeking. Barry (1994) discussed the potential of using clues to identify characteristics of documents that could be used by an IR system to retrieve documents (i.e., going beyond topicality). However, the interpretation of perceptual clues are dependent on structures of goals held in memory and expertise, i.e., a personal perspective (Chase and Simon, 1973). Importantly, identifying the characteristics of perceptual clues, where the discovery of novelty is an essential element, cannot be achieved from post-hoc generalisations. The lack of personal perspective may be the result of cognitive load imposed on an individual. More useful / accurate feedback judgements will be made if both an individual's intrinsic cognitive load and extraneous cognitive load is low. We currently have little knowledge of how uncertainty or different cognitive styles affect information behaviour. It is currently impossible to speculate how uncertainty or adopting a particular cognitive style triggers transfigurations in schemata.

Kuhlthau's (1993a; 1993b) 'uncertainty principle' has served as a valuable insight into the nature of uncertainty. Experimentation attempted to explore Kuhlthau's ideas by attempting to incorporate affective aspects of uncertainty within a model of information behaviour. The possibility that manifestations of uncertainty are symptomatic of limitations to cognitive capabilities has been considered. The ability to assimilate new information is burdened by cognitive load. Kelly's (1963) personal construct theory is an attempt to explain the affective experiences of individuals. Kelly suggested that when new information is assimilated, confusion increases as inconsistencies and incompatibilities are found. If the information becomes too threatening, then it is discarded. Kelly believed that the user's mood (invitational or indicative) dictates the ease with which information can be assimilated. No evidence was found that suggested goal-directed / exploratory behaviour could be attributed to the cognitive load imposed on an individual (*see* Section 11.10). However, a user's indicative mood was correlated with lower levels of 'technical / affective uncertainty' (*see* Section 11.10).

Dervin (1983) suggested information seeking could be viewed as a process of sense-making. An individual is actively involved in finding meaning that fits in with what they already know within a personal framework of reference. This makes the process of identifying novel concepts during the process of providing feedback difficult.

Kuhlthau (1991) argued that a model representing a user's sense-making should incorporate: physical, actual actions taken; affective, feelings experienced; and cognitive, thoughts concerning both process and content. Since people have a limited capacity of assimilating new information, they purposefully construct meaning by selectively attending to that which connects with what they already know. Kuhlthau speculated that the mismatch of user perception and actual experience might increase confusion and anxiety. The representation of the intrinsic cognitive load concept enables Kuhlthau's speculation to be tested. Intrinsic cognitive load is a measure of a mismatch between perceptions (an initial utility judgement) and actual experience (post-task utility judgement) (*see* Section 9.1).

Evidence was found to support the assumptions that 'conceptual / cognitive state' uncertainty and 'technical' / 'affective' uncertainty were reliable measures of knowledge obtained from previous search interactions (*see* Section 11.3). It has been discovered that knowledge obtained from previous search interactions was responsible for intrinsic cognitive load, and consequently, could be partially responsible for the way individuals assimilate information. Individuals who were able to manage uncertainty in response to situational demands experienced less intrinsic cognitive load (*see* Section 11.10).

12.3 INTRINSIC AND EXTRANEOUS COGNITIVE LOAD

Intrinsic load is the individual-specific difficulty associated with a retrieval task (dependent on user expertise and task complexity). Extraneous load is the individual-specific difficulty associated with identifying pertinent information (dependent on learner activity).

Intrinsic factors can be conceptualised as components of an individual's 'anomalous state of knowledge' (Belkin, 1977), or 'state of uncertainty' (Ingwersen, 1992). Essentially, intrinsic factors are components of an individual's knowledge state, which is comprised of schemata (Cooper, 1990), which are accessed using heuristics (Simon, 1969). The state of an individual's knowledge governs the amount of cognitive load imposed on the individual. Sophisticated knowledge states can be held more easily in working memory. Less sophisticated knowledge states cannot be held entirely within working memory so a higher cognitive load is imposed. These principles are identical to the ones proposed by all researchers who apply Cognitive Load Theory to their various research fields (*see* Section 6.2). No new assumptions about an individual's cognitive architecture have been made. Knowledge obtained from previous search interactions is responsible for intrinsic cognitive load, and consequently, could be partially responsible for the way individuals assimilate information.

Extraneous factors can be conceptualised as components of an individuals 'work space' (Ingwersen, 1992) or 'naming and projected structure stage' (Fauconnier, 1997). Extraneous load is governed by the suitability of the heuristics chosen for addressing an individual's information need at a specific point in time. More suitable heuristics enable information to be processed in a way that is more compatible with existing knowledge schemata. Task complexity (*see* Section 11.8) is responsible for extraneous cognitive load, and consequently could be partially responsible for the way individuals interact with information objects. Individuals who were able to spontaneously restructure knowledge in response to situational demands experienced less extraneous cognitive load (*see* Section 11.10). Selecting suitable heuristics that can, in some way anticipate holistic task needs, reduces task complexity and extraneous cognitive load.

12.4 UNIVERSAL CAUSAL AND ASSESSMENT FACTORS

Both causal (intrinsic) and assessment (extraneous) factors affect cognitive load. Causal factors are the characteristics of an individual (e.g., cognitive abilities, and domain knowledge), while assessment factors are characteristics of the mental effort needed and the mental load imposed. Previous studies[1], which used Cognitive Load Theory, reported similar conclusions that are possibly universally applicable to many domains. The following aspects are known to impose a heavy cognitive load: inappropriate problem solving methods; integrating several sources of information; and unnecessarily repetitive information. The Cognitive Load Theory proposed within this thesis drew similar conclusions (*see* Section 12.3). Knowledge obtained from previous interactions can cause problems when assimilating (integrating) several sources of information. Task complexity can cause inappropriate heuristics to be selected (problem solving methods). A universal aspect not investigated was that of 'unnecessarily repetitive information'. Documents presented to experiment participants contained conceptually different information. Future research could investigate this aspect by presenting documents that conceptually overlap.

The natural progression of the information seeking process ensures that behaviour progresses through a number of characteristic stages. A number of information seeking behaviour models exist (*see* Chapter 4). The majority have attempted to represent search behaviour by modelling a single process. Wilson (1999) believed that a unifying framework is needed to express the structure and the processes involved in successive searching. This is an aspect that previous models have not addressed. Wilson identified that a key part of the problem solving process is that of 'uncertainty reduction'. Schutz (1967) believed that stored experiences contain non-ostensive characteristics that can be used to perceive new experiences. From this, Wilson hypothesised that when uncertainty fails to be resolved, this may result in a feedback loop to a previous stage in the problem solving process. Increasing the certainty associated with a previous stage may reveal new characteristics that can be used to perceive new experiences.

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[1] Ayres, 1993; Paas, 1992; Van Merrienboer and Krammer, 1987; Cooper and Sweller, 1987; Sweller, Chandler, Tierney and Cooper, 1990.

Wilson also believed that during goal-seeking behaviour, an individual moves from uncertainty to increasing certainty and that there are stages in the problem resolution process that are identifiable and recognisable to an individual (*see* Figure 12.1).

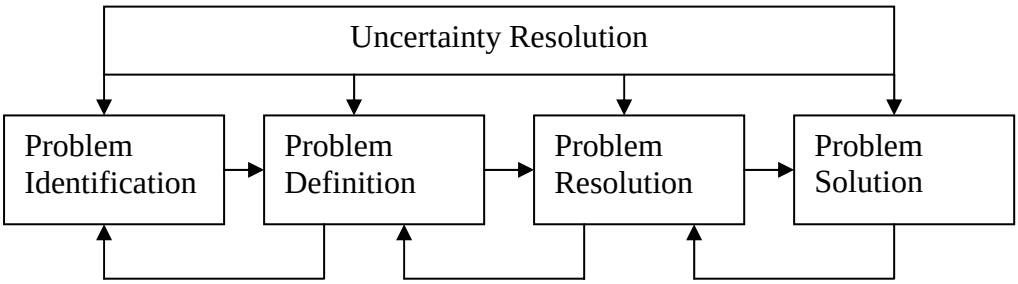

FIGURE 12.1: UNCERTAINTY RESOLUTION (Source: Wilson, 1999)

Although Wilson's problem resolution chain model was a worthwhile attempt at enabling the unification of information seeking models, it is not suitable for modelling the feedback process investigated within this thesis. Wilson's reliance on Schutz's 'uncertainty' conjecture should be called into question. A 'global uncertainty' measure is assumed to trigger a feedback loop.

Evidence was found (*see* Section 11.6) that if an experiment participant was able to identify passages as not being useful, this implied that 'conceptual and cognitive state' uncertainty was low enough to allow this behaviour. If a participant was able to identify passages as being potentially useful, but was unable to integrate these within an answer construction, this perpetuated 'technical / affective' uncertainty. Results show that an 'Initial Utility Judgement' can be better explained when both 'conceptual and cognitive state' and 'technical / affective' uncertainty are considered at the same time. Although they measure separate aspects, when combined, they are likely to be more effective in assessing overall uncertainty. However, it was discovered that a measure of overall uncertainty was not a suitable predictor for the level of intrinsic or extraneous cognitive load imposed on an individual. This finding suggested that the use of a global uncertainty measure is unsuitable for modelling feedback utility. An alternative approach is required. This approach might also be suited to modelling a unifying problem solving structure and the processes involved in successive searching (*see* Figure 12.2).

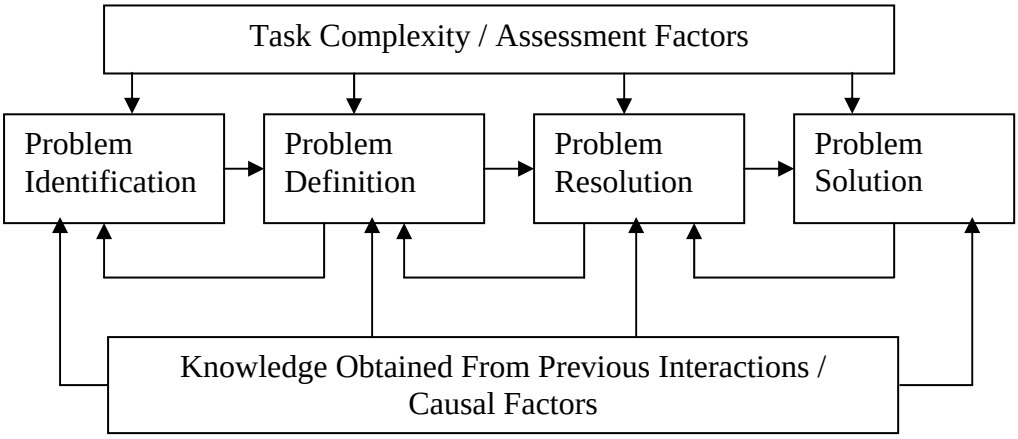

FIGURE 12.2: CAUSAL AND ASSESSMENT FACTORS

Figure 12.2 shows that a feedback loop is more likely to be triggered by causal and assessment factors rather than global uncertainty. For relevance feedback purposes knowledge obtained from previous interactions is a powerful causal factor; and task complexity is a powerful assessment factor. If either of these factors are found to impede the resolution of the next problem solving stage, this might trigger a feedback loop to a previous stage. It must be emphasised that different causal and assessment factors need to be investigated to provide a generalizable model. The flexibility of using Cognitive Load Theory may allow new causal and assessment factors to be identified for different types of information seeking behaviour, i.e., not just for relevance feedback.

12.5 HEURISTICS

Intrinsic factors are components of an individual's knowledge state, which is comprised of schemata, which are accessed using heuristics. Extraneous load is governed by the suitability of an individual's heuristics at processing information objects. More suitable heuristics enable information to be processed in a way which is more compatible with existing knowledge schemata. An argument, detailed in Section 12.1, proposed that individuals are not consistent in applying the same processing style for every task they undertake. It is theorised that new search heuristics are generated when an individual is unable to assimilate information during the search process.

Theories of field dependent and field independent cognitive styles have a number of implications for information seeking behaviour. Witkin and Goodenough (1981) identified a number of other cognitive styles that have an impact on learning: Differences in the extent and intensity of attention; Differences in remembering distinct memories versus the tendency to merge similar events; Speed and adequacy with which alternative hypotheses are formed and responses made. Although it is possible to observe some types of cognitive behaviour during information seeking, most cognitive styles cannot be observed directly. Categorising participants as possessing a particular cognitive style by performing psychometric testing is often the only method. It is proposed that individuals are not consistent in applying the same processing style for every task they undertake. Categorising an individual as a holist or serialist is not always a valid approach (*see* Section 12.1).

Pask (1976b) and Witkin et al. (1977) both found that learning outcomes were positively affected by presenting the same information in a way that matched an individuals learning style. Daniels (1986) claimed that when developing user models, crude over-generalisations might arise when the system is forced to match a user with a preconceived behavioural template. Individuals undertake information seeking to facilitate understanding. Pollock, Chandler, and Sweller (2002) found that artificially reducing the element interactivity of complex information allows elements to be processed serially.

Results from Pollock et al's study indicated that for complex information processing, information is often better understood through isolating interacting elements. This finding is of considerable importance to the study of information behaviour. It may help explain one of the reasons why individuals undertake different information seeking (or browsing) behaviour even though they can be categorised, by psychometric testing, as possessing a preferred cognitive style. During the answer construction process, participants who made more modifications were likely to be engaged in a more active learning / problem-solving process. This indicated that the cognitive load imposed on them was not high enough to prevent the modification of heuristics. It is theorised that new search heuristics are generated when an individual is unable to assimilate information during the search process. These heuristics may be used to enable understanding by isolating interacting elements.

12.6 PREDICTION

Cognitive Load Theory applied to the domain of problem solving provides a pragmatic insight into how information can be presented in a way that circumvents cognitive limitations. When Cognitive Load Theory is applied to the domain of learning, fewer pragmatic insights are likely as the interpretation of meaning affects understanding in ways that cannot be modelled by Cognitive Load Theory. However, Cognitive Load Theory can be a useful framework for the exploration of behavioural processes during learning.

The development of a relevance feedback system that attempts to predict usefulness is problematic. Such a system would need a model of situational usefulness that can be inferred from the user. Passage relevance feedback is most likely to allow the context of a situational need to be inferred, as selection of individual terms does not reveal context. The model of Cognitive Load developed within this thesis enables the utility of feedback to be predicted during the information seeking process. Feedback has been shown to be more accurate when an individual is able to manage the cognitive load imposed by identifying 'usefulness clues'. These clues trigger new heuristics that may be more appropriate for addressing an individual's information need.

Bruner (1986, 1990) believed that IR should ideally be a structured process so that it can facilitate an individual's understanding. Studying information behaviour allows an understanding of the experiences and contexts that enable an individual to successfully retrieve information. Figure 12.3 shows that intrinsic and extraneous cognitive load has the potential to affects an individual's heuristics (search strategies) in different ways. It is theorised that the intrinsic cognitive load imposed on an individual limits the type of heuristics deemed suitable by that individual for addressing their information need. Depending on an individual's capabilities, the most suitable repertoire of heuristics will be selected by them. This selection is based on the knowledge they have obtained from previous interactions (*see* Section 11.3). Individuals who were able to manage uncertainty in response to situational demands experienced less intrinsic cognitive load.

It is theorised that the extraneous cognitive load imposed affects the way in which heuristics are modified. Modification of heuristics is essential to enable information objects to be processed in a way that is compatible with an individual's existing knowledge schemata. Task complexity (*see* Section 11.8) is responsible for extraneous cognitive load, and consequently, could be partially responsible for the way individuals interact with information objects. When an individual discovers concepts that turn out to be much more important than the ones they were contemplating at the beginning, task complexity increases. Modifying heuristics that can, in some way anticipate holistic task needs, reduces task complexity and extraneous cognitive load.

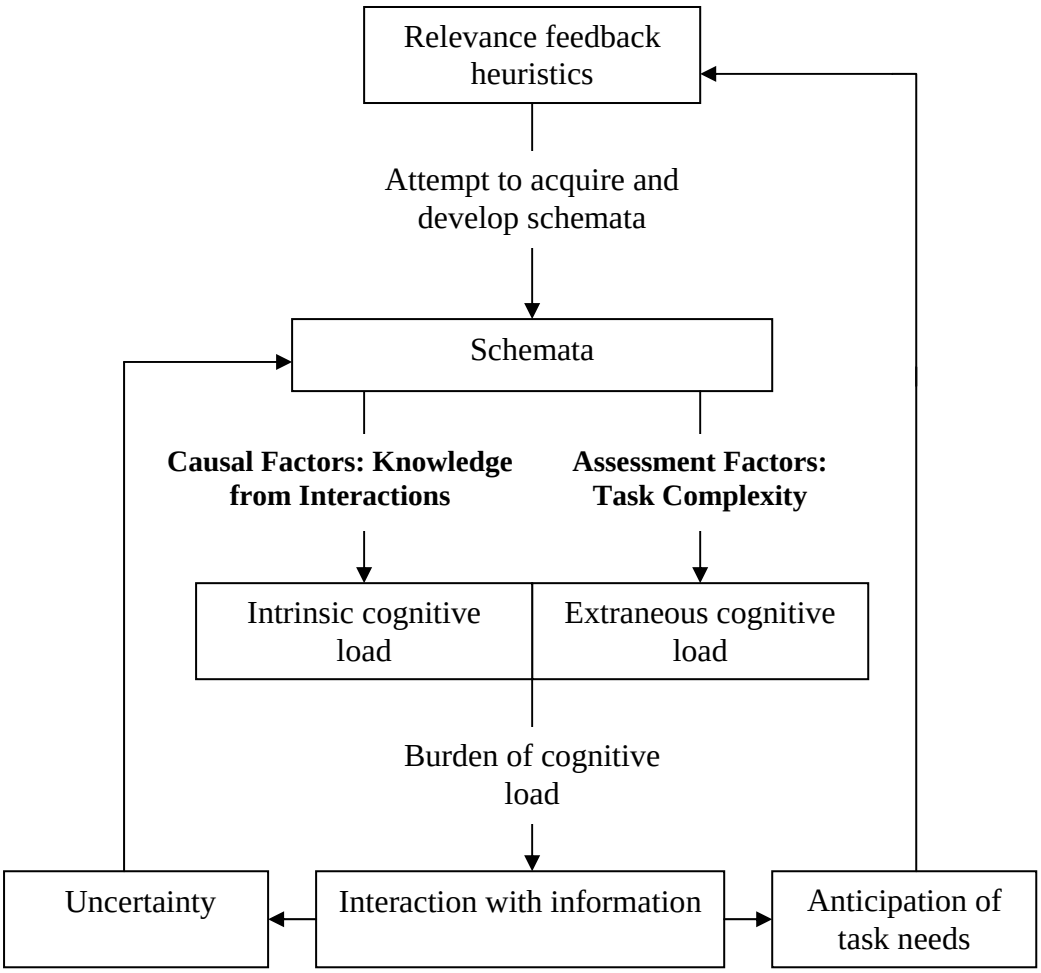

FIGURE 12.3: COGNITIVE LOAD THEORY FOR RELEVANCE FEEDBACK

It is proposed that a feedback mechanism could allow the burden of cognitive load to be modelled. This would require the monitoring of causal and assessment factors during information seeking. The aim is to aid the discovery of new heuristics, which may be more suitable for addressing an individual's information need.

An answer construction process, similar to the one detailed in Section 10.3.3, might allow usefulness incongruities to be identified. An individual's usefulness judgements made during an earlier stage of the search process were generated using less developed knowledge schemata. The analysis of an answer construction process may reveal causal and assessment factors which previously resulted in a high cognitive load being imposed.