Enhancing User eXperience during Waiting Time in HCI: Contributions of Cognitive Psychology

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ABSTRACT
Despite technological progress, daily Human-Computer Interactions (HCI) are still encompassing moments where the interaction between the user and the system is temporarily interrupted (file download, setup of a program, etc.). These waiting times are often sources of anxiety and irritation. In order to enhance the User eXperience (UX) during waiting time in HCI, this research based on cognitive models of time perception focuses on the impact of several variables on the satisfaction and waiting time perceived by a user. Variations in waiting time duration, cognitive workload and informational level of a feedback screen are therefore experimentally created to study their impact on satisfaction and waiting time perception. The results confirm the existence of a link between cognitive workload and waiting time perception and may provide valuable information for User Interface design.

Author Keywords
User experience, Time Perception, Cognitive Workload, Cognitive Models, User Interface.

ACM Classification Keywords
H.5.2 [Information interfaces and Presentation (e.g., HCI)]: User Interfaces - Graphical user interfaces (GUI).

General Terms
Human Factors, Experimentation.

INTRODUCTION
The concept of time passing by has always been the subject of many debates through the centuries. Aristotle pointed out that the temporal consciousness does not capture only the present but also the past and the immediate future. Daily, during Human-Computer Interactions (HCI), users have to wait in front of their computer: during the loading of a web page, the setup of a program or its start. In the field of ergonomics, a main part of the recommendations for the usability of systems emphasizes the importance of the feedback provided to the user on the system state [35], especially during these waiting periods. However, research on the estimation of waiting times shows that the fact that a user focuses on these time-related information makes the wait seems even longer [29]. Beyond usability, the ever growing interest of designers toward User eXperience (UX) leads to the need to rethink the interaction. A better understanding of the users and their cognitive and emotional functioning could be the key to effective User Interface design. Cognitive sciences, and especially psychology, therefore contribute to enhance UX of interactive systems. This paper relates how cognitive models of time perception may provide clues to better understand the interaction during waiting periods and thus to design more effective interactive systems.

COGNITIVE PROCESSES IN TIME PERCEPTION

Main Models in Psychology of Time
Temporal information processing in humans has long been of interest in the field of cognitive psychology and psychophysiology [1, 15, 37, 38]. Temporal judgment is indeed a critical psychological capacity for individuals to interact with their environment. The sense of time cannot be directly perceived but is reconstructed by the brain. Underlying cognitive processes are complex and several models have been built in order to identify mechanisms and resources mobilized during the assessment of time and to explain the distortions of subjective time perception (under or over-estimation) [3].

The main models developed are based on the existence of an internal clock [2, 9, 38, 42]. Whatever the model, this clock is always composed of a pacemaker-accumulator system. The pacemaker continuously emits pulses, counted by the accumulator. The subjective evaluation of time relies on the number of pulses counted by the accumulator. The main differences between these models relate to items that are between the pacemaker and the accumulator, or also to the functioning of the pacemaker itself. Each model advocated by its authors seeks to identify the components that promote distortions of subjective time perception.

The first model of internal clock proposed by Treisman [38] defends the postulate that the pacemaker produces a regular pulse rate. Distortions of subjective time therefore only rely on the accumulation of pulses allowed by turning on or turning off a switch. When the switch is turned off, the connection is established between the pacemaker and the accumulator, and the latter may then count the number of pulses transmitted by the pacemaker. When the subject pays no more attention to time, the switch turns on and stops the accumulation of pulses. Therefore, the evaluation of time is based on the amount of pulses the switch has let pass through the pacemaker to the accumulator. A decision-making process completes the model.

The Scalar Timing Theory defended by Gibbon [15, 16] is based on two different assumptions. First, unlike Treisman's model [38] described above, the pulses transmitted by the pacemaker would not follow a regular rhythm, but a distribution under Weber's law. Weber's law "has been taken to mean that variability of an underlying temporal distribution should show a constant coefficient of variation" [16]. The scalar timing model thus relies on time information processing at three interconnected levels: clock, memory and decision. Cognitive processes in terms of memory and decision-making are equally important in explaining the evaluation of time than the clock composed of a pacemaker and an accumulator, separated by a switch.

Finally, it is useful to look at the attentional gate model proposed by Zakay and Block [44] (Figure 1). This model is based on studies by Thomas and Weaver [37], which show that "the experienced duration of a time period depends on the amount of information encoded by a temporal information processor and by a nontemporal information processor […]. Task demands determine the way in which a person divides attention between the two processors. If less nontemporal (stimulus) information processing is required, the person allocates more attention to temporal information, and vice versa"[44]. Therefore, the attentional gate model includes an additional element between the pacemaker and the switch, called a "gate". The gate is a component that takes temporal information into account and coordinates the activation of the switch. The more a person pays attention to temporal signals, the more the door opens, leaving thus numerous pulses crossing through it. Conversely, if the person does not pay attention to temporal stimuli or is distracted by other events, the attentional gate will therefore tend to close, thus leaving few pulses crossing through. Last component of this model, working memory will in turn create a representation of elapsed time, based primarily on the number of pulses relayed.

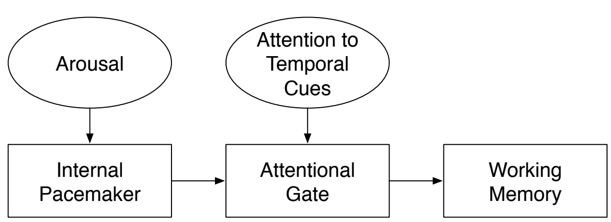

Figure 1. The Attentional Gate Model of Prospective Time Evaluation ([4], adapted from [23]).

Following this model, if one has the will to shorten the perceived time duration; it must either reduce the person's level of arousal or divert his attention from time signals [43].

Among the models described (for a more comprehensive literature review of the models in cognitive psychology, please refer to [3, 17, 28]), we selected here the attentional gate model described above [44]. Indeed, we believe it encompasses the necessary features to be applied to the study of temporal judgments in the context of HCI.

Several arguments support our choice. First, the components of the attentional gate model are quite easily understandable and may be operationalized in the context of an interactive system. The adaptation proposed by Block et al. [4] might be accessible even to a non-expert audience and we could think of teaching this cognitive theory to interactive systems designers. Understanding the factors impacting the perception of time may indeed help designers and UX specialists to think about new ways of designing user interfaces. Second, beyond the practical interest for practitioners, the attentional gate model is well suited to explain the distortions of time perception in the field of HCI research. Branaghan and Sanchez [6] already applied this model to the effects of various feedback displays on user preferences, perceived waiting duration, waiting time reasonableness, and other user experience measures. Finally, the model takes full account of the attention paid by the subject to the information presented to him. Now, we believe that the role of attention is crucial in the context of HCI since tasks performed on computers usually involve significant cognitive resources, which encompass attention [7]. The main interest lies in the possibility for designers to attract or divert users' attention, therefore acting directly on their perception of time.

To summarize, in agreement with Kum, Lee and Yeung [26], we consider that the perception of waiting time is not a linear and stable cognitive construct, whose growth is estimated from constant and continuous flows. It relies instead on complex cognitive processes that take into account both the moment when the estimation of perceived time occurs (evaluation during or after the waiting time), but also, during a subsequent evaluation, the recovery mechanisms that are involved in memory and influenced by recency and primacy effects [36].

Prospective vs. Retrospective Duration Judgments

Research on the perception of time distinguishes two paradigms depending on the moment when the evaluation of a perceived duration is performed by a subject. In a prospective paradigm, individuals are informed that they will have to estimate the duration of a given time interval. Conversely, if they are not aware before the experiment that they will have to estimate a perceived time duration, they are performing a retrospective judgment [43]. In a meta-analysis performed on 117 experiments, Block, Hancock and Zakay [4] show that when the cognitive load is high, appraisal time decreases while the retrospective assessment increases. Prospective evaluation of time would thus be dependent on attentional processes while retrospective evaluation would be influenced by memory processes. Zakay [43] adds that in a situation of waiting, people are automatically busy performing a prospective duration judgment because waiting time attracts their attention and becomes the most salient factor in their environment.

The Primacy-Recency Effect

Relevant research on memory has shown that humans do not reminisce about the events in a consistent and linear way, but rather with selectivity and bias [1, 5].

Thus, the effects of primacy and recency respectively denote the phenomena of remembering more easily the first or the last moments of an event. Unlike the primacy effect, which is stored in long-term memory (LTM), the recency effect depends on short-term memory (STM). It is therefore less stable and can be affected by a retention delay exceeding 15 to 30 seconds or by the performance of an interfering activity [13]. A retrospective evaluation after such a period or following an interfering activity would therefore be solely dependent on the primacy effect. Conversely, prospective or retrospective assessment carried out without retention delay would be dependent on both primacy and recency effects.

Time Perception and Cognitive Workload

Block, Hancock & Zakay [4] demonstrated the importance of cognitive load in time judgment processes. Mental workload is defined as "the effect of a complex interaction of individual, technical, organizational and social factors"[24]. O'Donnell et al.'s definition [33] focuses more on individual characteristics that come into play when performing a task: "the term workload refers to that portion of the operator's limited capacity required to actually perform a particular task". According to Zakay [43], cognitive load may affect attentional processes when performing a task. If a specific task requires a high level of information processing, individuals tend to allocate more attention to this non temporal information, therefore paying less attention to temporal information.

When focusing on how cognitive load can influence the perception of waiting time, it is the measure of the subjective load that is of particular interest. Xie and Salvendy [41] distinguish subjective measures, performance measures and physiological measures to assess cognitive load. Subjective measures allow to collect direct opinions of users toward mental effort. They therefore belong to an individual subjective assessment, like the temporal judgment tasks. There are many methods for cognitive load subjective assessment. Among these, scales are commonly used [41].

Two scales were used in the present study: a unidimensional scale called SMEQ [45] and a multidimensional scale: the NASA-TLX [19].

The SMEQ (Subjective Mental Effort Questionnaire) consists of a single-item visual analogue scale with graded categories and numerical values (range:[0,150]). This scale is often used in UX studies since the cognitive load is considered as an element that may influence the overall evaluation of an interface [12, 22, 39].

NASA Task Load Index (TLX) uses six dimensions to assess mental workload: mental demand, physical demand, temporal demand, performance, effort, and frustration. Twenty-step bipolar scales are used to obtain ratings for these dimensions. A score from 0 to 100 is obtained on each scale [34]. Although sometimes criticized for its lack of sensitivity [11], NASA-TLX is one of the most widely used cognitive load subjective scales in psychology.

WAITING TIME IN THE FIELD OF HUMAN-COMPUTER INTERACTIONS (HCI)

Acceptable Waiting Time in HCI

The first studies in HCI on what constitutes an acceptable waiting time almost agreed on the identification of a 10-second threshold. Nielsen [32], for example, identified a 10-second limit over which users do not focus effectively on their task anymore. In a study related to the tolerance of users in a waiting situation on the web, Bouch et al. [5] collected the users' opinions on the time they considered to be acceptable. In agreement with Nielsen [32], Bouch et al. [5] demonstrated that a delay longer than 10 seconds was considered as unsatisfactory. It could also be misleading for the users and even reduce their effectiveness at work.

Waiting Time and Feedback

It is now widely accepted that feedback on the waiting time improves the usability of an interactive system [32, 35]. This feedback display can take many forms: icons, progress bars, text messages, etc. In a study on tolerable waiting time, Nah [31] looked at the influence of feedback on users' satisfaction. The author, in agreement with Geelhoed et al. [14] or Bouch et al. [5], showed that the presence of a feedback display greatly increases the time during which a user is willing to wait. Feedback information not only improves the confidence of users towards the system, but also constitutes a way to make them wait better.

The temptation would therefore be to offer the user a very detailed feedback, especially by providing information on the waiting time and details regarding the ongoing process. However, if one can naturally think that a very informative feedback will help the user to wait in a more efficient way, it appears that giving many details on the progress of the ongoing process makes the wait seem longer [29]. Indeed, the amount of information the user encodes during the wait period increases the perception of waiting time. As he or she interprets every event as time-consuming, the user has the impression that a waiting period with more events seems longer than a waiting phase including fewer events [6]. These findings are consistent with the model of the attentional gate described above [6] (Figure 1), as a very detailed feedback tends to focus the person's attention on temporal signals, thus opening the attentional gate and leaving free passage to many pulses. These latter will be recorded by working memory, which will assess the waiting time as being relatively long.

Temporal Metaphors in HCI

Progress bars [30] are often used as a temporal metaphor for an ongoing process. They are usually represented as bars filling up gradually from 0% to 100% completion. Some studies have shown that among the different types of feedback given to users, progress bars obtain the best results, both in terms of acceptability for the attention and of users' preference [6, 18, 20, 23]. Myers [30] shows that the presence of a progress bar during a waiting time improves self-efficacy and the attractiveness feeling of the user. Thanks to a progress bar, users can know that their application was considered, accepted and performed, and finally that the system tries to give them an answer. Conversely, the lack of progress bar is a source of trouble, doubt and lack of concentration.

One of the limitations of this approach is that it is often difficult to determine precisely how long the wait of the user will last. The filling process of the progress bar is often variable, which reduces the informational value of the latter [6]. Eager to understand the effects of this variability on various factors involving the user, studies were conducted in order to measure the influence of progress bar behavior on the perception of waiting time [21, 6].

PROBLEMATIC AND RESEARCH HYPOTHESIS

Based on studies in cognitive science and HCI on the perception of waiting time, we believe it is possible to influence users' perception in order to give the feeling that waiting time was shorter than in reality [29]. The aim of this research is therefore to enhance UX during waiting time in HCI.

To address this problematic, the present study aims at using inputs from the cognitive models and theories described previously. Three assumptions are made:

H1 *waiting duration*: there is a positive correlation between real waiting duration and perceived waiting time. Moreover, we assume a positive correlation between waiting duration, waiting estimation and underlying satisfaction.

H2 *feedback display*: the informational level of the feedback screen will influence both perceived waiting time and satisfaction, but not in the same direction. With a low informational level on the waiting time, we expect the perceived waiting time to be shorter but the satisfaction to be lower. With a high informational level, we conversely expect the perceived waiting time to be longer but the satisfaction to be higher. The assumption regarding perceived waiting time originates from the attentional gate model, whereas the assumption regarding satisfaction originates from HCI theories and usability research.

H3 *cognitive workload*: even if not explicitly included within existing models of time perception, results of previous research suggest that the concept of cognitive workload may impact time perception in the context of interactive systems, since it could affect attentional and judgment processes. We assume that the higher the cognitive workload is, the lower the estimation of waiting duration is and, therefore, the higher the satisfaction will be.

METHOD

Study Design

This research focuses on the impact of several variables on the satisfaction and waiting time perceived by a user when the interaction with the system is interrupted and requires the presentation of a feedback display representing the expected waiting time.

Using a between-subject design, each participant experienced one and only one experimental condition. The assignment of each participant to a specific condition was randomly performed by the application.

Three independent variables were manipulated: waiting time duration (0, 5, 10, 15, 20 seconds), position of the feedback screen (inter-item or intra-item condition) and informational level of the feedback screen (low vs. high).

Note that the variation in the position of the feedback screen had the purpose of creating an experimental variation of the cognitive workload. This operationalization was successful since the inter-group difference was highly significant regarding the assessment of cognitive workload, both using the SMEQ (*diff*=17.04, $t(770)=10.08$, $p<.01$) or a NASA_TLX global score (*diff*=11.71, $t(770)=9.4$, $p<.01$).

Materials and Procedure

The material used for this experiment was a memory game. Instructions displayed on the welcome screen indicated that the experiment was a memory game and provided general instructions to achieve the task. The game consisted in remembering the position of images distributed in a grid. Thus, six images were randomly distributed in a grid of 25 squares (the grid was displayed for 3 seconds). Then participants had to reposition images by memory in a blank grid. The game was repeated 5 times, each time with a new grid to remember. Before the start of the game, a preliminary training item was proposed to the participants to ensure a good understanding of the rules. After completion, a screen indicated the score attained in the training item and provided a button to start the game.

The material was a pretext to induce a waiting situation and to present to each participant a feedback screen. Depending on condition, the duration of the wait varies from 0 (control condition), to 5, 10 or 15 seconds. Except for the control condition that involves no waiting time, the feedback screen was presented either during each game (between the target grid and the blank grid, intra-item condition) or between each of the five trials (inter-item condition). Moreover, the feedback screen would be either highly informative (with a progress bar indicating the percentage of completion and a dialog text "Loading…Please wait" = high informational level condition) or poorly informative (only a dialog text "Loading…" = low informational level condition).

Note that log files were not controlled to check if people were multitasking during the waiting time imposed before the presentation of the results. However, thanks to the large sample size and the relatively short duration of the waiting time, this effect is assumed to be negligible and will therefore not be considered.

After the end of the game, participants were asked to complete a questionnaire including demographic information (gender, age, native language) and to assess their experience with interactive systems on a 7-point Likert scale from 1 "*not at ease at all with technological devices*" to 7 "*completely at ease with technological devices*".

Cognitive workload was measured using two distinct tools: a) a single-item measure called SMEQ [45] "*Did you find the memory game difficult to achieve?*" (on a 150 points scale from 0 "*no difficulty*" to 150 "*extreme difficulty*")

b) six 100-point scales adapted from the NASA-TLX tool [19] respectively assessing: mental demand, physical demand, temporal demand, performance, effort and frustration; where 0 means that the demand was low and 100 high. A global NASA-TLX score was computed (*Cronbach's alpha* α =.80) to allow comparison with the SMEQ.

Participants also answered five questions related to waiting time. First, they estimated the duration of the waiting time by selecting from a list ranging from 0s to 30s. Then, they rated on 7-point Likert scales: the focus on the wait (from 1 "*not focused at all*" to 7 "*completely focused*"), the reasonableness of the wait (from 1 "*not reasonable at all*" to 7 "*completely reasonable*"), the satisfaction related to the wait (from 1 "*not satisfied at all*" to 7 "*completely satisfied*") and the justified nature of the wait (from 1 "not justified at all" to 7 "completely justified")

Finally, participants were asked if the game was stimulating (7-point scale from 0 "*not stimulating at all*" to 7 "*very stimulating*") and, after the presentation of their score on 30 points, if they were satisfied with the latter (7-point scale from 1 "*not satisfied at all*" to 7 "*completely satisfied*").

Figure 2 summarizes the procedure of the study.

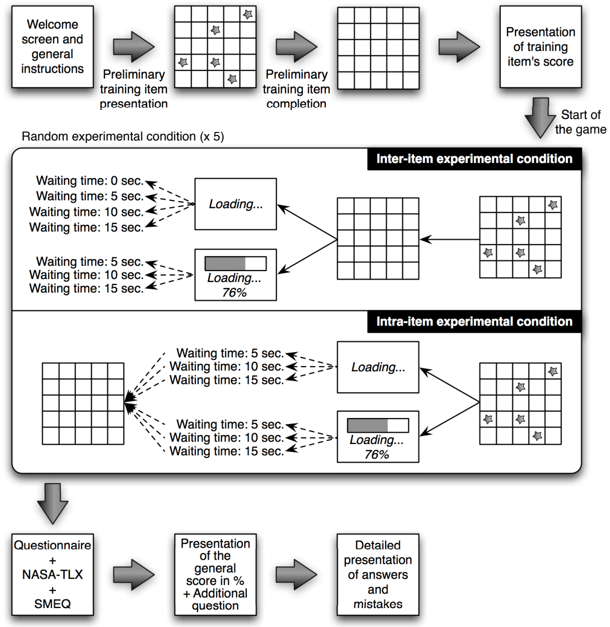

Figure 2. Material and procedure of the study.

Participants

The experiment, available online, was broadcast on multiple communication channels (forums, social networks, mailing lists). 950 distinct subjects (controlled Internet Protocol address) were involved, including 525 women and 425 men. The mean age of the sample was 31.5 years (*SD*=8.85). Most of the participants (93.9%) were native French speaker and felt at ease with technology in general (84.4 % rated 5 to 7 on the 7-point scale assessing experience with interactive systems).

The distribution of participants according to each condition is shown in Table 1.

Waiting Time Duration			Informational level of the feedback screen		
			low	high	*Total*
0	Position of the feedback screen	N.A.	N.A.	N.A.	**178**
5	Position of the feedback screen	intra-items	76	75	**151**
		inter-items	80	53	**133**
		Total	**156**	**128**	**284**
10	Position of the feedback screen	intra-items	59	52	**111**
		inter-items	66	68	**134**
		Total	**125**	**120**	**245**
15	Position of the feedback screen	intra-items	51	66	**117**
		inter-items	62	64	**126**
		Total	**113**	**130**	**243**
Total	Position of the feedback screen	intra-items	186	193	**379**
		inter-items	208	185	**393**
		Total	**394**	**378**	**950**

Table 1. Distribution of participants according to each condition.

RESULTS AND DISCUSSION

General results

The average score of the memory game was very high (M= 27.2 on 30, SD=3.39) as well as the satisfaction score (M=5.77 on 7, SD=1.58). The stimulating nature of the game was evaluated as medium (M=4.70 on 7, SD=1.66). Note that the memory game was not meant to be difficult to achieve, in order to avoid a bias of frustration related to the failure of the game and therefore not linked to the waiting situation.

Waiting related variables

Overall, variables related to the assessment of the waiting period are rated negatively by users (average mean under M=4 in all cases, excluding control condition).

Wait time duration		Wait Estimation (in seconds)	Wait focalisation (reversed)	Wait Reasonableness	Wait satisfaction	Wait justified
0	Mean	2.29	6.40	6.34	6.18	5.52
	SD	2.44	1.19	1.19	1.25	1.48
5	Mean	5.29	4.24	4.27	3.94	3.69
	SD	4.09	2.02	2.02	2.07	2.13
10	Mean	8.06	3.89	3.72	3.36	3.09
	SD	4.93	1.92	1.86	1.80	1.9
15	Mean	10.57	3.81	3.27	2.82	3.00
	SD	6.31	1.95	1.78	1.72	1.91
Total	Mean	6.79	4.44	4.26	3.92	3.70
	SD	5.57	2.08	2.08	2.12	2.11

Table 2. Descriptive statistics: assessment of the waiting period according to wait time duration (rated on 7-point scales from 1 "low" to 7 "high").

All the measures related to wait satisfaction are strongly correlated to real waiting time duration and also strongly intercorrelated (p<.01). A global satisfaction score composed of *wait reasonableness*, *wait satisfaction*, *wait justified* and *wait focalization* was computed (Cronbach's alpha α = .87) (including control condition M=4.08, SD=1.77).

As expected in hypothesis H1, participants estimated longer times for longer durations ($F(3,946)=119.88$, $p<.01$). Note that whereas their estimation of the 5-sec waiting condition was quite accurate, they tend to underestimate longer durations (10 or 15sec). In contrast to some studies where participants are aware of the temporal nature of the evaluation task [20], we preferred an experimental research design in which a waiting situation was integrated in the context of a primary task, as is often the case in reality. However, it is likely that subjects did not give their full attention to the waiting imposed on them. This finding is consistent with the model of the attentional gate [5]. The less attention is paid to cognitive signals, the less temporal impulses reach the memory, giving the user the impression of having waited less than he actually did.

Participants judged shorter waits more positively than longer ones ($F(3,946)=157.02$, $p<.01$) and the decrease in global satisfaction is linear (tested by post hoc analyses, $p<.01$). Not surprisingly, participants judged short waiting periods to be more reasonable than long ones ($F(3,946)=113.05$, $p<.01$), but also more satisfying ($F(3,946)=124.68$, $p<.01$), more justified ($F(3,946)=73.09$, $p<.01$) and less inclined to focalized them on the waiting period ($F(3,946)=84.82$, $p<.01$). For each of these variables, the decrease in satisfaction is linear among the four waiting time conditions (tested by post hoc analyses, $p<.01$). These observations support the results of the studies mentioned above [5, 31, 32]. Moreover, Nielsen's theory [32] on the acceptable waiting time in HCI is confirmed in our context since we observed after a 10-second delay that the reasonableness of the wait was assessed under the average rate of the scale (M=3.72, SD=1.86) (inter-group differences tested by post hoc analyses significant at $p<.01$ level).

Finally, we observed a weak negative correlation between waiting time duration and score satisfaction ($r=-.115$, $p<.01$). It leads us to think that waiting time may even impact some unexpected aspect of the interaction. Being satisfied with a score should not, at first sight, be related to a waiting period but only to the effective score and the expectation of the user. This kind of link therefore confirms that acting on the design of waiting displays may enhance the whole User eXperience regarding a specific user interface, as previously shown by Branaghan & Sanchez [6].

Feedback display

In this study, we intended to act on the attention to temporal cues by varying the informational level of the feedback screen. According to the attentional gate model of time perception [4], the more a person pays attention to temporal signals, the more the attention gate opens, leaving thus numerous pulses crossing through it. Conversely, if the person does not pay attention to temporal stimuli or is distracted by other events, the attentional gate will therefore tend to close, thus leaving little pulses crossing through and giving the impression of a shorter waiting period.

As expected in hypothesis H2, our results show a significant link between information level of the feedback screen and waiting time estimation ($diff$=-.73 sec, $t(770)=-1.83$, $p<.05$). Users estimate the waiting time as being longer in the case of a high informational level display (M=8.2, SD=6.07) than in the case of a low informational display (M=7.47, SD=5.03).

From a theoretical point of view, this phenomenon can be explained by the amount of information the user encodes during the waiting period that increases the perception of waiting time. Since every event is interpreted as time-consuming, the user has the impression that a waiting period with more events has a longer duration than a waiting phase including fewer events [6]. By providing precise information on the ongoing process (progress bar + loading message + percentage of achievement), the high level feedback display increases the number of events perceived by the user. These findings are also consistent with the model of the attentional gate described above [6] (Figure 1). Indeed, with a very detailed feedback, users tend to focus on temporal signals, thus opening the attentional gate and leaving free passage to many pulses. These latter are recorded by working memory, which in turn assesses the waiting time as being relatively long.

Starting from this observation, one may think that providing users with a very low informative display, or even not providing any information at all on the waiting situation, could be the best design option.

However, more surprisingly (but still following our assumptions – H2), results show a converse and significant effect of the informational level of the feedback screen on users' satisfaction measures (Figure 2). Both global satisfaction (*diff*=-.30, *t*(770)=-2.68, *p*<.01) and waiting time satisfaction (*diff*=-.31, *t*(770)=-2.23, *p*<.05) were increased in the case of the high level feedback. The high level feedback condition also increases the likeliness of assessing the waiting period as reasonable (*diff*=-.43, *t*(770)=-3.1, *p*<.01) or avoid focusing on waiting times (*diff*=-.59, *t*(770)=-4.23, *p*<.01). No significant link exists between informational level and the fact of assessing the wait as justified.

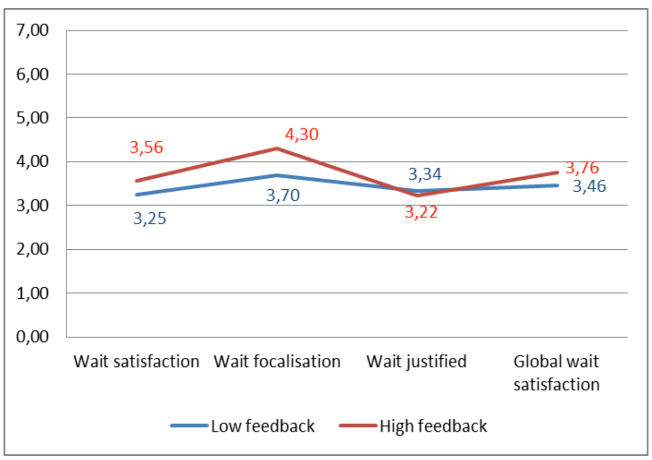

Figure 3. Means of satisfaction measures according to the informational level of the feedback screen.

In agreement with the findings of Branaghan & Sanchez [6], our study shows that users prefer more feedback rather than less, even if it makes the wait seem less reasonable. These results help to understand the importance given to feedback in the main widely spread ergonomic recommendations in HCI [35, 32]. Several authors [14, 5] showed that the presence of a feedback display greatly increases the time during which a user is willing to wait. This statement can be related here to the fact that users assess the wait as more reasonable when the informational level of the display is high (low feedback, *M*=3.57, *SD*=1.85 vs. high feedback, *M*=4, *SD*=2).

Finally, we can note that there is no link between feedback level and factors related to the memory game, like the evaluation of the stimulation provided by the game or the satisfaction related to the score obtained.

Cognitive workload

As mentioned in the methodological section, note that the variation in the position of the feedback screen had the purpose of creating an experimental variation of the cognitive workload. This operationalization was successful since the inter-group difference was highly significant regarding the assessment of cognitive workload, both using the SMEQ (*diff*=17.04, *t*(770)=10.08, *p*<.01) or a NASA_TLX global score (*diff*=11.71, *t*(770)=9.4, *p*<.01). Our independent factor "position of the feedback screen" explains approximately 10% of the variance in cognitive load (Eta coefficient).

Whatever the condition, overall cognitive workload was assessed as quite low (Table 3) with an average rating of *M*=33.24 on 150 (*SD*=24.09) to the SMEQ (corresponds to the statement "*the memory game was a bit difficult to achieve*") and a global score of *M*=36.79 on 100 (*SD*=17.89) to the NASA-TLX scales. The two measures are highly correlated (*r*=.68, *p*<.01), which proves the good convergent validity of both tools.

Considering the six NASA-TLX scales (Table 3), mental demand was assessed with the highest mean (*M*=51.26), followed by Effort, Time Pressure, Frustration, Performance and finally Physical Demand (*M*=18.71).

We observe differences between men and women regarding subjective cognitive load assessment both for the SMEQ (*diff*=7.15, *t*(948)=-4.6, *p*<.001) and the NASA-TLX global score (*diff*=6.12, *t*(948)=-5.32, *p*<.001). Slightly but significant differences between gender regarding the game's score (*diff*=1.10, *t*(948)=5.04, *p*<.01) could be an influence factor.

Regarding the role played by subjective cognitive load in waiting time perception, results show that cognitive load (SMEQ) depends on waiting time duration (*F*(3,946)=9.33, *p*<.01). The cognitive load related to the control group (*M*=24.88, *SD*=17.78) was fairly lower than the one of the other conditions (*M*=35.42 for 5-sec condition, *M*=34.03 for 10-sec condition, *M*=36.03 for 15-sec condition).

Waiting Time (in seconds)		SMEQ (150-point scale)	NASA-TLX (100-point scales)						
			TLX mental	TLX physic	TLX pressure	TLX performance	TLX effort	TLX frustration	TLX Global
0	Mean	24.88	49.90	15.35	49.28	26.23	41.67	29.33	35.29
	N	178	178	178	178	178	178	178	178
	Std. Deviation	17.78	25.22	18.38	26.79	24.45	24.45	25.23	16.67
5	Mean	35.43	51.84	19.23	44.89	30.87	43.73	36.60	37.86
	N	284	284	284	284	284	284	284	284
	Std. Deviation	24.45	25.65	19.74	26.90	24.60	24.54	26.26	17.91
10	Mean	34.03	50.53	19.81	40.70	31.56	40.98	33.91	36.25
	N	245	245	245	245	245	245	245	245
	Std. Deviation	23.92	26.28	20.15	26.66	26.31	24.33	25.85	17.47
15	Mean	36.03	52.30	19.45	36.74	32.95	45.28	36.56	37.22
	N	243	243	243	243	243	243	243	243
	Std. Deviation	26.54	27.23	20.60	27.56	27.18	26.04	27.94	19.11
Total	Mean	33.24	51.26	18.71	42.55	30.71	43.03	34.53	36.80
	N	950	950	950	950	950	950	950	950
	Std. Deviation	24.10	26.12	19.86	27.30	25.77	24.88	26.51	17.89

Table 3. Descriptive statistics: assessment of the cognitive workload according to wait time duration. Low score means low cognitive workload.

We also notice a positive correlation between cognitive load (SMEQ) and the estimation of waiting time (r=.193, p<.01). The higher the cognitive load induced by the task, the higher the estimation of waiting time. This observation goes against hypothesis H3.

Conversely, cognitive load is negatively correlated with measures of users' satisfaction (Table 4). A high cognitive load is associated with low wait reasonableness, low satisfaction and low assessment of the justified nature of the wait. Moreover, a high cognitive load is also associated with an important focus on waiting time.

Measures of users' satisfaction	Measures of cognitive load	
	SMEQ	NASA-TLX
Wait focalisation (R)	r = -.201**	r = -.214**
Wait reasonableness	r = -.268**	r = -.209**
Wait satisfaction	r = -.267**	r = -.211**
Wait justified	r = -.135**	r = -.1**
Global satisfaction	r = -.258**	r = -.217**

Table 4. Correlations between cognitive load and measures of users' satisfaction (for p.value <.01).**

According to Zakay [43], a demanding task (high cognitive load) should attract the attention of the subject so that he or she will pay less attention to temporal information. Our results are not compliant with that statement since cognitive load has here a negative impact on both waiting time estimation and satisfaction's measures. Hypothesis H3 is therefore not confirmed by this study. However, Leclerc, Schmidt and Dubé [15] showed that time evaluation depends largely on the context and the characteristics of the situation in which subjects were asked to assess it. By placing users in conditions where they could win or lose money while they wait (which influenced their perception of time), their results showed the importance of the nature of the context and the task in perceptual processes. In our case, because the feedback display interrupted the game (in the intra-item condition, which induced a high cognitive load) and may have an impact on the score, time perception might have been biased by the context. Moreover, following Branaghan & Sanchez [6], ratings of wait time reasonableness were consistent with the attentional gate theory of prospective timing, since attention-demanding activity caused the wait to seem less reasonable [6].

CONCLUSION

The present research aimed at building a bridge between theories in cognitive sciences and good design practices in the field of HCI. By trying to provide and articulate a sound theoretical explanation of a UX practice that may be already in effect, this empirical work may contribute to research advances in the field of HCI. Thanks to the multidisciplinary nature of ergonomics research, numerous paths can be established between theories of the human mind and practical implications for user interface design.

Concretely, our results provide interesting evidence on the relation between waiting duration, feedback display, cognitive workload and the satisfaction related to waiting periods. For example, paradoxical results related to the informational level of feedback screens (a detailed feedback leads to a higher estimation of waiting time but is conversely also associated to a higher satisfaction) indicate that designing for User experience is not only a matter of applying pre-established recommendations. Trade-offs have to be made during a design project and the better way to decide what to do is to be aware of the implications of every choice available. In some situations, satisfaction may be the most salient factor to consider whereas, in some others, efficiency, effectiveness or reliability of the system may be the most critical issues.

Another interesting approach towards waiting time in HCI is proposed by Hurter et al. [13]. In many cases, especially when the duration of the wait is long, people do not sit still waiting for computers to respond. Instead of waiting passively, they are performing other tasks. Beyond the improvement of feedback displays themselves, the authors therefore suggest to reflect on how we could help the user make a better use of this waiting time. "Active progress bars" they describe in their recent study of 2011 provide users with features enabling them to carry out temporary activities during the wait (e.g. consultation of their calendar or mail, reading their to-do lists or even information on the news or weather). Although a careful attention should be paid to the control of actions by the user in this context, we truly believe that such studies open new perspectives in the field of HCI. It could therefore be interesting to carry out further research in which multitasking would become part of the experiment itself. The results could help designers to create interactive systems able to provide users with multitasking functionalities, always keeping in mind the concern of taking users back to their primary task as soon as waiting time is over. In an experiment to come, multitasking will be introduced as a variable in order to study how it could help people to make best use of waiting times and increase their global satisfaction by that way.

Finally, many perspectives remain to be explored in user interface design in order to enhance User eXperience. From a practical point of view, one should always remember that, as with any activity in the field of ergonomics, the design of feedback displays in HCI is the object of trade-offs. It is once again the context of use and the knowledge about target users that will be help to determine design decisions and to provide users with the best UX when interacting with interactive systems.

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