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School of
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Human Adaptation to the Web

A Proposal for a Research Programme

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This report elaborates on those research areas that the initial background report of the COPE project uncovered. As a general and common idea, we posit that in order to build a model of Web interaction that is able to describe and predict adaptive user behaviour in a more accurate and comprehensive way, it is of utmost importance to consider how the Web environment constraints the interaction. We propose a rationale for a research programme while leaving some doors open for conducting concurrent and medium-term research on some aspects related to the current proposal. The way users interact in constrained Web interaction environments will be observed to build an initial model, laboratory testing will refine such model, longitudinal observations will confirm its validity and unobtrusive measures will help to cross-validate different findings. Interventions to ameliorate the performance of users and bypass situations of stress will be subject to the predictive power of the model.

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The aim of the COPE project is to investigate the behavioural strategies users adopt while interacting with the World Wide Web, identifying coping situations and providing technological solutions to overcome such difficulties. The COPE web pages may be found at `http://wel.cs.manchester.ac.uk/research/cope/`.

COPE Reports

This report is in the series of WEL COPE technical reports. Other reports in this series may be found in our data repository, at `http://wel-eprints.cs.manchester.ac.uk/view/subjects/cope.html`. Reports from other Web Ergonomics Lab projects are also available at `http://wel-eprints.cs.manchester.ac.uk/`.

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1 Introduction

In our previous report we performed an extensive literature review in order to establish solid foundations for future research in the realm of human adaptation to the Web [24]. Based on such readings, this report aims at uncovering the research avenues opened by identifying those issues that require most attention to advance in the field. Moreover, some hints are given to explore these newly opened research pathways. We discuss how to tackle each of these avenues, which are the expected outcomes and which is the relationship among the research lines. Moreover, we propose a full research programme to comprehensively address all the identified pathways, explore their dependencies and analyse the demanded requirements. Finally, a rationale to follow one research path, out of the identified ones, is made in the context of the COPE project, and future works are anticipated.

2 Background

Based on human behaviour evidence, Simon Harper's [8] and Yeliz Yesilada's [26] PhD theses provided visually impaired users with mechanisms to overcome accessibility problems in the Web. As a natural continuation and extension of their work, Darren Lunn's Phd thesis, *Towards Behaviour-Driven Transcoding of Web Content Through an Analysis of User Coping Strategies* [12], paved the way to investigate the behavioural strategies that visually impaired users adopt in the Web. This work particularly focused on identifying the coping strategies visually impaired users adopt while browsing the Web so that a transcoding tool could bypass coping situations and improve the Web interaction experience. Based on user observation and informal discussions that took place during two periods of two months (see [14], [15] for each period respectively) and an independent third-party data source [11], a complete set of coping strategies were found [13]. The outcomes of such observations are invaluable as they give a novel perspective on how visual impaired users react and find solutions when they find obstacles. In addition, the deployment into a transcoding tool of those mechanisms that allow to bypass such situations resulted in an increased performance of users.

In order to go further, this report aims at revealing how future research could naturally extend the research line that has run so far. This report addresses the questions that can give some hints on the possible research directions to be taken. Not only are such directions described in detail, but also a coherent sequence is proposed, and the relationships and dependencies among them are taken into account.

3 Considering Internal Regulation Processes in Web Interaction

In this section we propose an observational model of Web interaction that establishes a two-loop perspective to analyse adaptive human behaviour in the Web. The primary loop describes the interaction and it is the result of following behavioural strategies. Users keep track of how their strategy is coming along while continu-

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ously receiving feedback from the Web environment. If it is considered that the current strategy is correct users will maintain it, whereas if the current strategy is regarded as misleading or erroneous the strategy may be changed or redirected. As we have learned, keeping track of the strategy is fundamental to attain successful outcomes and it is highly dependent on working memory load. Skilled users[1] apply their strategies in an almost automatic way and their freed working memory enables them to keep track of the state of the interaction. On the other hand, inexpert[2] users' working memory is busy trying to decide their next step towards the goal. These are some of the keys of why skilled users perform better: automatization of tasks and having enough working memory to assess current state with respect to the goal.

The secondary loop illustrates how internal regulation mechanisms send alerting signals to the individual when, as a consequence of the actions taken in the Web environment, user resources are exceeded. As a result, users' internal equilibrium and autonomy is lessened, and the secondary loop describes how users act to gain this equilibrium and increase their freedom by operating the Web environment. Appraisal and coping work as internal regulator mechanisms to overcome the instability caused by external disturbances. We posit that both coping and appraisal do affect the interaction on the primary loop as a way to gain internal balance. Appraisal is the evaluative process that assesses the risk involved by the disturbance. We therefore hypothesize that appraisal impacts on the problem-solving strategy of the users. There are two types of coping strategies: emotion-focused coping and problem-focused coping strategies. The former try to overcome the emotional demands of the encounter (or interaction), and the latter aim at tackling the problem applying strategies directed to the Web environment, to users themselves or to the external environment.

We found that depending on the expertise level, different strategies can be adopted in the primary loop. Therefore, these strategies can also trigger different internal reactions on users depending on their expertise. Hence, the expertise level strongly determines the way regulations occur and the interplay between the interaction loop (primary) and the internal regulation loop (secondary).

3.1 A Novel Perspective on Web Interaction

Navigation is the most complex form of spatial orientation. As far as Web navigation is concerned, there are several relevant studies and taxonomies on browsing behaviour in the Web [27]. We show an ethologist perspective adopted by Franz and Mallot [5] that mimics animal behaviour with respect to navigation and way-finding because of its generality and applicability to any domain (see table 1). The table is divided between local navigation (upper side) and way-finding (bottom side) mechanisms. According to the provided definitions, navigation requires recognising the location of the goal and choosing the actions that lead to the goal within the range of possibilities of the current environment. On the other hand, way-finding involves

[1] Skilled users are those who have enough expertise to accomplish tasks in unknown sites without major difficulty.

[2] Inexpert users are those who find problems to accomplish their tasks in any site.

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the recognition of several places and it allows to find places that are out of the scope in the current environment. Each navigation mechanism requires the competences that can be found in the fourth column of table 1.

Table 1: Navigation mechanisms drawn from biological navigation mechanisms [5].

		Behavioural Scale prerequisite	**Navigation Competence**
Navigation behaviours	Search	goal recognition	finding the foal without active goal orientation
	Direction following	align course with local direction	finding a goal from one direction
	Aiming	keep goal in front	finding a goal in a local area
	Guidance	attain spatial relation with surrounding objects	finding a goal by its relation to the surroundings
Way-finding behaviour	Recognition triggered response	association sensory-pattern action	following fixed routes
	Topological navigation	route integration and planning	flexible concatenation or route segments
	Survey navigation	embedding into a common reference frame	find paths over novel environments

It has to be taken into account that navigation is a goal-oriented behaviour and there are some other forms of spatial behaviour such as exploration, obstacle avoidance and foraging, amongst some others, which are not considered in table 1. In this report, when referring to all spatial orientation in the Web in general, be it goal-driven or purposeless, it will be called browsing.

When it comes to the implications of adopting different browsing strategies, the fact that they set different expectations on their outcomes and require different degrees of competence leads to different levels of reinforcement, if expectations are met. In this sense, we learnt that depending on the tactics adopted different emotional responses such as arousal, effort or activation are triggered [24]. Also, depending on the strategy, individuals may allocate different attentional or memory resources to accomplish their goals. Therefore, we claim that the particular browsing strategy should be considered when analysing the impact of internal regulation processes on the performance.

The individual is the entity that operates the Web environment; assuming that the consequences of such operation have reciprocal causation entails that human action effects on both the environment and on the individual. An ecologically valid approach that deals with internal regulations should take into account the interplay between cognition and the Web environment, and the consequences of destabilizing perturbations in both of them.

We have learned that users operate the environment making use of adaptive behavioural strategies. Generally speaking, under regular conditions inexpert users adopt a conscious problem-solving approach, while skilled users tend to automatize their actions and operate (mainly) unconsciously. While users operate the Web environment disturbances can be provoked: when users' autonomy and freedom to operate decreases; and when adequate information of the environment (because

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of lack of information or because of its overload) cannot be kept. As a result, individuals' physiological variables are set out of an acceptable range, causing stress and interfering in learning, memory, perception and ultimately in performance [20]. In such circumstances, in order to get to a stable situation the user will adopt a coping strategy to overcome exceeding emotional and environmental demands. Inexpert users tend to adopt an emotion-focused strategy, while skilled users often take a problem-focused coping strategy. Compared to a regular problem-solving strategy, problem-focused coping is more evaluative due to appraisal processes. The relational perspective to analyse stress states that stress should be analysed in the scope of the relationship between individuals and their environment.

Thus, if we are to consider the effects of adaptive behaviour in a Web environment, we believe on the suitability of the lens model. The lens model contemplates, and allows to address, the following requirements that enable to analyse the effect of internal regulations on Web interaction:

- It is suitable to shape the embodiment between human cognition and its operation on a Web environment.
- A goal Web page can be considered a distal object, while the cues that lead to it can consist of the contextual information of hyperlinks such as the link label, with surrounding text, proximal headings and multimedia content.
- Adaptation and coping often act as heuristic approaches that introduce uncertainty; this calls for a framework that leaves out determinism and can be probabilistically modeled.
- It is suitable to model navigation and way-finding strategies in an hypertexted Web due to the nature of links as cues that lead to distal pieces of information.

The lens model can partially be deployed into the primary loop of an individual-Web environment reciprocal interaction scenario. However, the lens model does not take into account the role of secondary and remaining loops. That is, the influence of appraisal and coping on the interaction with the Web environment is left out despite the fact that the ultrastable system potentially provides a skeleton for such considerations. We propose a workflow that deploys the lens model on its primary loop, illustrated by figure 1:

At the primary loop,

1. Users operate the Web environment applying adaptive strategies that focus on selecting the proximal cues that lead to a distal goal.
2. Users keep track of the state of their strategy as the Web environment gives feedback in terms of the effects caused by the execution of actions.

At the secondary loop, the effects of a given strategy on the primary loop can cause the following situations:

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- **Option 1**. Users are not able to keep internal conditions as their actions and information processing capabilities have been exceeded due to any of these two reasons:
  - The lack or excess of information does not allow users to keep adequate information about the Web environment they are operating.
  - The limited autonomy or freedom to operate the environment.

  Exceeding users' resources provokes stress entailing that they will make use of coping strategies (either emotional or problem-focused) to increase their autonomy or get to the right place, where the desired piece of information is located. Some strategies will be directed to the Web environment (e.g., selective attention), others are directed to the user (e.g., trust on oneself) and some others are directed to the external world (e.g., active invocation of help).
- **Option 2**. Internal conditions are maintained within limits and the strategy at the primary loop is kept.

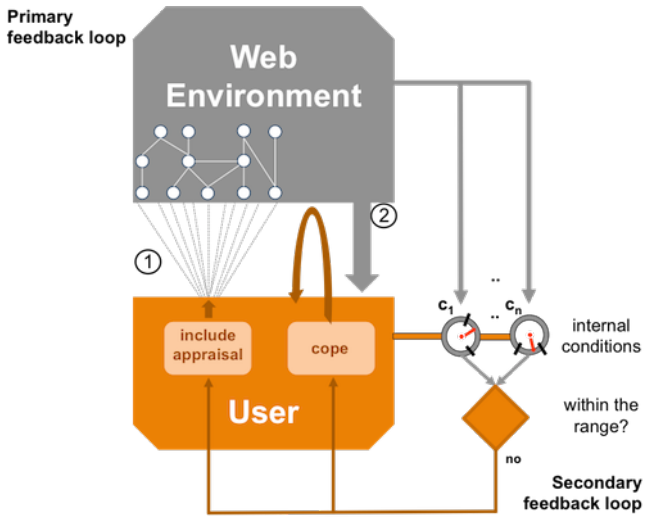


Figure 1: The effect of appraisal and coping on the interaction with the Web environment.

Coping is preceded by an evaluative appraisal stage. Concretely, appraisal is the assessment of a situation that causes stress so that stress can be overcome. Therefore, under stress, the appraisal of proximal cues does play a fundamental role in the interaction, link search and link selection strategies. Consequently, assuming there are not constraining time factors the situational factors that influence appraisal should be carefully considered, if coping strategies are to be analysed:

- *Novelty* is related to the expertise of users because their past experiences will shape the way they address a forthcoming problem or the way in which they will pursue a goal. Therefore, past experiences will determine the way a user will operate a new Web interface or conduct a new task in a familiar

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one. Cognitive models of Web navigation analysed in the first COPE report [24] address link selection and searching strategies in such novel situations. Similarly, the implications of expertise are thoroughly explained in section 3.3.1. Summarizing, we can affirm that skilled users have more procedural and factual knowledge already available in long-term memory compared to what inexpert users have. Therefore skilled users are able to directly apply such knowledge in their strategies while using working memory to keep track of the current strategy. On the other hand, inexpert users' performance is hindered because their working memory is occupied with problem-solving strategies, which does not leave room for keeping track of the status of the strategy. We conclude that the management of working memory determines in an important way how the primary loop works, and it could be a proxy for measuring user expertise.

- *Predictability* conveys the ability to anticipate the outcome of an action. Specifically in this context, predictability is about being able to ascertain in advance that the operation on a Web interface control will produce a certain effect, or following a link will lead to an expected location. The ability to predict is dependent on previous satisfactory outcomes that reinforced the capacity of assessing the predictive values of currently available cues. Being able to identify isomorfic problems and situations on different websites is the key to execute efficient problem-solving strategies.

- *Uncertainty* determines the degree of autonomy and freedom of the user. The less information it is available in a Web environment, the more uncertain it is to operate it. This happens because the environment provides too much information (information overload) or too little. As it is explained above, the lack of freedom causes stress and leads to applying appraisal and coping mechanisms.

- The way hyperlinks and their contextual information (surrounding text, labels and headings) are assessed is determined by their *ambiguity* because it implies a higher number of fixations and assessments of candidate links, and actions taken on the interface. We learnt that a higher number of distractors (e.g., ambiguous link labels) entails a higher number of assessments prior to making a choice.

3.2 Modeling Human Adaptation to the Web

Human behaviour is too diverse to model unless it is sufficiently constrained by the situation or the environment [1]. Therefore, modeling user behaviour is not a straightforward task. When these environmental constraints exist, in order to model behaviour adequately, the environment must be modeled too. This goes in line with the lens model and methodological adaptationism. By adopting Brunswik's model one can use multiple, proximally displayed information sources (cues) of various degrees of reliability (ecological validity) to reach remote (distal) environmental objects. Even if there are some aspects that are beyond the reach of being captured

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for model building, the lens model allows to diagnose the limitations of individuals' performance.

Behavioural data of users' interaction allows to identify their strategies in such a way that interventions to fix strategic and knowledge-based deficiencies can be applied [2]. This will also pave the way to provide mechanisms that help users mastering the execution of strategies under stressful circumstances. Under these conditions, two factors determine the performance of skilled users: (1) the required declarative knowledge; and (2) the efficiency and consistency by which knowledge-based strategies can be executed, that is, procedural knowledge. Systematic failures of knowledgeable users under ordinary conditions implies knowledge deficits, whereas under conditions of stress skilled users do not fail on a systematic basis; while inexpert users are more prone to coping under stress. Therefore, user expertise should be considered when applying interventions to boost adaptivity while removing coping:

- Under ordinary conditions, interventions should aim to provide inexpert users with basic problem-solving knowledge.
- Under extraordinary conditions, interventions should aim to remove the need of inexpert users to cope.
- Under ordinary conditions, interventions should aim to ameliorate knowledge deficits of skilled users.
- Under extraordinary conditions, interventions should aim to enhance the abilities or the strategies of skilled users.

From a perspective of the lens model, knowledge is represented by the appropriateness on the selection of the candidate cues, their reliability and the way cues are combined to make a judgement. It should be noted that in those cases in which uncertainty is diagnosed as the cause of low performance, providing help does not suffice. Instead, adaptive performance will only be improved by enhancing the overall reliability of the proximally displayed information. This entails the improvement of those features that make easy the appraisal stage: removing uncertainty, ambiguity and increasing the predictability of cues.

Appraisal and coping, the adaptive mechanisms adopted as a response to stress, can be analysed by observing individuals' behaviour. Laboratory tests help in isolating those processes that take place while users cope although practical and ethical considerations make it difficult to expose users to stressful situations. That is, one has to wait to adaptive processes to happen instead of forcing its manifestation. Therefore, observations of human adaptation and the effect of internal regulations on behaviour cannot be punctually made but require longitudinal studies. It is only in this way that human adaptation and learning can be measured: by observing how interaction, and link searching and selection strategies change over time. We can say that, in order to capture the dynamic nature of the phenomena, an ecological observation setting is required.

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Ecological settings call for unobtrusive observation tools and techniques. A longitudinal observation tool should harvest interaction data considering those requirements that cognitive models of Web navigation should satisfy (see [24]). We enumerate the features a data collection system should gather in each Web patch[3], distinguishing between the minimum requirements and desirable features as follows:

- **Minimum requirements** are those essential features required to understand the interaction between the primary and secondary loop. They basically consist of the available proximal cues, human action and any physiological response.
  - The number of available links, their labels and contextual information: e.g., surrounding text, headings.
  - The number of available actions: e.g., search box, form submission.
  - The path taken within a Web page: the Web patches navigation path.
  - The path taken between Web pages: the Web pages navigation path.
  - Executed actions such as keystrokes and pointing device clicks.
  - Arrival time and the time elapsed at each Web patch.
  - Physiological measures of stress: e.g., galvanic skin response, blood pressure.
  - Timestamp for all the above.
- **Desirable features** are those by which an extra understanding would be gained and would help building more accurate models.
  - Explicit verbalization that a goal has been attained.
  - Eye-tracking data to model visual attention.
  - Cursor movement, as it has been suggested that helps to understand search behaviour [10].

Table 2 summarizes the way inexpert and skilled users articulate their adaptations, which serves for building stereotyped user models that describe hypothetical inexpert and skilled users. It should be noted that, as they consist of stereotypes, they are mere but useful approaches to depict real users. The transition from the lower-end (inexpert user) to the higher-end (skilled user) of the range contains a large number of intermediate cases, which are very specific and disjoint among individuals.

Users will evolve from the inexpert to the skilled stages by training, by experiencing with different environments and by the mere exposure to them. In this process, search control knowledge is accumulated, which will lead to skill gaining. Not all users are the same and this evolution will be determined by their working memory capacity, information processing constraints and the strategies they used throughout time.

[3]We define the Web patch as the view of a Web page that users can find available without zooming or scrolling. Note that for some users the Web page cannot be considered as the atomic interaction unit because of their constrained view of Web pages (e.g., small display users).

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Table 2: User models that describe how inexpert and skilled users adapt to Web environments.

	Inexpert users	**Skilled users**
The role of consciousness	Conscious adaptation	Unconscious adaptation
Processing	Serial	Parallel
Location at the skill dimension [3]	Problem-solving	Skilled cognitive behaviour
Skill acquisition	Requires effort and concentration	Identification of isomorfism
Amount of search control knowledge	Little	Large
Main browsing strategy	Way-finding	Navigation
Behaviour under regular conditions	Problem-solving	Automatized behaviour
Behaviour under stress	Emotion-focused coping	Problem-focused coping
Behavioural strategies	Backtracking, pauses, trial & error	Deliberated modelessness
Number of strategies considered	High	Low
Error management	Error prone	Errors are still made but fast recovery mechanisms are implemented
Role of attention	Selective attention	Habituation
Role of working memory	Busy focusing on problem-solving and cannot keep track of feedback from the environment at the first loop	Keeping track of the environment at the first loop
Role of long-term memory	Contains disconnected and non-cohesive knowledge units	Large highly interconnected units of procedural knowledge
Goal of interventions in ordinary situations	Provide knowledge	Amend knowledge weaknesses
Goal of interventions in extraordinary situations	Remove the need to cope	Increase ability & strategies
Predictability of behaviour	Low	High

3.3 On the Interventions to Overcome Internal Regulations and to Facilitate the Adaptation Process

One of the goals of modeling user behaviour is to provide interventions that ameliorate user experience in the Web. The goal of interventions would consist of the reduction of the likelihood of suffering from stress and increase of interaction efficiency by providing help to overcome stressful situations. User stereotypes have been proposed in order to cover the wider audience and mainly because human adaptation to the Web is a dynamic and evolutionary skill gaining process. Since user adaptation is a longitudinal process, at each stage of such continuous process, users

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behave in a different way; users can have incompatible needs and requirements and may demand conflicting interventions. User models are used by adaptive systems to tailor interfaces taking into account the features defined in them. However, there are some considerations that should be taken into account when it comes to the use of adaptive interfaces as a mechanism to mitigate internal regulation processes. Next sections warn about the use of adaptive interfaces and the problems of using them as a way to boost the learning process.

3.3.1 Implications on the Expertise Level of Users

Individuals' behaviour can easily be influenced under stress so a minor intervention can make a difference. However, some users (mostly, but not only, skilled users) are reluctant to having interventions. In order to illustrate the issues on the acceptance and usefulness of interventions that aim at improving the skills and performance of end users, Carroll and Rosson describe how the eagerness to action and prior experience determine computer use and interface learning [4]. The fact that learning to operate an interface is complex and users' skills increase at a low rate makes it more difficult. While bad interface design can be blamed for bad computer use, the mentioned phenomena constitute a paradox on interface operation rather than a design problem, namely the active user paradox. There are two paradoxes that constitute the active user paradox: *the production paradox* and the *assimilation paradox*. The production paradox establishes that users stick to their operating procedures even if more efficient techniques are available. In the case of inexpert users, they prefer to adopt exploratory trial and error strategies instead of being provided with guidance, while skilled users prefer to stick to the methods they use. In both cases, users assess whether the time taken to learn new procedures is worthwhile compared to their throughput. In order to foster user involvement in learning new procedures to improve their performance in a short-medium term, some design guidelines have been proposed:

- Reinforcing the user with rewards such as achievement, satisfying curiosity or providing sense of control over the environment.
- Removing the sense of risk when operating the interface by providing simulations of the effect of certain actions.
- Disclosing complex and error-prone functionalities as the expertise level increases.

Additionally, the assimilation paradox posits that individuals apply what they already know in order to interpret and operate new situations. This is useful when previously experienced situations and new situations are similar. Nevertheless, wrong assessments of isomorfic situations lead users to erroneous procedures and prevent them from using available functionalities they have at hand. Therefore, inexpert users are eager to operate an interface rather to learn to use it. Their little knowledge leads them to erroneous inferences about the effects of their operations on the interface. Similarly, prior learning inhibits skilled users from learning. Design

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guidelines to overcome assimilation propose arguable solutions like developing interfaces that mimic exactly the functionalities of the metaphors used (e.g., desktop or notebook).

Aiming at resolving the active user paradox from a cognitive viewpoint, Fu and Gray [6] found that in interactive tasks users adopt generic procedures to operate because it requires less cognitive effort. Since users do not make use of those functionalities that are more efficient than the ones being currently used, they will require more adaptive efforts in the long run. Hence, this strategy leads to a suboptimal yet stable performance. It was found that this happens even when users are aware of optimal procedures, casting some doubt on the rationality principle [3]. In conclusion, individuals ignore procedures that make them more efficient (production paradox) and their reliance on previous knowledge (assimilation paradox) makes them underperform.

3.3.2 Implications for the Adaptive Web

> Interfaces should accommodate universal limitations and exploit universal human strengths. Jef Raskin [17].

Following Raskin's claim, we suggest taking advantage of the habituation phenomena, one of the universal strengths, to design interfaces that allow users to develop habits. Habituation leads to the desired automatization of behaviour that brings about increased performance. It is said that a habituating feature would be the one that can be successfully operated by a blind user. However, exploiting this feature is a double-edged sword as absorption, one of the consequences of habituation, despite being essential for productivity and efficiency, makes it difficult to change one's locus of attention and can cause absent mindlessness. An example for such situation would be the system state that is not visible for the user if is out of the locus of attention. It also explains the production paradox of the active user paradox [4], as the locus of attention on the task makes users unaware of existing interface functionalities (see section 3.3.1).

Absorption is often articulated as a behavioural strategy when the difficulty of the task and stress caused by computer operation absorb users and distract them from operating the interface. Stress leads users to focus on just a few features of the interface making use of selective attention, which is understood as an emotion-focused form of coping. Absorption can be deliberately implemented, and it is often the main objective of interaction designers because it is understood as one of the main features that any aesthetic experience should have [16].

Mechanisms that foster habituation can be implemented by means of modeless interfaces, while some other times *modelessness* is a deliberate strategy to operate an interface when users stick to methods ignoring existing alternatives (production paradox). Modeless interfaces set the path to habituation leading to addictive software products and loyal users. Additionally, uncertain settings are also known to produce engagement on the user (e.g., videogames), which is another manner to provoke absorption. Because of this, playfulness is regarded as one of the features that bring about a satisfactory user experience. Nevertheless, the authors of this

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report believe that generalising the implementation of playful interfaces is a counterproductive practice: users get distracted if the focus of attention is set where it is not due and efficiency decreases, which can be a problem for time critical tasks.

One of the measures proposed by Carroll and Rosson to overcome the production paradox consists of adaptive interfaces [4]. However, it is not clear how these adaptations disturb habituation. When adaptive interfaces change (e.g., from a novel to an expert user interface) it may make users feel in an unfamiliar ground, making them feel unstable and unsettling because learned habits become useless and struggling adaptation (and maybe coping) take place again. According to Gray's research on the active user paradox [7], those users following a non-optimal strategy on a "hard-interface" keep the same strategy when forced to use an "easy interface". On the other hand, when users are transferred from the "easy interface" to the "hard interface" they change their strategy. In conclusion, users adapt more quickly to changes in costs than changes in benefit. Similarly, adaptivity or setting user preferences constitutes modes that can cause frustration on the user: adding customization makes a system more complex and difficult to learn. Users will customize the interface according to subjective judgement, which does not necessarily increase productivity.

There are some interventions that can conventionally remove stress triggers. For instance, when operating an artefact the functionality of interface elements has to be apparent by merely looking at them. This phenomenon is called *interface affordances*. When talking about designing efficient interfaces, the imprecise term *intuitive interface* does often show up. Regarding anticipated behaviour we learnt that individuals do not make use of intuition to make judgements but they are based on previous experience and knowledge. Intuitions are inconsistent between users and thus designing an intuitive interface is an impossible task. Expertise unlike intuition is real. Therefore, we suggest that the terms *habitual*, *familiar* or *already learned* are more appropriate than *intuitive*.

4 Addressing the Identified Challenges

The observational model we propose in section 3.1 is not intrinsically based on our evidence but it is a theoretical perspective built upon empirically backed findings of cybernetics, ethology, evolutionary psychology, behaviourism or cognitive psychology, and even human-computer interaction, in an effort to address individuals' adaptation to their environment. We therefore draw from these fields in order to propose a human-Web environment adaptation paradigm.

Nevertheless, such paradigm has to be put in practice to test whether it leads to better and more accurate observations of human interaction in the Web. Therefore, in order to validate our observational model we suggest to conduct a set of user studies ranging from *in situ* observation to longitudinal user interaction data logging. It is only by this means that we will be able to claim the validity of our approach.

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4.1 Validation of the Web Interaction Model

The proposed observational Web interaction model is a broad scope perspective on human adaptation to Web environments. These environments can be of a different nature and the validation of any navigational model that the observational model can bring about, and its subsequent refinements, requires taking into account those particular characteristics that are determined by situations. A too specific point of view that considers all the interaction context variables is theoretically the most accurate view although it is hardy feasible and generalisable. All environment and situations have their particularities and thus they are all different, there are not two equal situations. On the other hand, a too general perspective would seem a useful starting point to subsequently build more refined models although it may be incomplete and many details might be missing. Therefore, it is necessary to find a niche where we could, to a certain extent, benefit from all the strong points of extreme cases (too focused or too generic) and get rid of their weaknesses.

Our proposal emphasizes that current cognitive Web navigational models do not consider the role of internal regulations. We posit that disturbances caused by the Web environment are of different type, frequency and intensity depending on the interaction context where they take place. A generic Web interaction modality would consider all those situations where any interaction with the Web can occur. The validity of this general approach remains unknown as far as Web interaction and adaptation are concerned. We hypothesize that some situations are more prone to produce stress to the user, as the constraints imposed by the environment are more evident. These environmental limitations cause a lack of freedom to operate the environment because all the available cues are not equally reachable. Figure 2 depicts the relationship between the constrained situation modalities with respect to other modalities.

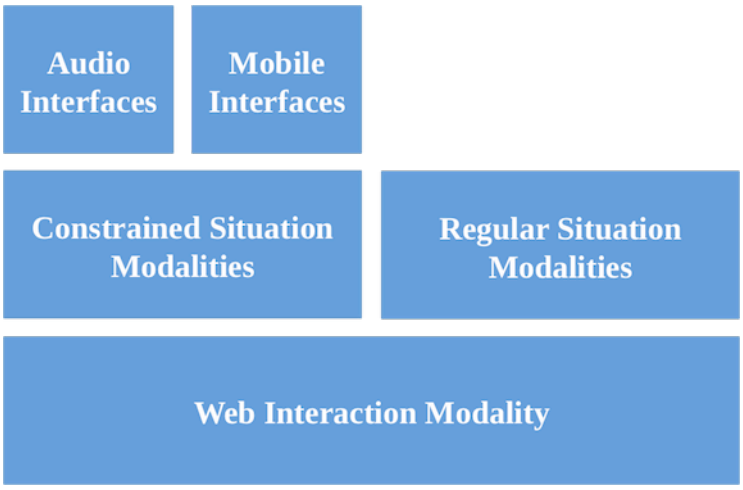


Figure 2: Modality nesting.

We therefore suggest that a Web interaction model that considers internal regulation processes will be better built based on the evidence extracted from constrained modalities, that is, those situations that cause situational impairments or disabili-

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ties [19]. This viewpoint establishes that at certain situations anybody can suffer interaction constraints imposed by the setting. The interesting side-effect of this approach is that interventions aiming at ameliorating such situations are considered to be effective not only in constrained modalities but also in regular ones. We contemplate two main constrained scenarios based on the limitations caused by the output modality:

- **Audio interfaces**. Audio interfaces render content in a linear fashion forcing the user to access information in a quasi-sequential way. In-car devices or screen readers are some of the technologies that provide audio output of on-screen content. User navigability in such interfaces is reduced because only a small portion of the interface is operable at each step. What is more, due to the sequential nature of audio processing and working memory limitations in humans, it is very cumbersome to keep up with an overall view of the interface. When the number of proximal cues is large, the interaction context is likely to be lost.

- **Small devices**. Small displays of mobile or ubiquitous devices do not allow to grasp the interaction context and hide the available cues. Reduced or on-screen keyboards decrease also user throughput compared to desktop computers. Visually impaired users of screen magnifiers have analogous problems to those produced by small screen access restrictions, whereas assistive input technology users and restricted keyboard users share similar problems. Not only physical limitations of devices can cause perturbations on the user but also the situations where these interfaces are operated. People using mobile phones while on translation are more likely to be interrupted from external world events, which distract them from completing their tasks and disrupting their interaction flow. In addition to device constraints, walking while texting or using a location based service, browsing the Web while on a public transport in a bumpy road or tweeting in freezing winter weather are situations where disturbances can destabilize the internal balance of the user.

4.1.1 Case Studies

We propose several observational settings in order to validate a model that would consider internal regulation processes. Even if the observational settings will differ depending on the interaction modality (see section 4.1), data collection strategies would not differ.

1. *In situ* ethnographic studies should be conducted to observe and interview users. One of the goals would be to detect appraisal and coping events of people while conducting their tasks in the Web. The qualitative data extracted from these sessions is valuable in that it allows to gather the motivations of users and their emotional reactions to difficulties. As the observation process should not interrupt regular routines and cause interferences that would otherwise bias the data, obtrusive apparatus and unfamiliar settings should be avoided. Therefore, the browsing strategies that users follow cannot be

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precisely gathered but only a coarse, although still useful, viewpoint can be provided.

2. User observation and interviews are not suitable if the goal is to accurately describe link selection strategies and Web interaction behaviour. Laboratory settings with eye-tracker and physiological analysis tools can give an accurate standpoint to analyse how appraisal and coping affect on human behaviour in the Web. Galvanic skin response, heart rate or blood pressure are widely used biometrics to measure stress; however, the apparatuses used to get these signals are often obtrusive and can interfere on user actions. However, it is the only way to get accurate data on physiological response to stimuli.

3. One of the requirements of the proposed Web interaction model is that data should be harvested in a longitudinal way so as to human adaptation to the environment could be analysed. Even if to some extent ethnographic studies allow to do so, unobtrusive data harvesting by an automatic tool that collects interaction data requires less human resources and is able to gather diverse data types. Thus, remote longitudinal observation of user interaction can be used for confirmatory model validation purposes and to keep track of the learning process.

Table 3 describes the strong and weak points of each observational setting. Intentionally, ethnography allows to get in close touch with users in a naturalistic and unobtrusive setting. However, unobtrusiveness is seldom reached: data and conclusions obtained from these experiences can contain high rates of invalidity due to The Guinea Pig Effect or Interviewer effect amongst others. That is why, in order to avoid these sources of invalidity, and also for cross-validation purposes, unobtrusive measurement could be an invaluable tool [25] jointly with in situ observations. It is feasible to run *in situ* longitudinal studies although they require the presence of the observer, and time is often a scarce resource. This is another reason why unobtrusive measurements can also help ethnographic analysis to obtain observations in a longitudinal fashion.

On the other hand, laboratory settings allow us to gather a large variety of precise data that can range from physiological signal measurement and attentional strategies observation to interviews with users. This comes at the cost of an increased obtrusiveness that can again alter the findings. Neither laboratory tests nor ethnographic observations allow to have a large number of participants, and even if longitudinal studies are feasible they require human, time and monetary resources.

Remote analysis of interaction comes to supply the need of quantitative longitudinal data. Even if obtaining physiological data for a long period of time calls for the utilization of wearable measuring instruments, interaction data can continuously be obtained if appropriate software tools are used. That is why remote longitudinal scale studies require a tool for data harvesting, analysis and visualization.

We posit that a Web interaction model that considers internal regulation processes should consider that browsing behaviour is kept track continuously as depicted by the primary loop, while events taking place in the secondary loop are

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Table 3: Characteristics of different observational settings to validate a Web interaction model that considers internal regulation processes.

Setting	Obtrusiveness	Type of data	Physiological apparatus	Longitudinal scale	Number of users
Unobtrusive observation	low	qualitative & quantitative	✗	✔	high
***In situ* observation**	medium	qualitative	✗	✗	low
Laboratory	high	qualitative & quantitative	✔	✗	low
Remote	low	quantitative	✗	✔	high

discrete. Therefore, in order to have data that allows to investigate the effect of internal regulations on human interaction in the Web, we suggest a combination of the above-mentioned observational approaches. It is only in this way that we can back our hypotheses with valid data. *In situ* ethnographic observation will give initial insights on the phenomena, laboratory data will help in accurately collecting data that otherwise will be difficult to collect, remote longitudinal data will allow to have a more faithful approach to the phenomena of adaptive behaviour and unobtrusive measures will help (not only) to cross-validate the findings. Since it is difficult to obtain longitudinal physiological data, laboratory data should allow to find Web browsing patterns that would be matched with remote interaction data patterns. In this way, we will be able to claim which particular behaviours are caused by internal regulation processes.

4.1.2 Open Issues

The validation of the navigational model we would propose is dependant of the experimental settings where user observation is conducted. While there might be overlaps between interaction modalities (see section 4.1), particular modalities can elicit different browsing behaviours and internal regulation processes can be caused by different stimuli. As a result, the impact of internal regulations on Web browsing has to be addressed in a different way depending on the modality to validate. A preliminary set of open questions enumerates a set of considerations that any Web model should address to cover current limitations. The gaps that future research on cognitive Web models could aim at bridging were extensively described in [24], and can be summarized as follows:

- The adoption of search and scanning strategies backed by empirical evidence.
- The implementation of attentional models.
- The effect of the layout on link selection and scanning.
- Taking into account internal regulation mechanisms in problem-solving strategies.

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- The consideration of user behaviour on familiar websites.
- Contemplating the effect of browsing skill and expertise level on browsing.
- The effect of browsing style on human adaptation to the Web.
- The introduction of irrational choices and behaviours.
- Considering the effect of fuzzy goals.
- The interrelationship of all of the above.

We do not mean that all of the above issues remain unexplored by the scientific community but we propose their inclusion in cognitive Web models. However, there are still some unexplored issues, especially in the realm of constrained interaction modalities, which require further attention, such as the effect of internal regulations on browsing strategies. Some considerations regarding to attentional models, the effect of layout and browsing style are particular to each modality and need special attention:

- Mobile interfaces.
  - Attentional models. Since mobile devices are used on the move, mobile browser users are more likely to be interrupted by external world stimuli. In this context, interruptions are considered those events that are triggered by external entities (e.g., the continuous push of people while standing up on the tube while trying to operate the mobile device at the same time) and by users themselves (e.g., dividing the attention between the screen of a mobile device and the landmarks on the pavement not to deviate from one's way).
  - The effect of layout. The screen and input is often of a limited size and devices tend to have insufficient capabilities so the interfaces tend to be built in three ways: (1) device-tailored interfaces are built considering the specific physical requirements and constraints of the device; (2) transformed interfaces consist of adaptations of higher complexity or more abstract interfaces to a particular device. An example of the latter would be the adaptation of a desktop website into a mobile friendly one through proxies or user agent transformations; and finally, (3) when transformations are not provided, some user agents apply zooming or navigation mechanisms based on the visual layout of Web areas. Obviously, a combination of the three techniques is not infrequent.
  - Browsing style. When it comes to the mobile Web, the above-mentioned user-agent mechanisms are the more frequently used ones. Therefore, users do not have an overall view of an initial Web page as long as they do not completely zoom out. Even then, many elements are lost or the visual layout appears cluttered. We thus hypothesize that the browsing style will determine link scanning and selection, and strategies will be strongly tied to Web patches (zoomed areas and Web spots) rather than to the entire original Web page.

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- Audio interfaces.
  - Attentional models. Users get the output of the interface mainly through the auditory channel and the role of the visual channel is limited or non-existent. Therefore, due to the sequential processing nature of the audio-channel and limited working memory capacity, an overview of the interface is hardly grasped. Link scanning and interface operation is determined by such constraints.
  - The effect of layout. There is no a spatial arrangement of interface elements but they are linearised according to the order of appearance. If the audio interface is specially built for such purposes, a more specific hierarchy and element arrangement can be set in advance. Otherwise, if the audio interface is the result of the transformation of a visual interface by an intermediate user agent (e.g., screen reader), a chaotic arrangement can be encountered.
  - Browsing style. The predominant browsing style is a sequential one. Specially in the case of screen readers, browsing style is determined by the provided navigation mechanisms. Apart from sequential content reading, screen readers provide quasi-sequential mechanisms of link and header navigation. Some users develop their own workarounds: for instance, users tend to memorise the number of links they have to skip, without listening to them, in order to get to a specific target.

For the mentioned constrained modalities, it remains without being explored amongst many others, the way cognitive load and browsing style influence on page-leaving and link selection compared to regular situation modalities; or the impact of accessibility barriers on link selection strategies.

A Proposal for a Web Interaction Model. Some of the open issues mentioned above such as the consideration of visual search strategies are at a mature completion stage [21], while some others such as supporting the skills of novel users can be regarded to be at their outset [23]. The model we will propose should at least be built taking into account the effect of internal regulations in order to be consistent with the goals of the COPE project. Additionally, those aspects that are considered important in order to address human adaptation to Web environments such as behaviour on unfamiliar sites or skill development through time will get special attention. We hypothesized that regulations would be more evident in constrained environments so the models we aim at building will gather evidences from these modalities. Nevertheless, the effect of regulations on regular situations will also be analysed to support our hypothesis and to collect more evidences that help us to complete a holistic model.

4.1.3 Harvesting Web Interaction

For the laboratory and remote observational settings a Web interaction harvesting tool is required. This will facilitate the collection of interaction data and their

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analysis. If we are to focus on Web pages it is of utmost importance to have the time line of updates that happen on those Web pages the user interacts with. Web pages change constantly either by internal updates caused by script execution (e.g., a timer or AJAX call), user action or by updates made by developers. In order to analyse the behaviour and strategies of users, the exact state of a Web page at a given time has to be easily recoverable to make well founded inferences.

To do so, we propose to keep track of changes in the DOM by extracting all necessary information from it and putting it into a more manageable file. The DOM of a Web page has a large amount of information, most of which is not valuable for our needs. The profile we need should contain the necessary pieces of information we previously enumerated (see section 3.2). The information in that profile would be structured following a determined declarative language (e.g., XML-based language) so that it is machine-understandable and processable.

Similarly, user actions will also be monitored according to the mentioned requirements. Analogously, the users' behaviour profile will be built containing keystrokes, mouse-pointer location and timestamps, amongst others. Conversely to DOM updates that happen in a discrete fashion, human behaviour is continuous so it has to be established the sampling frequency for discretization purposes or decide after which event will be the information processed. The information flow of the DOM and behaviour profiles can be described as follows (and illustrated by figure 3):



Figure 3: Information flow of the Web interaction harvesting tool.

1. Once the HTML code is loaded onto the browser for the first time, the browser creates an internal representation of the Web page, that is, the DOM. At this stage, an empty DOM profile is created at the server side and filled out with all the needed information sent from the client. In this way the initial instance of the DOM profile is created. Also, a human behaviour profile that is linked to a sequence of consecutive DOM profiles will be generated.

2. The system will actively monitor DOM updates and human actions. Changes in the DOM are caused by the execution of programmes, use action or updates made by developers. In any case, the system will track and collect such information.

3. When a change in the DOM has consequences on any of the features that are considered important according to the requirements enumerated in section 3.2, the event is sent to the server, where an incremental DOM profile is created. The incremental profile consists of the differential content of DOM profiles between meaningful events. As data may be sent over HTTP (specifically using the `XMLHttpRequest` JavaScript object) on a frequent basis, the rationale

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behind sending incremental updates instead of the entire representation of the DOM profile is to not overload the connection sending a full instance of the DOM. In the case of human action, only the information related to meaningful events will be sent. As a result, both profiles will be updated at the server-side.

As far as the deployment of the client side is concerned, on regular desktop modalities a browser extension or the inclusion of a JavaScript function call will suffice. On the other hand, to date, many mobile or ubiquitous devices do not have scripting capabilities and require more complex settings. Therefore, in order to harvest the interaction in this constrained modality an intermediate Web proxy server would allow to retrieve linking path information, although keystrokes and pointing device actions would be left out, missing in this way substantial information.

4.2 Information Analysis and Visualisation

At different observational settings, interaction and behavioural data can provide information of different type. For instance, at a remote longitudinal setting, depending on the interaction modality only navigation path data (mobility scenario) or, in addition to that, user actions (desktop scenario) can be collected. In both cases, user reporting can also be considered as a way to gather their impressions or answers to particular questions. However, this mechanism lessens the ecological validity of the proposed approaches. As previously mentioned, the laboratory observational setting allows to collect more information, especially physiological and attentional data.

4.2.1 Remote Longitudinal Setting

Assuming all data are available (including those related to human action on a given website), at a remote analysis setting the behaviour profile will consist of a series of events caused by user action. Additionally, a sequence of DOM profiles will store all the states of any Web page while the interaction with it took place. Figure 4 depicts the interplay of two sequences of profiles through time: behaviour profile and DOM profile. In this way, the observer should be able to ascertain the state of the system at a specific time, t_i, by combining the data of those profiles that are more recent with respect to t_i, in this case: DOM_{t1} and $event_1$.

4.2.2 Laboratory Setting

Similarly, in addition to the data gathered at a remote setting, the laboratory observational setting allows to collect behavioural and physiological data. These data could also be encapsulated into profiles in order to facilitate the reproduction of human behaviour in a more accurate way. Physiological data are continuous so it has to be set a particular time threshold, ε, after and before which, physiological and attentional data are considered relevant for event analysis purposes (see figure 5).

Longitudinal data extracted from remote analysis will give a confirmatory sense to the model we want to validate although it lacks the richness and accuracy of the

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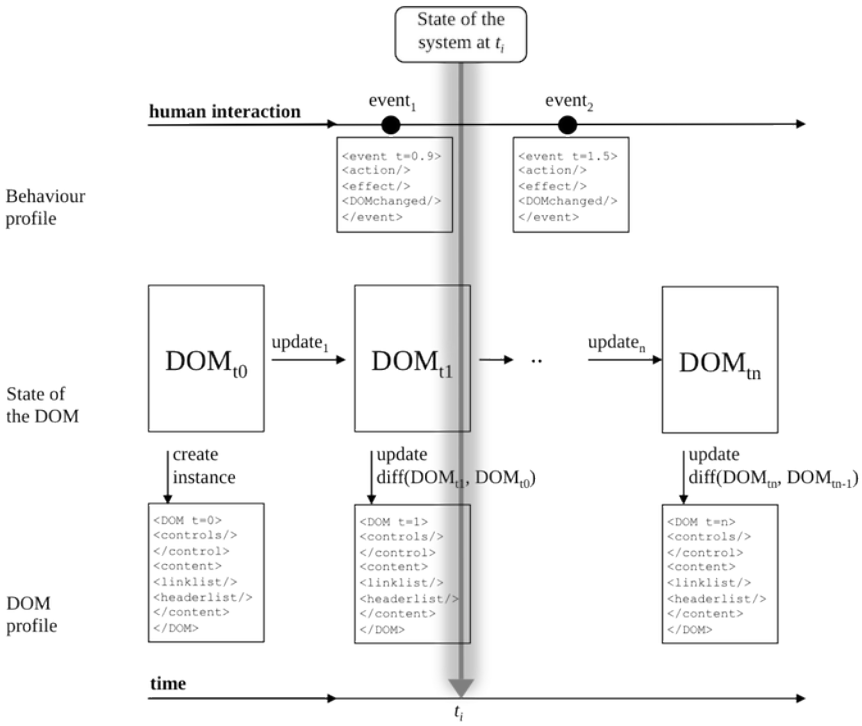


Figure 4: Web interaction harvesting timeline.

observational data extracted at the laboratory setting. Therefore, it is necessary and valuable for research purposes to have the ability to infer particular human behaviour from remote data. To do so, the behaviour patterns found at the laboratory setting will be matched with remote longitudinal data timelines and infer from them, for instance, that a user was trying a trial and error strategy or that a given strategy was adopted to alleviate stress.

5 Predictive Capabilities of the Model

Analysing the predictive capabilities of the model is closely related with the validation of the model. This is because the validation of the model will depend on its predictive power: the more the model predicts user behaviour, the more valid it will be. Existing cognitive models of Web navigation do not have full predictive power because of their weaknesses, but they can predict certain aspects. Nevertheless, these models show some strength when predicting particular behaviours such as link selections, amount of time elapsed in a certain page or Web page-leavings, amongst others.

One envisaged option would be to extend the ACT-R software[4], which is the software that mimics the ACT-R unified cognitive model, with the features that our proposal would take into account (see some open issues in section 4.1.2). CogTool-Explorer [21], a tool that implements the ACT-R cognitive model and addresses

[4]Available at http://act-r.psy.cmu.edu

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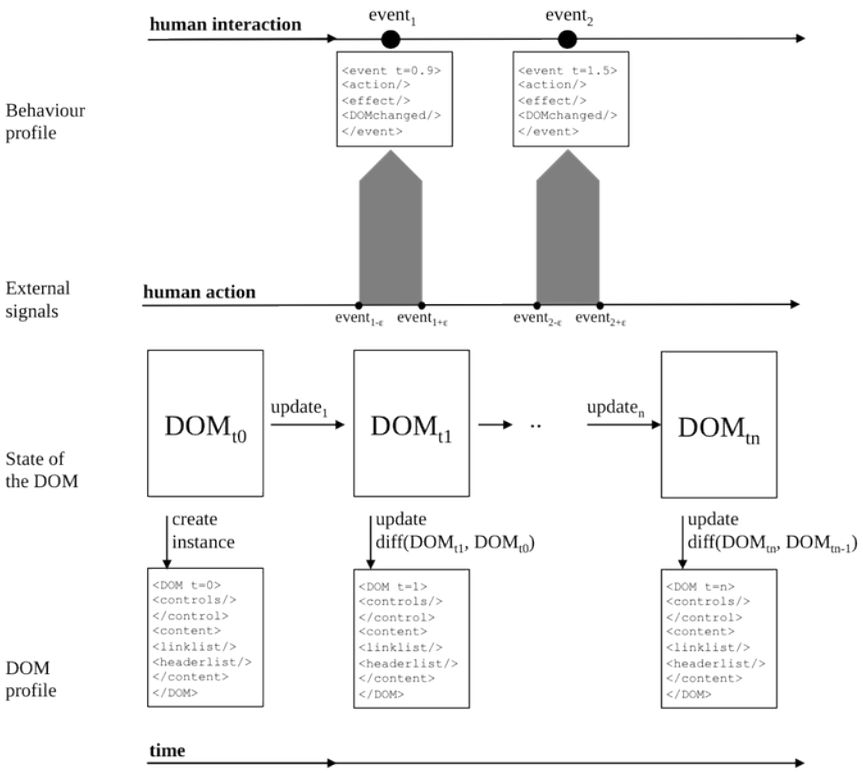


Figure 5: Including physiological data in a Web interaction harvesting timeline.

some of the mentioned open issues such as the deployment of visual search strategies, would be an appropriate platform to extend. Then, its predictive power would be measured by comparing observational data from different settings with the simulation data produced by the enhanced ACT-R based tool.

5.1 Interventions

The interventions that can be made in a given interface in order to accommodate human adaptation will aim at facilitating the learning and skill acquisition process while avoiding stressful situations. However, the type of intervention that can be applied is closely related to the outcomes we get from measuring the model's predictive power. This happens because the modifications that could be injected to help users will only be successful if the intervening tool has strong behaviour prediction capabilities. As a result, if the model was a good predictor of link search and selection strategies, an intervening tool would be able to suggest, for instance, following certain links when users deviate from expected paths. Moreover, if the model was able to infer or anticipate stressful situations, interventions would lead the user towards avoiding (or lessening) such situations.

We hypothesize that interventions will boost user performance and satisfaction with respect to a baseline scenario. Experimental tests should be conducted to investigate the usefulness of interventions. Moreover, since interventions are based

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on Web models, if the implementation of interventions turns out to be successful, the validity of such models would be reinforced.

5.2 Interface Evaluation

A strong predictive power of an hypothetical model would allow to evaluate interfaces according to the criteria established in such model. According to our hypothesis, if this model was used, user performance evaluation in the conceived Web interaction modalities would be more accurate than traditional GOMS or keystroke level models (KLM). This is a particularly unexplored area in the realm of constrained environments. Even if there are some contributions for mobile devices [9] (applying KLM) and screen reader users [22], [18] (applying KLM and GOMS respectively), taking into account the effects that internal regulations have on task completion times and in the decisions made can increase the accuracy of interface evaluation models. In a similar way as in the interface interventions stage, positive outcomes on interface evaluation would back the validity of the model.

6 Research Programme

Throughout this report we have described the challenges that Web interaction models face, especially but not only, when it comes to considering internal regulation processes. If these needs were covered, our hypothesis is that a more faithful approach than state-of-the-art models would be attained. We have made a particular emphasis on the validation stage, as we understand it is of utmost importance to have solid foundations to pursue forthcoming stages. We tried to convey that remaining stages (or research subprogrammes) are strongly tied to the results of model validation; the interventions aiming at ameliorating the interaction of the user, and interface evaluation would pivot on the validity of the hypothetical model. Figure 6 depicts the research programme for building and validating the model, its stages and their dependencies.

Figure 7 depicts a roadmap on the basis that the model shows a good predictive power. Roadmap in figure 6 is to some extent independent of the modalities chosen to build the models (see section 4.1). Conversely, the stages depicted by figure 7 (especially the interventions subprogramme) are dependent on the modalities (if any) the hypothetical model aims at describing. In addition, these roadmaps can be followed in any situation where novel cognitive models for Web navigation are proposed, regardless the consideration of internal regulation processes.

Next sections illustrate how the choice of a particular modality determines the way some of the stages depicted in the roadmap figure 6 and figure 7 can be implemented. Nevertheless, as mentioned, some stages are still independent of the modality studied.

6.1 Building a Novel Cognitive Model for Web Interaction

A priori, non-constrained interaction models are those where users interact with a computer in a *regular* setting (see figure 2). However, all interaction contexts

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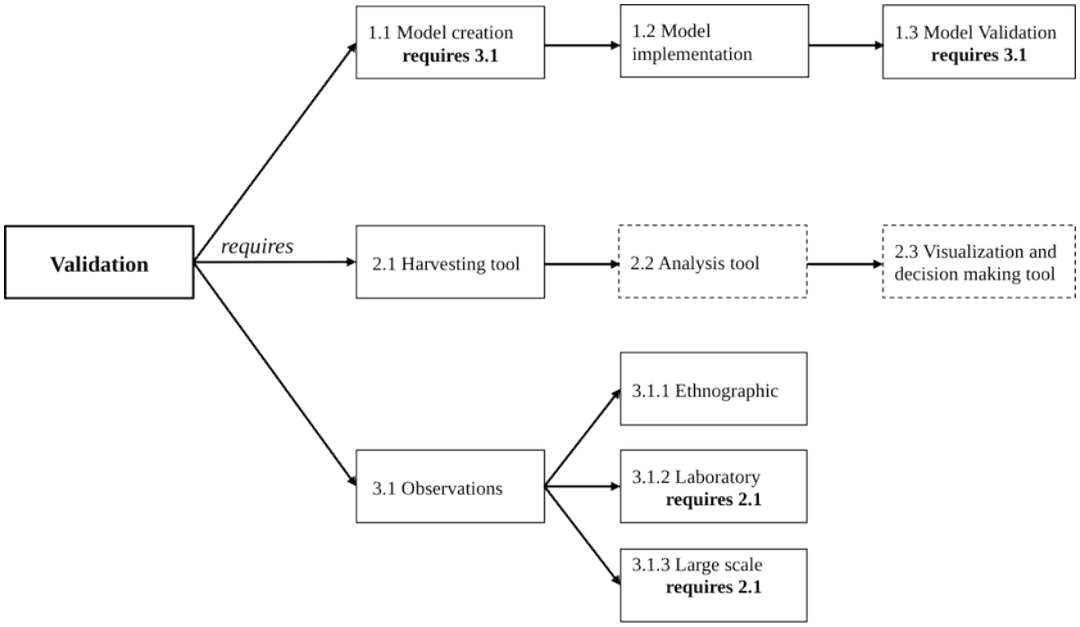


Figure 6: A roadmap to advance in the validation of Web interaction modelling.

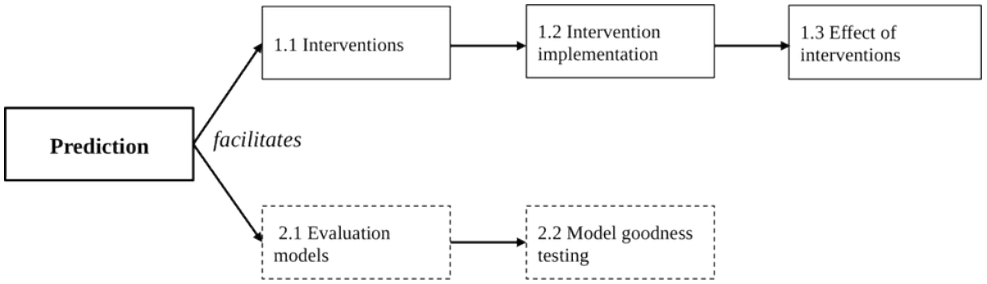


Figure 7: The implications of the predictive capabilities of the model on a roadmap for interface intervention and on evaluation subprogrammes.

are constrained to a certain extent by the abilities and knowledge of the user, the physical limits of the accessing computer or the setting where the interaction takes place. Therefore, drawing a line between constrained and non-constrained interaction of computer interfaces would be a fallacy. For practical purposes, since the vast majority Web interfaces are built with desktop computers and visual displays in mind, those scenarios that meet this conceptualization will be considered regular situations, while those that are far from it will be regarded as constrained situations.

Regular Web interaction models can be enhanced with the listing of identified missing points described in section 4.1.2. Addressing some of these points is a great deal of work and any positive outcome can be regarded as a valuable research contribution. If we had to prioritize, we should bear in mind the goal of the COPE project; therefore, the role of internal regulations in cognitive models of Web navigation would prevail. As far as constrained models (non-regular interaction models) are concerned, we hypothesize that constrained modalities are the most appropriate

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scenarios to observe appraisal and coping phenomena in the Web. The findings in these modalities can be transferred to build not only constrained models but also regular models.

The proposed observational approach of Web interaction described in section 3.1 will provide a better understanding about the role of internal regulation mechanisms at any interaction modality. Since adaptation to Web environments is one the main outcomes of regulation processes, those aspects that address adaptational issues should also be included in a future model. Finally, further stages could also cover those aspects that are not related to internal regulation processes.

6.2 Harvesting Tool

Depending on the Web interaction modality to investigate, the implementation of a harvesting tool for human behaviour observation has the following particular challenges. Regular modalities show some flexibility in that the deployment of the harvesting tool can vary according to architectural and data requirements: as a monitoring script, implemented as a built-in functionality or as proxy. When it comes to constrained modalities and especially to audio interfaces, these interfaces pose some problems if they are embedded into small devices (in-car devices) or are conveyed by screen readers. The former may not allow data to be collected as most of them are close systems, while for the latter, if not the settings of the screen reader (e.g., reading speed), keystroke combinations should be captured with relative ease. In order to capture interaction data, ubiquitous or mobile devices should facilitate the inclusion of monitoring tools and similar; otherwise, users should browse the Web through a proxy.

The development of analysis and visualization tools has a lower priority (denoted by dashed lines in figures 6 and 7) and at the initial stages of the COPE project data analysis could be done manually.

6.3 Observations

Ethnographic and laboratory observations aim at giving a balanced perspective of human interaction with computers. Observation of desktop computers users (both in constrained and non-constrained environments), even if still challenging, can be done in a controlled environment, while a purely ecological ethnographic observation of mobile device users requires outdoors watch.

6.4 Interventions and Interface Evaluation

The major difference between interaction modalities is not the analysis of the behaviour that will lead to model building but the design of interventions. At this stage, not knowing the internal regulation mechanisms and their effects on Web interaction makes it risky to foresee how interventions will be injected. No matter which specific interaction modalities are modeled (aiming to build a generic interaction model or to model a particular modality), interventions will have to be adjusted to the requirements of each model.

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7 Conclusion

This technical report presents an observational Web interaction model that allows a better understanding of adaptive behaviour in Web environments. The novelty of our proposal resides on the consideration of internal regulations to model human interaction in the Web. The foundations of the observational model establish that any human action in the Web is the result of the interaction of two main loops:

- At the primary loop, human action can be illustrated as a problem-solving strategy (in the case of inexpert users) or automatized behaviour (in the case of skilled users) while users try to operate a given Web interface; users dynamically correct their strategies based on the feedback received from the environment.
- The effects of operating the Web can cause physiological destabilization and ultimately stress on users. The secondary loop depicts how users try to find emotional stability by influencing the decisions on the primary loop. As a result, decisions become highly evaluative due to appraisal processes and (mostly) novel users do cope to lessen emotional distress.

It is not by chance that the two-loop perspective is adopted to describe adaptive human behaviour in the Web. This concept is drawn from a cybernetics approach to design self-regulating systems. We adopt the metaphor of Ashby's ultrastable system as it is a generic and adjustable workflow for a common goal: attaining adaptive behaviour [24]. Although there are some resemblances, mainly on the conceptualization and on the goals, the observational model of self-regulating Web interaction is more than a self-regulating system. Apart from the obvious, one of the major differences is that the ultrastable system reacts to external stimuli (matching with the stimuli-response learning paradigm), while our perspective (see section 3.1) leans towards a stimuli-action-effect oriented learning approach. This view is adopted because we assume that human behaviour in the Web is adaptive in that users learn from everything they do. The outcomes of learning are increased performance, skill gaining, and overall, a better adjustment to the Web environment.

The fact that adaptation is a dynamic and a longitudinal process allows to frame adaptive behaviour into user profiles that describe low adaptation characteristics and profiles that encapsulate higher degrees of adaptation. Using another terminology, we can split these profiles into novel and expert users. Based on the adaptation degree of users, we accurately describe two stereotypes (inexpert and skilled users, see table 2) as a coarse grained approach to model human adaptation in the Web. We are aware that user adaptation to the Web is a continuous and gradual process, and thus, there is room for intermediate profiles.

After diagnosing the weaknesses of cognitive models of Web navigation in [24], we propose future works that, in addition to considering internal regulations, try to address some of the identified weaknesses. The objectives to pursue a Web interaction model that considers internal regulation processes are varied:

- It is an invaluable analytical tool to understand user behaviour in the Web and concretely to comprehend how internal regulations affect on user interaction.

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To do so, we identify the environmental and human variables that should be analysed.

- Predictions about how users will interact with a particular interface allow to use the model as an interface evaluation tool.

- We can propose interventions to improve the adaptation process by avoiding stressful situations or, at least, by providing mechanism to bypass them.

We examine the possible limitations of assisting users in facilitating their learning process (see section 3.3.1). We also show a sceptical view on interfaces that adapt to the individual features of users as a way to improve users' adjustment to the environment (see section 3.3.2). To do so, we rather support an approach that targets universal human strengths and limitations.

Taking into account the goals of the COPE project, our following steps will analyse the role of internal regulations in Web interaction. Mobile interaction is left out as it requires particular harvesting tools and observation methods. Moreover, the requirements of constrained and regular desktop environments are more consistent between them than those requirements between particular constrained modalities. Therefore, the model we will propose in the following stages of the project will describe how internal regulations affect on the interaction of individuals with Web pages built with desktop computers in mind. By following this rationale we aim at covering larger audiences with similar resources. What is more, we will set our focus on *edge-cases*, which are the constrained modalities, in order to build non-constrained Web interaction models. We hypothesize that regulation mechanisms at constrained modalities are more observable because they are more frequent and intense than those at non-constrained modalities. However, we posit that regulation mechanisms are of a similar nature and can be treated equivalently regardless the interaction modality. Following this philosophy we can propose that the regulation mechanisms of screen reader users can be transferred to build a model that considers these mechanisms in non-constrained desktop modalities. This goes in line with the *situational impairment* viewpoint to design users interfaces [19].

Based on the roadmaps depicted in figures 6 and 7, the steps that will be taken are described as follows:

1. *In situ* ethnographic observation will give initial evidence on the effect of internal regulations on Web interaction (3.1.1). As a result, a preliminary coarse model will be created (1.1).

2. The development of the harvesting tool.

3. Laboratory observation (3.1.2) will give a more comprehensive view of the phenomena. Thus, the preliminary model will be refined, allowing its first implementation (1.2).

4. The analysis of remote longitudinal data will lead to a confirmatory analysis of the model (1.3), which will be measured by its predictive power.

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5. Throughout the development of the project unobtrusive measures will help to cross-validate findings.

6. Depending on the predicting capabilities of the model, interventions will be implemented and their effect will be measured with respect to a baseline.

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8 Associated Files

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