HEC MONTRÉAL

La perception du temps en contexte d'interfaces utilitaires

par

Michael Truong

Sciences de la gestion

(Option Expérience utilisateur dans un contexte d'affaires)

Sous la codirection de

Pierre-Majorique Léger, Ph. D. et Sylvain Sénécal, Ph. D.

Mémoire présenté en vue de l'obtention

du grade de maîtrise ès sciences en gestion

(M. Sc.)

Juin 2019

Résumé

Une tâche qui prend trop temps va nuire à l'expérience de l'utilisateur. Il est alors important de comprendre les mécanismes qui influencent la perception temporelle. Ce mémoire par article étudie l'impact des traits individuels et des états psychophysiologiques sur la perception du temps lorsque l'utilisateur interagit avec différents niveaux de complexité d'interfaces utilitaires.

Une étude en laboratoire a été menée auprès de 53 participants. Les participants étaient invités à accomplir des tâches bancaires, et ils devaient estimer le temps de chaque tâche. Le but de l'étude était d'identifier la différence d'estimation de temps entre des tâches faciles et difficiles. De plus, un second objectif était de comprendre si la relation entre la complexité des tâches et la perception du temps était influencée par des traits individuels et l'état de l'utilisateur.

Les résultats suggèrent que les utilisateurs perçoivent que le temps passe plus rapidement quand ils interagissent avec une tâche facile en comparaison avec une tâche difficile. Ces résultats semblent expliquer par le fait qu'une augmentation de la complexité de la tâche cause une augmentation de la charge mentale requise, ce qui, par la suite, cause une augmentation de l'estimation du temps. De plus, à un niveau égal de charge mentale, les utilisateurs qui ont des traits élevés d'impulsivité ou d'orientation de temps (l'importance du temps pour l'utilisateur) vont percevoir que le temps passe moins rapidement que les utilisateurs qui le sont moins. D'ailleurs, les résultats de ce mémoire contribuent à combler le manque dans la littérature sur des résultats qui reflètent plus la réalité, et à aider les designers en expérience utilisateur à mieux comprendre les mécanismes qui influencent la perception du temps d'un point de vue pratique.

Mots clés : Perception du temps, Psychophysiologie, Interface utilitaire, Bancaire, Émotion, Effort cognitif, Type d'interface

Table des matières

Liste des tableaux et des figures

Liste des figures

Article

Liste des tableaux

Article

Liste des abréviations

UX : Expérience utilisateur

UX : « *User Experience* »

Avant-propos

Ce mémoire par article a été approuvé par la direction du programme de M.Sc. de HEC Montréal. Ce mémoire a été rédigé sous la forme d'un article complémentaire. L'approbation des coauteurs a été obtenue pour chacun des articles présentés dans ce mémoire. Le comité d'éthique en recherche (CER) de HEC Montréal a approuvé ce projet de recherche en février 2017.

Remerciements

À mon arrivée à HEC Montréal en 2015, je ne croyais jamais terminer mon baccalauréat encore moins poursuivre et compléter une maîtrise. Mon travail acharné m'a permis de sortir de ma zone de confort et d'accomplir des réalisations que je ne pensais jamais atteindre. Cette année marque la fin d'un chapitre rempli d'embuches, d'essais et d'erreurs. Elle témoigne de moments de doutes et de sacrifices, mais aussi de moments de satisfaction et de bonheur. J'espère que les leçons et les expériences que j'ai acquises dans cette aventure vont m'aider à bien débuter la prochaine. La rédaction de ce mémoire n'aurait pas été le même sans l'apport de plusieurs personnes.

Dans un premier temps, je tiens à remercier mes codirecteurs, Pierre-Majorique Léger et Sylvain Sénécal, pour leur incroyable soutien et de m'avoir donné l'opportunité de faire un stage d'été au Tech3Lab en 2017. Sans ce stage, je crois que je n'aurais jamais considéré poursuivre mes études aux cycles supérieurs. Merci pour votre mentorat, vos conseils et vos disponibilités exemplaires. Je suis très reconnaissant de ma chance d'avoir intégré l'équipe du Tech3Lab et d'avoir eu la chance de vivre une expérience assez incroyable et unique. Je suis certain que cette expérience inoubliable me suivra dans ma carrière professionnelle.

J'aimerais également remercier tous les assistants de recherche et l'équipe opérationnelle pour leur travail formidable pour que ma collecte puisse bien fonctionner. Un énorme merci à Carl pour ta grande patience lors de mes analyses statistiques. Un merci particulier à Emma et Vanessa pour votre bonne humeur. Votre enthousiasme m'a permis de rester positif durant le processus.

Un merci aux étudiants du Tech3Lab et à mes amis de la M.Sc. Ma croissance personnelle est un aspect qui est extrêmement important dans ma vie. Je suis très reconnaissant d'avoir eu la chance d'avoir eu autant de support que cela soit au niveau académique, mais aussi personnel tout au long du processus. Je ne crois pas avoir autant de réussite si j'avais été seul. Merci de m'avoir sortie de ma routine. Merci de m'avoir fait sortir de ma zone de confort et me faire découvrir de nouvelles choses. Syndrome de l'imposteur, timidité, confiance en soi, manque d'assertivité, mais surtout mon anxiété sociale, j'ai pu affronter sur ces faiblesses grâce à vous. J'ai extrêmement évolué et j'en suis très reconnaissant. Je ne serai pas la personne que je suis aujourd'hui sans vous avoir rencontrée. Vous êtes tous sharp! Je suis certain que vous allez tous avoir du succès dans vos futures réalisations. J'espère que nos chemins se recroiseront bientôt. Je suis très fier d'avoir fait partie d'un groupe avec des personnes exceptionnelles et dynamiques. Un merci à Caroline, Christophe et Ariane de m'avoir invité à une soirée d'information en consultation. Je n'aurai jamais pensé travailler en conseil sans cet événement marquant de ma vie #consultingtech3. Vous avez illuminé mon futur chemin. Merci à Karl-David, Émilie, Mario et Gabrielle pour votre soutien moral et votre support tout au long de la maîtrise. Merci pour vos relectures et d'avoir été à l'écoute durant mes moments d'inquiétudes. Ma vie à la maîtrise n'aurait pas été aussi enrichissante sans vous avoir rencontré. Un énorme merci particulier à la personne qui m'a aidé à rester calme et à garder la tête haute dans un moment très difficile dans ma vie. *Thank you from the bottom of my heart*.

Je voudrais remercier le Conseil de recherche en sciences naturelles et génie (CRSNG), Prompt et la Chaire en Expérience utilisateur (UX) pour leurs soutiens financiers me permettant de réaliser mon mémoire sans stress financier. J'aimerais également remercier mon partenaire Banque Nationale d'avoir eu l'opportunité de collaborer avec eux pour mon projet et d'acquérir de l'expérience de travailler en industrie.

Pour finir, je tiens à remercier ma famille pour leur support et encouragement, peu importe les décisions que j'ai prises. Merci pour tous vos sacrifices et de votre décision de venir vivre au Canada pour donner un meilleur futur à leurs enfants. Merci de me faire confiance et de me donner l'opportunité de suivre et de forger mon propre chemin.

Trust yourself

Break some rules

Don't be afraid to fail

Ignore the naysayers

Work like hell

Give something back

Compare yourself with who you were yesterday,
not with who someone else is today

Change requires willingness to experience pain.
You have to face the lifetrap head-on and understand it.
Change also requires discipline.
You have to systematically observe and change behaviours every day.
Change cannot be hit-or-miss.
It requires constant practice.

A ship is safe in harbor, but that's not what ships are for

Excelsior

Introduction

Mise en contexte de l’étude

L’apparition du web au milieu des années 90 a permis à l’émergence de nouveaux types de service pour les entreprises; celles-ci se sont tournées vers la dématérialisation de leurs services en se numérisant (D’Orazio et Shotton, 2018). La transformation numérique permet de créer, transformer et conserver toutes les données en format digital, ce qui implique une transformation des processus concernés. En se numérisant, ces entreprises optimisent leurs processus en se délaissant du format papier qui était autrefois grandement utilisé. Cette transformation vient notamment bouleverser le comportement et mode de consommations des clients. Par exemple, au lieu de se rendre physiquement à une banque, les clients peuvent se connecter pour effectuer leur transaction en ligne. Idéalement, ce changement de paradigme permet un gain de temps et d’argent pour les deux parties. Cependant, cette réinvention implique aussi de nouveaux enjeux auxquels les banques doivent faire face.

Un défi que les concepteurs en expérience utilisateur souhaitent relever est de rendre le processus plus efficace et efficient. Certains utilisateurs sont réticents à transitionner vers l’ère numérique, car ils perçoivent notamment que les processus en ligne sont moins efficaces (Orlando, 2019). Ces utilisateurs préfèrent se rendre à une branche physique ou de parler à une vraie personne en ce qui concerne de faire l’achat de nouveaux produits financiers ou pour demander des conseils (Orlando, 2019). Les services traditionnels peuvent prouver à être plus fiable lorsque l’individu n’est pas habitué à utiliser le service (Orlando, 2019). Effectivement, les utilisateurs trouvent qu’il y a peu d’assistance humaine en comparaison avec les processus traditionnels (L’Hostis, 2018). Par conséquent, cela rend le processus plus long que prévu, car les utilisateurs sont moins engagés lorsqu’ils interagissent en ligne (Davis, Schulte et Golluscio, 2018). Il faut aussi noter que les services en ligne permettent d’accélérer le processus pour des tâches simples au lieu de se rendre à une branche physique (Orlando, 2019). Ainsi, cela permet aux utilisateurs de faire un gain de temps.

Le temps est un facteur qui est très important pour la complétion d'une tâche utilitaire en ligne. Un utilisateur qui perçoit que le processus prend trop de temps va simplement quitter le processus (Heinig, 2018). En effet, le taux d'abandon d'un formulaire en ligne est d'environ 81% (Delgado, 2018). De plus, le taux d'échec et de complétion d'une tâche augmente lorsque l'utilisateur perçoit qu'elle est trop longue (Atkinson, 1999). D'autre part, créer une interface qui permet aux utilisateurs d'avoir un meilleur sentiment de contrôle est un enjeu clé pour le succès de l'adoption de l'interface (Davis, Schulte et Golluscio, 2018). Ainsi, le temps est un concept pertinent en ce qui concerne l'expérience utilisateur (Revang, 2016).

La perception du temps est l'habileté à précisément estimer un intervalle de temps de façon prospective ou rétroactive (Richard A Block et Zakay, 1997). C'est une activité critique dans la vie de tous les jours, mais aussi lorsqu'un utilisateur souhaite accomplir des tâches spécifiques. Que ce soit pour estimer le temps de voyage d'un point A à un point B, pour estimer la durée d'un rendez-vous, ou pour estimer le temps requis pour payer ses factures en ligne, il est primordial pour l'individu d'être capable d'avoir une estimation qui soit la plus proche possible de la réalité. Une activité qui dépasse le temps alloué à celle-ci va souvent causer beaucoup de frustration à l'utilisateur (Gorn *et al.*, 2004). Cependant, bien que le temps soit une ressource qui est constante pour tout le monde, chaque individu la perçoit de manière différente (Lake, LaBar et Meck, 2016).

La perception du temps est un sujet populaire dans la recherche en psychologie (Allan, 1979; Thomas et Weaver, 1975; Fraisse, 1984; Hornik, 1984), et ce sujet est encore étudié aujourd'hui (Droit-Volet et Gil, 2016; Jokic, Zakay et Wittmann, 2018; Kononowicz, Van Rijn et Meck, 2018). Depuis, beaucoup de modèles ont vu le jour, et ceux-ci ont été testé empiriquement à travers le temps (Richard A Block, Hancock et Zakay, 2010; Hicks, Miller et Kinsbourne, 1976; Woehrle et Magliano, 2012; Zakay et Block, 1997) notamment le *attentional-model* (Zakay et Block, 1997). Il y a une expression qui dit que le temps passe plus vite lorsqu'on s'amuse et que le temps passe plus lentement lorsqu'on s'ennuie (Droit-Volet et Meck, 2007). Ainsi, il y aurait donc beaucoup de facteurs qui peuvent venir influencer la perception du temps d'une personne. Il y a eu de nombreuses études qui ont essayé d'identifier des facteurs qui sont en lien avec la distorsion temporelle, c'est-à-dire des facteurs qui vont venir perturber l'horloge interne d'un individu. Celles-ci suggèrent que les émotions telles que la valence et l'activation jouent un grand rôle dans la perception du temps (Droit-Volet et Meck, 2007; Droit-Volet, Brunot et Niedenthal, 2004; Droit-Volet, Tourret et Wearden, 2004). De plus, il y a des études qui suggèrent que la charge mentale joue également un rôle dans la perception du temps (Richard A Block, Hancock et Zakay, 2010; Brown, 2008). D'ailleurs, des études antérieures suggèrent que les traits individuels tels que l'âge et la personnalité vont influencer la perception du temps de chaque individu (Jokic, Zakay et Wittmann, 2018; Lake, LaBar et Meck, 2016).

L'étude sur la perception du temps a aussi été étudiée dans un contexte en ligne. Par exemple, une étude suggère que les couleurs d'un site web influencent la perception du temps de l'utilisateur (Gorn *et al*., 2004). Les utilisateurs vont percevoir que le temps passe plus rapidement lorsque les couleurs du site web induisent la relaxation. Une autre étude suggère que la présence d'une rétroaction sur le site fait en sorte que les utilisateurs sont un peu plus patients lors du téléchargement d'une page web (Nah, 2004).

Toutefois, bien que la littérature sur la perception du temps soit assez riche, il semblerait qu'il y ait des lacunes dans la littérature actuelle sur la perception du temps. Premièrement, la plupart des études de la perception du temps étudient le phénomène dans un petit intervalle allant de millisecondes à secondes (Drake et Botte, 1993; Eisler, Eisler et Hellström, 2008; Fraisse, 1967). Il y en a aussi qui étudie des intervalles un peu plus longs allant de secondes à des minutes (Bisson, Tobin et Grondin, 2008; Grondin et Plourde, 2007). Cependant, nous n'avons trouvé aucune étude qui considère la perception du temps sur des intervalles d'une durée qui dépasse 10 minutes. Ce phénomène peut être expliqué par le fait que les différents intervalles de temps opèrent sur des mécanismes de rappel et de mémorisation différents de la perception du temps (Woehrle et Magliano, 2012; Zakay et Block, 1997). Il est donc pertinent d'explorer davantage la littérature sur la perception du temps en ajoutant la composante d'intervalle de temps qui dépasse 10 minutes puisque plusieurs interactions en ligne sont de longues durées. Par exemple, remplir un formulaire de demande d'hypothèque en ligne.

Deuxièmement, les stimuli utilisés dans les études de perception du temps ont une faible validité écologique. Effectivement, des études ont utilisé des stimuli tels que le Stroop test (Sawyer, Meyers et Huser, 1994; Zakay et Shub, 1998), faire des calculs mathématiques (Grondin et Plourde, 2007; Woehrle et Magliano, 2012), regarder des points sur un écran (Tse *et al*., 2004; Wittmann *et al.*, 2007) ou dessiner des étoiles sur du papier (Brown, 1985). De plus, la littérature sur la perception du temps dans un contexte en ligne a uniquement étudié l'effet de télécharger des fichiers ou d'attendre passivement qu'une page se télécharge. Le contexte de la navigation sur le web n'a pas encore été étudié, car c'est un processus qui est beaucoup plus complexe (Egger *et al.*, 2012). Il n'y a pas d'étude sur la perception du temps lorsque l'utilisateur doit proactivement interagir avec une interface utilitaire. Il est pertinent d'étudier le phénomène de la perception du temps en utilisant des tâches qui permettent d'améliorer la validité écologique dans la littérature. Notre étude utilise des tâches utilitaires en ligne pour explorer le sujet de la navigation en ligne. Il y a beaucoup d'interactions utilitaires dans la vie de tous les jours avec la technologie qui nous entoure. Il est pertinent d'utiliser des tâches qui reflètent beaucoup plus la réalité.

Ce mémoire souhaite donc apporter des résultats qui ont une meilleure validité écologique dans la littérature en ajoutant des tâches utilitaires en ligne. De plus, le processus de navigation en ligne est relativement complexe, car il y a plusieurs types de tâches qu'un individu peut faire en ligne (Terai *et al*., 2008). Ces études ont montré qu'une tâche simple va être plus sous-estimée qu'une tâche complexe (Zakay et Block, 1997). De ce fait, ce mémoire cherche aussi à explorer si différents niveaux de difficulté (facile ou difficile) d'une interface utilitaire en ligne influencent la perception du temps sur des tâches de longues durées. Étudier le phénomène de la perception du temps dans un contexte de différent niveau de complexité de tâches utilitaires va permettre d'ajouter de la valeur dans la littérature, mais aussi de permettre aux concepteurs de site web de mieux comprendre les mécanismes qui influencent la perception du temps d'un utilisateur. Cela va permettre aux concepteurs de site web de designer de meilleures interfaces.

Questions de recherche

Étudier la perception du temps lorsque l'utilisateur navigue en ligne est complexe (Egger *et al.*, 2012). En effet, un utilisateur peut effectuer un nombre varié de tâches lorsqu'il interagit avec des interfaces utilitaires. Lorsqu'un utilisateur navigue en ligne, Terai *et al.*, (2008) proposent que celui-ci puisse faire deux types d'action. L'utilisateur peut chercher une information spécifique sur le web ou compléter une transaction en ligne. Compléter une transaction en ligne est plus complexe que de chercher une information sur le web, car l'utilisateur doit faire une tâche de motricité fine soit faire l'action de taper sur un clavier pour remplir les informations (Land et Hayhoe, 2001). L'utilisation du clavier demande à l'utilisateur une division de son attention entre le clavier, l'écran, et une réponse motrice, ce qui a pour conséquence d'augmenter la difficulté de la tâche (Al-Wabil et Al-Saleh, 2011). Il est pertinent pour notre étude de diviser l'interaction des interfaces utilitaires en deux catégories de complexité, soit simple et complexe, car les interactions avec les interfaces utilitaires ne sont pas toutes identiques. Cela permet une plus grande précision de nos résultats sur l'interaction des interfaces utilitaires en les classifiant en différent niveau de complexité.

Ce mémoire cherche à identifier les différentes caractéristiques d'états et de traits qui influencent la perception du temps lorsqu'un utilisateur doit interagir avec des types différents d'interfaces utilitaires. Le type d'interface utilitaire est manipulé en considérant deux facteurs, soit une tâche informationnelle (facile) ou transactionnelle (difficile) (Terai *et al.*, 2008). Les traits individuels de chaque participant sont observés à l'aide de données psychométriques recueillies par le biais de questionnaires (Barratt *et al.*, 1999; Zimbardo et Boyd, 2015). Des données physiologiques telles que l'oculométrie (Laeng, Sirois et Gredebäck, 2012), l'émotion faciale (Loijens *et al.*, 2015) et l'activité électrodermale (Boucsein, 2012) sont utilisées pour examiner le comportement des utilisateurs lorsqu'ils interagissent avec les différentes interfaces.

L'article cherche à développer les connaissances sur la perception du temps lorsqu'un utilisateur interagit avec de différentes interfaces utilitaires. L'objectif de l'article est donc d'identifier quels types d'interfaces génère une plus grande distorsion temporelle et d’identifier les différentes caractéristiques d’états et de traits qui influencent la relation. Cet article tente ainsi de répondre aux questions de recherche suivante :

Dans quelle mesure la complexité de l’interface influence la perception du temps lors qu’un utilisateur doit interagir avec des interfaces utilitaires?

Dans quelle mesure les états physiologiques et traits psychométriques influencent la relation entre la complexité de l’interface et de la perception du temps?

Objectif de l’étude et contributions

L’objectif de ce mémoire est notamment d’étudier la relation entre la complexité d'une tâche utilitaire et la perception du temps, et ainsi que les traits physiologiques et psychométriques qui influencent cette relation. D’un point de vue théorique, ce mémoire contribue à combler le manque de résultats ayant une bonne validité écologique dans la littérature sur la perception du temps en étudiant l’interaction avec des tâches de la vie de tous les jours. De plus, ce mémoire contribue à combler le manque de recherche sur la perception du temps dans un contexte en ligne. Ce mémoire contribue donc également à la littérature sur l’interaction humain-machine. Cette étude a ainsi démontré que les utilisateurs sous-estiment plus le temps d’une tâche simple qu’une tâche complexe. De plus, ce mémoire a démontré l’effet médiateur de la charge mentale entre la complexité de la tâche et de la perception du temps. Une tâche complexe va augmenter la charge mentale de l’utilisateur, ce qui a pour conséquence de faire augmenter l’estimation du temps. Les traits d’orientation du temps et d’impulsivité ont un effet de modérateur dans la relation de la charge mentale et de la perception du temps. L’effet de la charge mentale sur l’estimation du temps va être plus fort lorsque l’individu a un haut niveau d’impulsivité ou d’orientation de temps (l’importance du temps pour l'utilisateur). D’un point de vue pratique, ce mémoire permet aux concepteurs en expérience utilisateur (UX) de mieux concevoir des interfaces en considérant l’aspect de complexité de celle-ci. Par exemple, les concepteurs peuvent rendre une tâche plus simple pour que la charge mentale des utilisateurs diminue ce qui a pour conséquence qu'ils perçoivent que le temps passe plus rapidement.

Informations sur l'article

La collecte de données en laboratoire, sous une bourse de la Chaire de recherche industrielle CRSNG-Prompt, a été effectuée en trois phases soient : en été 2018, automne 2018 et hiver 2019. Les résultats de ces études ont permis à l'étudiant de ce mémoire de rédiger un article. L'article en question de ce mémoire est en préparation pour soumission à *AIS Transactions on Human-Computer Interaction*.

Contributions personnelles

Tableau 1 – Contributions et responsabilités dans la rédaction de l'article

Étape du processus	**Contribution et tâches effectuées**
Définition des besoins du partenaire	Identifier les besoins d'affaire du partenaire et définition de la question de recherche et la problématique Collecte 1: 80 % Collecte 2: 80% Collecte 3 : 80% • Le reste de l'équipe de recherche a contribué à identifier les besoins du partenaire.

Revue de la littérature	Élaborer et rédiger la revue de littérature pour déterminer les construits observés dans les études antérieures sur la perception du temps – 100 % Définir et proposer les outils de mesure à utiliser en communiquant avec le partenaire Collecte 1: 80% Collecte 2: 80% Collecte 3: 80% • Le reste de l'équipe de recherche a contribué à identifier les outils de mesure à utiliser pour le partenaire.
Conception du design expérimental	Faire la demande au CER – 80 % • Le reste de l'équipe de recherche s'est assuré que toutes les demandes complétées au CER soient adéquates Élaborer et rédiger le protocole d'expérimentation Collecte 1: 100 % Collecte 2: 100 % Collecte 3: 100 %

	Préparation de la salle de collecte Collecte 1: 100 % Collecte 2: 100 % Collecte 3: 100 %
Recrutement des participants	Élaborer le formulaire de recrutement Collecte 1: 90 % Collecte 2: 90 % Collecte 3: 90 % • Le reste de l'équipe de recherche s'est assuré que le formulaire de recrutement soit adéquat Responsable des compensations Collecte 1: 50 % Collecte 2: 50 % Collecte 3: 100 % • Le reste une firme externe s'est assuré d'avoir administrer les compensations

	Concevoir et le cartable d'expérience pour le suivi des participants Collecte 1: 80 % Collecte 2: 80 % Collecte 3: 80 % • Le reste de l'équipe de recherche s'est assuré de faire l'assemblage du cartable d'expérience
Prétests et collecte de données	Chargé des opérations lors des collectes de données Collecte 1: 50 % Collecte 2: 50 % Collecte 3: 50 % • Le reste de l'équipe de recherche s'est assuré que les données ont été collectées avec l'assistance des assistantes de recherche. Soutien technique et appui aux assistantes de recherche en cas d'un problème – 100 %
Extraction et transformation des données	Extraction et nettoyage des données physiologiques et psychométriques – 100%

Analyse des données	Analyses statistiques des données du mémoire – 80% • Aide sur Stata/MP 15.1 pour les analyses par le statisticien de la Chaire de recherche industrielle CRSNG-Prompt en expérience utilisateur (UX)
Rédaction des articles	Contribution dans l'écriture des articles – 100 % • Les articles ont été améliorés tout au long du processus de rédaction à l'aide des commentaires des coauteurs

Structure du mémoire

Le prochain chapitre de ce mémoire présentera l'entièreté des résultats de cette étude. Ainsi, le chapitre 2 de ce mémoire présentera l'article qui est en préparation pour soumission à *AIS Transactions on Human-Computer Interaction*. L'article en question rapporte les résultats complets pour l'ensemble des 53 participants qui ont participé à l'étude. Pour conclure, le chapitre 3 fera un rappel des principaux résultats, contributions et limitations de cette étude. De plus, ce chapitre abordera les futures avenues de recherche que cette étude pourrait prendre.

Chapitre 2: Article
Does time fly when performing online utilitarian task?[1].

Michael Truong[1], Pierre-Majorique Léger[1], Sylvain Sénécal[1], and Annemarie Lesage[1]
[1]HEC Montréal, Québec, Canada
{michael.truong, pierre-majorique.leger, sylvain.senecal,annemarie.lesage}@hec.ca

Abstract

Our perception of time is influenced by a myriad of external and internal factors. Literature on time estimation tries to uncover factors that can influence how we sense the flow of time. Past studies found many elements that influence perceived time, including emotional state, the level of cognitive attention toward the activity and personality traits. However, many of those studies lack ecological validity as these studies used classical psychology tasks as a stimulus. Thus, these tasks do not necessarily reflect how an individual will perceive time while doing a real-world human computer interaction task. This study investigates how different level of complexity of online utilitarian tasks (low complexity vs high complexity) influence the time estimation of an individual and what role individual states and traits play in the relationship. A within-subject laboratory experiment was conducted with fifty-three participants. Results show that the complexity of the task has a positive direct influence on the time estimation of the task. Cognitive load partially mediates the relationship between task complexity and time estimation. Individual traits such as impulsivity and time orientation have a moderating effect on the relationship between cognitive load and time estimation. For individuals with greater impulsivity or greater time perspectives traits, the relationship between task complexity and time estimation is stronger. These findings contribute to the HCI literature and the theory of time estimation by providing knowledge on how an individual see the flow of time when interacting with real-world utilitarian interface tasks.

Keywords: Time estimation, time perspective, impulsivity, valence, arousal, cognitive load, task complexity, ecological validity

---

[1] L'article est en préparation pour une soumission à AIS Transactions on Human-Computer Interaction

Introduction

The study of time estimation has been extensively studied in psychology research (Allan, 1979; Fraisse, 1984; Hornik, 1984; Thomas and Weaver, 1975) and it has continued to be studied even today (Droit-Volet and Gil, 2016; Jokic et al., 2018; Kononowicz et al., 2018; Lake et al., 2016). While time itself is a constant resource, it seems that how humans perceive time can be different between individuals. There is the expression that time flies when you are having fun or that time slows down when you are bored (Droit-Volet and Meck, 2007). Hence, our perception of time is not necessarily veridical.

Time estimation is the study of estimating a time interval while performing various kinds of tasks (Block and Zakay, 1997). It is the study on how accurate an individual can estimate the length of a task between its objective (real) and subjective (perceived) time. Objective time is a resource that is chronological, scarce, valuable, homogenous, linear, and divisible (Sahay, 1997; Sarker and Sahay, 2004). On the other hand, subjective time is neither objective nor chronological. It is considered as a measure that is heterogenous, discontinuous, and non-equivalent (Starkey, 1989, p.42). There are many external and internal events that can influence our sense of time.

Prior research tried to uncover factors that could explain why individual perceived subjective time differently than objective time. One of the reasons is that psychophysiological state of mind is different between every individual (Droit-Volet and Meck, 2007). Everyone experiences their lives differently. As a result, the emotions that the person lives influence their sense of time (Droit-Volet et al., 2013). Another reason is the individual traits (Jokic & al., 2018). Every individual is also different on a personality level. Thus, the sense of time is different between individual because of personal traits such as entitlement (O'Brien et al. 2011), boredom (Danckert and Allman, 2005), anxiety (Lamotte et al., 2014) and impulsivity (Wittmann and Paulus, 2008).

Some researchers studied short time interval in milliseconds (Drake and Botte, 1993; Eisler et al., 2008; Fraisse, 1967; Friberg and Sundberg, 1995; Tse et al., 2004) while others have studied longer intervals ranging from seconds to minutes (Bisson et al. 2008; Grondin and Plourde, 2007). Many studies in time estimation used simple non-temporal tasks with short time intervals (ranging from milliseconds to a few seconds) such as watching an expanding oddball (Tse, Intriligator, Rivest and Cavanagh, 2004), watching a green circle (Wittmann et al., 2007), doing the Stroop test (Sawyer et al., 1994; Zakay and Shub, 1998), sorting cards (Hicks et al., 1976; Zakay, 1992; Zakay and Shub, 1998), solving mathematical problems and making calculations (Grondin and Plourde, 2007; Woehrle and Magliano, 2012; Grondin and Plourde, 2007) or drawing stars on a sheet of paper (Brown, 1985). Moreover, some researchers also explore time estimation while doing non-temporal hedonic tasks such as listening to music (Bailey and Areni 2006; Brown and Boltz 2002; Noulhiane et al., 2007) or looking at photographic pictures (Angrilli et al., 1997).

To our knowledge, while these studies have strong internal validity, it seems they lack ecological validity as the non-temporal tasks used do not necessarily reflect real-world tasks. Past studies suggest that the perception of time is different depending on the type of task (Zakay and Block, 1997). An empty task containing no stimuli will be estimated differently than a task filled with a stimulus (Zakay and Block, 1997). Furthermore, the difficulty of the task will also have an impact on the estimation of time (Zakay and Block, 1997).

Hence, we suggest that the use of real-world task such as utilitarian task will have different results than the use of classical psychology stimuli because classical psychology stimuli are simple and monotonous whereas utilitarian tasks are more complex (Egger et al., 2012). Utilitarian task aims to provide instrumental value to the user, an objective beyond just completing the task itself. For example, it can be to increase productivity, performance, and efficiency of the user (Van der Heijden, 2004). Time was shown to be an important criterion for the user's experience of completing a task. A task that was perceived to be too long may result in a failure to completing it (Atkinson, 1999). Thus, it is crucial to further investigate the prediction behind time estimation by using authentic tasks, because it would allow to contribute to the literature on time estimation.

Furthermore, past studies of time estimation online were only done using passive stimuli because interactive web browsing is much more complex (Egger et al., 2012). Past studies stimuli were mostly done on downloading contents online. Terai et al. (2008) highlight the fact that there are different levels of complexity while web browsing. We are not aware of any study on time estimation that looked on task complexity using online utilitarian tasks. In addition, research shows that the complexity of the task influences the state of the individual (Arapakis et al., 2008). As a result, the lack of theory on time estimation using online utilitarian tasks give us the opportunity to explore further and to contribute. We look to investigate if changing the tasks to a more realistic one will have an impact on the individual's time estimation. There is possibility that individual will use different mechanism to estimate time as the tasks are different. Our study will try to investigate those differences.

The objective of this is to study is to investigate the relationship between task complexity and time estimation for online utilitarian tasks. Since past research has shown that individual traits and states do play a role on time estimation, we also integrate physiological data during the interactions to measures individual's unconscious reactions that can influence his time perceived. Moreover, this paper aims to look to understand the mechanism of individual psychophysiological state in the relationship between task complexity and time estimation as well as the mechanism of individual traits in the relationship between the individual state and time estimation. Understanding the internal mechanism that influence an individual's time estimation is important to help advance the literature.

This paper makes the following contributions to theory. First, our results have greater ecological validity than past studies on time estimation as they mostly used classical psychology stimuli. Second, our results show that a low complexity task results in a lower time estimate (underestimation) when compared to a high complexity task. Similar results were also found in past studies (Zakay and Block, 1997). Third, implicit measures such as cognitive load have a mediating role of the relationship of task complexity and time estimation. An increase in the task complexity will lead to a higher cognitive load which will lead to an increase of time estimation (overestimation). Past studies have shown that complex tasks are difficult to learn because of the high demand of cognitive load of the individual influences the cognitive load (Paas and Van Merriënboer, 1994). Moreover, past studies have shown that a high cognitive load will lead to an overestimation of time (Block and Zakay, 1996). Our results have shown that both mechanisms apply in the context of interacting with utilitarian tasks online. Finally, explicit measures such as impulsivity and time perspective traits show a moderating effect on the relationship of cognitive load and time estimation. The effect of cognitive load on time estimation will be stronger with an individual who is impulsive or has a high time perspective trait. Past studies suggest that impulsivity influence positively the perception of time (Wittmann and Paulus, 2008). Furthermore, researchers have found that higher time perspective trait lead higher estimation of time (Jokic, Zakay and Wittmann, 2018). Our results have shown similar effect of the impulsivity or time perspective traits on the relationship of cognitive load and time estimation. The relationship is stronger with an individual with higher impulsivity or time perspective traits. This paper provides insights that the complexity of the task influences an individual's perception of time. Results of this study provide practical insights for interface developers to optimize online interface to make them less complex as possible, so the users feel that time goes faster when interacting with them.

This paper is organized as follows. It starts with a literature review of the main concepts and the theoretical background. Then, it presents the conceptual model followed by the development of hypotheses. Afterwards, it explains the research methodology and the operationalization of the research variables. Finally, it explains the results and discuss their theoretical contributions and practical implications as well as limitations and future research.

Literature Review

Time estimation

Time estimation research is the study of estimating a time interval while performing various kinds of tasks (Block and Zakay, 1997). It is the difference between the individual's perceived and real time. There are currently many studies in time estimation (Angrilli, Cherubini, Pavese and Manfredini, 1997; Brown, 1985; Noulhiane, Mella, Samson, Ragot and Pouthas, 2007; Wittmann and Paulus, 2008) that used synonymous term such as timing ([Droit-Volet, Fayolle, Lamotte and Gil, 2013), interval timing

(Buhusi and Meck, 2005; Droit-Volet and Meck, 2007), temporal perception (Effron et al., 2006), duration judgments (Block and Zakay, 2004; Block and Zakay, 1997), time estimation (Burle and Casini, 2001), interval estimation (Mcclain, 1983; Taatgen et al., 2005) and temporal cognition (Glicksohn, 2001).

Hicks et al. (1976) explain that there are four factors that influence a person's time estimation: the method of estimation (time production, verbal estimation, reproduction, or comparative judgment time), the duration of the target interval, the type of task to be performed during the target interval, and if the time interval was estimated prospectively (before doing the task) or retrospectively (after doing the task). Additionally, Zakay and Fallach (1984) added a fifth factor, the delay between the end of the task and the moment the subject is asked to evaluate the time.

There are currently four main methods to estimate time. A duration interval can be estimated either verbally, by reproduction, by production or by comparison (Grondin, 2010). In the verbal estimation, the subject is asked to give a verbal estimate of the duration of the temporal interval (Brown, 1985). In the reproduction, the experimenter shows the duration interval and the subject reproduces it (Hemmes et al., 2004). In the production method, the experimenter states the duration range of an interval and the subject produces it (Berlin et al, 2004). Finally, in the method of comparison, the experimenter presents two different intervals and the subject judges the duration of both or chooses which interval is the longest or shortest ([Tse, Intriligator, Rivest and Cavanagh, 2004). It should be noted that all time estimation methods vary from one and another and produce different results; there is no method better than another (Alan, 1979).

There are two paradigms that researchers need to consider when studying the topic of time estimation: prospective and retrospective study (Block and Zakay, 1997; Block and Zakay, 2004; Grondin 2010, Ornstein, 1975). A prospective study is when the participant knows beforehand that he will need to estimate a time interval. This procedure is said to motivate the participant to be alert and monitor time and be aware of temporal cues (Doob, 1971). On the other hand, in a retrospective study, a participant will only be informed that they need to estimate the duration of a task after the task is completed (Block and Zakay, 1997; Brown, 1985; Zakay and Block, 2004). The weakness with the retrospective paradigm is that researchers must be sure that time judgments are genuine (Grondin, 2007) and that the participant will be aware of subsequent time estimation after the first one. Results from retrospective paradigm studies may therefore be biased (Block and Zakay, 1997). Both paradigms will give different results as they usually differ to the non-temporal task, the duration, and the nature of the judgment method (Brown, 1985). They also function through different mechanisms (Block and Zakay, 1997; Zakay and Block, 1997). In the prospective paradigm, attention is a primary factor because the participant will have the knowledge that time is measured. Thus, the participant's attention will be allocated to the flow of time. His attention will be divided between keeping track of time and doing the non-temporal task. In the retrospective paradigm, the participant will not allocate his attention to time during the non-temporal task because he won't know beforehand. Instead, the paradigm is based on memory as the participant will try to recall the task and estimate the time interval (Zakay, 1993). The results may change within the same task when different paradigms are used. However, it should be noted that some researchers argued that type of paradigm has no effect of results (Brown, 1985; Eisler et al., 2008).

The attentional-gate model (AGM)

The attentional-gate model (AGM) theory notably explains that the attention to the passage of time affects its accuracy to estimate it (Zakay and Block, 1997; Woeherle, 2012). The initial model of AGM was conceptualized by Treisman (1963) and the scalar expectancy theory (Gibbon et al., 1984]). Zakay and Block (1997) later added an important component to the model that the perception of time is only recorded when attention is on the flow of time. There are also many variations of the model that are relatively similar (Frankenhaeuser, 1959; Glicksohn, 2001; Hicks et al., 1977; Simen et al., 2013; Taatgen et al., 2007; Thomas and Weaver, 1975).

When performing a task, AGM assumes that there is an internal pacemaker based on the circadian clock (biological internal clock) that emit pulses at a continuous and constant rate. The pulses are then stored in an accumulator and are then retrieved with memory to estimate an interval later on. The attention of the person is split between focusing on doing the non-temporal task and paying attention to the passage of time. Hence, the more difficult the task is, the more focused the individual will be on the task. As a result, the level of attention allocated on the passage of time will decrease (Zakay, 1993). The number of pulses accumulated will increases resulting in an overestimation of the interval or a perception that the time is longer. On the other hand, when the task is simple, the individual will have a higher attention on the passage of time which decreases the number of pulses counted in the accumulator. Thus, the individual will perceive that the time will go faster. There will then have an underestimation of the time interval (Zakay, 1993; Woeherle, 2012). These findings were tested empirically in a laboratory experiment and gained empirical support (Burnside, 1971; Hicks et al, 1977; Zakay, 1989; Zakay and Fallach, 1984; Zakay et al, 1983). In sum, when the attention is toward the tasks, the individual will have a feeling that time drags, whereas when the attention is toward time, the individual will have a feeling that time flies.

The attentional-gate model does not necessarily need to be used in a prospective paradigm study. Jokic et al. (2018) used AGM in their retrospective studies because it has strong heuristic value in explaining subjective time. Furthermore, a retrospective study that last more than several minutes will indirectly induce prospective mechanism as a situation without distraction and paying attention to time is inevitable (Zakay, 2015).

Temporal dissociation

Temporal dissociation is a dimension of the cognitive absorption and flow construct (Nakamura and Csikszentmihalyi, 2014) which is defined as the inability to perceive the flow of time because the user is too engaged in interaction with the interface (Agarwal and Karahanna, 2000). A user with a high score in temporal dissociation will lose track of time while interacting with a computer interface as he is too absorbed on the task (Lee et al., 2012; Nakamura and Csikszentmihalyi, 2014; Skadberg and Kimmel, 2004).

The dimension was used in various information technology studies such as the study of Rutkowski et al. (2007) where they found that virtual team with a higher level of temporal dissociation demonstrates a higher level of performance and interpersonal conflict in a virtual team environment setting. Furthermore, Tan et al. (2015) studies found that temporal dissociation has a negative moderating effect on the satisfaction and continuance use of a smartphone. As the user scores a higher temporal dissociation, they will less likely be satisfied with the technology and will less likely continue to use it.

Hence, the temporal component is a critical factor to consider when evaluating an interface. Tan et al. (2015) studies have shown that there is a direct relation between the satisfaction of IT users and the temporal component of its interaction. Furthermore, according the IS Continuance Theory, IT users who are satisfied with their experience with the interface are more likely to use that interface system again (Bhattacherjee, 2001; Deng et al., 2010). In addition, some studies found a negative relationship between time distortion and online purchase intention ([Lee and Chen, 2010; Ozkara et al., 2017; Wu and Chang, 2005). User perceives the passage of time as a cost. As a result, as the consumer feels that a high amount of time has passed during a task, the less likely the consumer will want to make a purchase online. Thus, high temporal dissociation is not always good.

Research Hypotheses and Proposed Research Model

Task Complexity

A given task has a recognizable beginning and end. The former has a set of guidelines concerning goals to be taken (Hackman, 1969). A large task or simpler subtasks can also be defined as a task. Thus, not every task exhibits the same level of complexity. Little consensus exists among researchers concerning the properties that make a task complex (Campbell, 1988). Some researchers suggest that skill and knowledge define the complexity of the task (Locke and al., 1981); while others suggest that complexity is primarily psychological (Hackman and Oldham, 1976); while other researchers emphasized the objective tasks qualities (Latham and Yukl, 1975). Earley's (1985) study defined complexity in terms of the number of rules that needed to be satisfied to complete the task. Hence, there are many ways to categorize the complexity of a task.

In the context of our study where users must interact with utilitarian online tasks to either seek or fill information, we chose to categorize the complexity of our task based on the objective behind accomplishing the task because it is widely used in online information seeking studies (Byström and Järvelin, 1995). Some researchers also explore time estimation while doing non-temporal hedonistic tasks such as listening to music (Bailey and Areni, 2006; Brown and Boltz, 2002; Noulhiane, Mella, Samson, Ragot and Pouthas, 2007) or looking at photographic pictures (Angrilli, Cherubini, Pavese and Manfredini, 1997). Hedonistic tasks notably refer to pleasure-oriented task. The term hedonic comes from the word hedonism which follows the ideology that pleasure, and happiness is the secret in good life (Van der Heijden, 2004). The goal of a hedonic task is to provide self-fulfilling value (Van der Heijden, 2004). However, very few studies on time estimation have been done so far on non-temporal utilitarian task. Utilitarian tasks aim to provide instrumental value to the user, which means that there is an objective beyond doing the task (Van der Heijden, 2004). There are many studies on utilitarian task interaction on computer interfaces such as online shopping (Childerset al., 2001) and mobile interface (Wakefield and Whitten, 2006). Additionally, some researchers looked at the effect on time estimation while driving a car (Baldauf et al., 2009) or downloading a file on a website (Gorn et al., 2004). Nevertheless, we are not aware of any study that systematically assessed how individuals perceived the flow of time while interacting with a utilitarian computer interface.

In this paper, tasks are categorized by either simple or complex by using information seeking on the web categorization of Terai et al. (2008). Their study explained that there are two types of tasks when interacting with a web interface. The type of task depends on the nature of the goal that the user wants to accomplish. A transactional task is when the user needs to enter information by typing with the keyboard. Al-Wabil and Al-Saleh (2011) further describe a transactional task as necessitating a motor response from the user. The second type of task described by Terai et al. (2008) is the informational task. An informational task is when the user is seeking to find a particular piece of information on a website. A transactional task that requires the user to use the keyboard and a computer screen increases the difficulty of the task as it requires a higher motor response by alternating the user's fixation between the two objects (Land and Hayhoe, 2001). Thus, a transactional task is suggested to be more complex than an informational task. For our study, we categorized transactional web browsing tasks as complex and informational tasks as simple.

The type of task that users interact with might influence time estimation due to the differing task complexity. The more complex and difficult the task is to accomplish, the higher the estimated time will be (Zakay and Block, 1997). A widely accepted model that explains this phenomenon is the attentional-gate model (AGM). In the retrospective paradigm, as the difficulty of the task increases, the attention of the participant will be directed on the task. Thus, the amount of attentional capacity devoted in keeping the time is disrupted. A more difficult task will make a person pay less attention to time. Thus, making a person feel that a time period is longer than normal (Treisman, 1963; Woeherle and Magliano, 2012; Zakay and Block, 1997). Underswood (1975) also found similar results when estimating a time interval after recalling a list of words. We thus propose the following hypothesis pertaining to the effect of task complexity on the time estimation.

H1: The complexity of the utilitarian task will positively influence the participant's time estimation. The time of a complex task will be overestimated in comparison to a simpler task.

Individual States

The individual state is considered as "a function of a state of physiological arousal and of a cognition appropriate to this state of arousal. The cognition, in a sense, exerts a steering function." (Schachter and Singer, 1962, p. 380) The state of an individual varies depending on his interaction with the system. In fact, the states of an individual "varies in intensity and fluctuates over time as a function of the intrapsychic or situational stresses that impinge upon an individual." (Spielberger., 2010, p.146) As a result, there are many internal mechanisms that can influence the state of an individual. Internal mechanisms are dynamic and change depending on the individual's experience with the system (Egges and al., 2003). Past study suggests that the state of the individual can vary during depending on factors such as the complexity of the tasks (Wimmer et al., 2010). Study also suggests that task complexity is primarily psychological to the user (Campbell, 1988). Moreover, individual states can also be measured or quantified through implicit metrics such as valence, arousal or cognitive load (Albert and Tullis, 2013). Some studies suggest that complex tasks affect positively on the state of the individual (Campbell & Gingrich, 1986). Therefore, it is important to measure the state of the individual during his interaction with different types of tasks to have a better insight on the individual's perceptions and behaviours. We suggest in our study that the complexity of the task will influence the user internal states through implicit measures such as cognitive load, arousal and valence. Hence, those implicit measures will influence how the user will perceive time. In addition, past studies found that internal psychological states such as trust and perceived risk are critical mediators that influence a users' online purchase intention using the Stimulus Organism Response model (Chau et al., 2007). Thus, we also suggest in our study that individual states will mediate the relationship of task complexity and time estimation.

Cognitive Load

Cognitive load refers to the information-processing demands of the subjects. In other words, the amount of mental effort needed for a participant to perform a certain set of tasks (Proctor and Van Zandt, 1994). It is the internal cognitive processes such as the demand on attentional capacity and resource sharing to perform a certain task (Brown and Boltz, 2002). Many researchers studied cognitive load to minimize individual to experience high mental workload as it can cause frustration or mental fatigue (Mizuno & al., 2011). In addition, prior studies suggest that lowering the cognitive load affects positively the individual's satisfaction with online tasks (Gwizdka, 2010).

Past study has shown that both subjective and objective measure of cognitive load are sensitive to task difficulty (Mirhoseini et al., 2017). Prior research suggests the complexity of the task play an important role on the cognitive load of the individual as it was extensively studied in the learning literature (Van Merrienboer and Ayres, 2005). Past study suggests that highly complex cognitive tasks was difficult to learn for novices because of the inappropriate excessive cognitive load that is imposed on the learner (Paas and Van Merrienboer, 1994). Moreover, researchers suggest that individual's learning performance is decreasing as the task complexity increases because the cognitive load is high. The learning performance is increasing when the individual is in a group as cognitive load can be divided (Kirschner et al., 2009). Studies also shown that learning complex task is limited by the cognitive load capacity of the individual (Van Merriënboer et al., 2003). However, limited research has been done regarding the role of cognitive load and the complexity of online tasks. For example, researchers suggest that future studies in the field of learning and instruction should do online (Van Merrienboer and Ayres, 2005). In online shopping, studies suggest that cognitive load was at the highest when users conducted high complexity task (Wang et al., 2014).

Past studies have shown that cognitive load influence time estimation (Block and Gellersen, 2010). Indeed, Block et al. (2010) suggest that estimation paradigm influence the estimation of time. A higher cognitive load leads to an underestimation of the time interval in the prospective paradigm, but a higher cognitive load leads to an overestimation of time in the retrospective paradigm. Past studies have shown that both paradigms show opposite effects on duration judgments (Block, 1992; Block & Zakay, 1997). In the retrospective paradigm, similar results were also found on time estimation (Block and Reed, 1978; Poynter, 1989). Researchers suggest that an individual that perform two tasks simultaneously will overestimate time in a high-capacity tasks (Woehrle and Magliano, 2012). In a context of simulated car driving, study suggests that time estimation increases as complex driving situations increase (Baldauf, Burgard and Wittmann, 2009).

Our review has shown that task complexity influences cognitive load and that cognitive load influences time estimation. Hence, our review has shown that cognitive load may have a mediating role between task complexity and time estimation. As both factors are influenced by the mechanism of cognitive load, we propose that cognitive load mediates that relationship between task complexity and time estimation. We thus propose the following hypothesis:

H2a: Cognitive load mediates the relationship between task complexity and time estimation. Specifically, cognitive load will have a positive effect on the relationship. Time will then tend to be overestimated.

Emotional states

Emotions can be defined as "a response of the whole organism, involving physiological arousal, expressive behaviours and conscious experience." (Droit-volet and Meck, 2007, p.504). Two constructs can be used to measure emotion: arousal and valence (Russell, 1980). Emotional arousal is the reaction to an emotional stimulus characterized by psycho-physiological level of vigilance or a state of attention (Kandel et al, 2000). It ranges from states of low arousal (calm) and high arousal (aroused) (Boucsein, 2012). The arousal construct is widely used in the human computer interaction literature (Pastore, 2001). Emotional valence is defined as the "positive and negative nature of an emotion" (Colombetti, 2005, p.103). The construct allows us to know the emotional state of the user, ranging from the state of pleasure (happy) to displeasure (unhappy) (Boucsein, 2012; Lane et al, 1999).

Previous studies on task complexity that measure the effect of emotion when performing easy and difficult task suggests that a complex task result in a stronger negative emotion but not positive emotion (Anshel and Martin, 1996). Furthermore, study find evidence that when performing level of difficulty of maze puzzles, the task performance and emotion decrease as the level of difficulty increases (Huber, 1985). Hokanson and Burgess (1964) suggest that individuals with high levels of arousal performed better on low complexity task but their performance decreases when the level of complexity increases. Past studies suggest that specific patterns of emotion emerge from specific type of tasks (Arapakis, Jose and Gray, 2008). Moreover, a study shows an increase of task difficulty is related to an increase in specific facial muscle activity during a word processing tasks (Branco et al., 2005). Thus, the study suggests that a specific level of a task difficulty is related to a specific level of emotion. Hence, past studies suggest that task complexity influences the emotion of the individual.

Emotions have been shown to influence the perception of time (Tse, Intriligator, Rivest and Cavanagh, 2004; Yamada and Kawabe, 2011). Arousal and valence seem to have an influence on the person's subjective experience of time. However, many of the findings of past studies suggest that the perception of time is influenced by emotions in a way that contradicts the expressions "Time flies when you're having fun" (Kellaris and Kent, 1992). Indeed, studies have shown that an increase in arousal and valence increases perceived duration of time (Angrilli, Cherubini, Pavese and Manfredini, 1997; Droit-Volet and Meck, 2007). Previous studies suggest that individuals will underestimate the time of a low-arousal stimulus than a high-arousal stimulus when looking at standardized photographic slides Angrilli, Cherubini, Pavese and Manfredini, 1997). Similar results were also found in studies using music such as the International Affective Digital Sounds (IADS) (Noulhiane, Mella, Samson, Ragot and Pouthas, 2007). Moreover, Bisson et al. (2008) suggest that joyful musical excerpts were judged to be longer than sad excerpt. Some research implied that time estimation was longest for individuals exposed to positively valence music and shortest for negatively valenced music.

In summary, the literature offers strong evidences that arousal and valence have an impact the time estimation. Furthermore, our review has shown that both task complexity affects the level of emotions of the individual. As both factors are influenced by the mechanism of emotions, emotions may have a mediating role between the relationship of task complexity and time perception. We have shown in our review that task complexity has an influence on emotions and that emotions have an influence on the time estimation. We suggest that emotions mediate the relationship between task complexity and time estimation. We posit the two following hypotheses:

H2B: Emotional arousal mediates the relationship between task complexity and time estimation. Specifically, arousal will have a positive effect on the relationship. Time will then tend to be overestimated.

H2C: Emotional valence mediates the relationship between task complexity and time estimation. Specifically, valence will have a positive effect on the relationship. Time will then tend to be overestimated.

Individual traits

When interacting with information technology (IT), not every individual will react the same way. Indeed, individual traits refer to characteristics such as personality, situational, and demographic variables that influence the individual’s beliefs about and his interaction with technology (Agarwal and Prasad, 1999). Individuals traits are fixed whereas individual states are dynamic (Egges, Kshirsagar and Magnenat-Thalmann, 2003). Past studies found factors such as personal innovativeness, computer playfulness, computer self-efficacy, or even computer anxiety to have an impact on how individuals perceive and use information technology (Agarwal and Prasad, 1998; Webster and Martocchio, 1992; Compeau and Higgins, 1995; Harrison and Rainer Jr, 1992). In the field of emotions, researchers suggest that an individual personality will influence the mood of the individual when interaction with a dialogue system (Egges, Kshirsagar and Magnenat-Thalmann, 2003).

Researchers suggest that there are many factors that moderate temporal distortions, such as individual differences, emotional state, and biological relevance (Lake, LaBar and Meck, 2016). Thus, variability of personality traits has a relation on the perception the passage of time. Many studies in the literature have looked at the effect of personal traits on the perception of the flow of time. O'Brien et al. (2011) found that people who scored higher on the entitlement trait estimated that dull tasks took longer to complete. Entitlement is when a person feels that he/she is more deserving than others of all good things in life (Campbell et al., 2004). Twenge et al. (2003) found that people who are socially rejected overestimate the time intervals and focus more on present than the future. Danckert and Allman (2005) found in their studies that individuals who are more prone to boredom tend to overestimate the duration of the time. In Watt's (1991) study, people who are bored in a tedious task feel that time pass slowly. Lamotte et al. (2014) study found that individuals who are anxious feel that time passes more slowly. Draaisma (2006) study also found that demographic variables, such as age, have an influence on time estimation. The study notably found that older people perceive time to move faster. In sum, studies have shown that individual characteristics can be a determinant factor of whether or not an individual will overestimate or estimate a time interval. For our study, we will focus on the individual trait of impulsivity and time perspective as they are traits that still need better theoretical foundation and further researches in the individual states and time estimation literature (Wittmann and Paulus, 2008; Jokic, Zakay and Wittmann, 2018).

Impulsivity

Impulsivity is defined as "swift action without forethought or conscious judgment, behaviour without adequate thought, and the tendency to act with less forethought than do most individuals of equal ability and knowledge." (Moeller et al., 2001, p.1783) An individual who is impulsive will often devalue temporal delayed rewards more strongly than normal individual (Wittmann and Paulus, 2008). Impulsive people will then opt for smaller and immediate reward than delayed higher rewards because those individuals perceived that waiting for the delayed reward might take too long. Therefore, this behaviour might be explained by their altered sense of time. Studies have shown that impulsivity and time estimation are closely linked (Van den Broek, Bradshaw and Szabadi, 1992). Researchers suggest that patients with damage to the orbitofrontal cortex (OFC) are more impulsive, tend to experience more subjective anger and tend to overestimate subjective sense of time (Berlin, Rolls and Kischka, 2004). People who are more impulsive tend to overestimate duration because they feel that they are trapped in time as they have less control on their action (Glicksohn et al., 2006; Moreira et al., 2016; Van den Broek, Bradshaw and Szabadi, 1992). Jokic et al. (2018) assessed impulsivity in a context of waiting in an empty room for exactly 7.5 minutes. They notably found that individuals who score higher on impulsivity tend to overestimate the waiting time. We posit the following hypotheses:

H3a: Impulsivity will have a moderating effect on the relation between the individual states and time estimation. The relationship between individual states and time estimation will be stronger for more impulsive individuals. Time will then tend to be overestimated.

Time perspective

Time perspective is defined as "the totality of the individual's view of his psychological future and psychological past existing at a given time." (Lewin, 1951, p.75) Every individual perceives the passage of time differently whether it is in the past, present, or future. The concept of time perspective has been studies in psychology (Boniwell and Zimbardo, 2003). Time perspective can exert a dynamic influence on many important judgments, decisions and actions of a person (Zimbardo and Boyd, 2015). Previous studies suggest that students with high depression score are highly correlated with time perspective (Keough et al., 1999). Researchers also suggest that homeless individuals will tend to score high on time perspective (Pluck et al., 2008). Past studies suggest that delinquent boys have lower time perspective than the group of non-delinquents as the delinquent boys produce shorter time span's stories (Barndt and Johnson, 1955). In time estimation studies, time perspective traits have been used to observe how individual use temporal information to perceive the real time (Lasane and O'Donnell, 2006). Past studies found that individuals with higher time perspective score tend to have higher overestimation while waiting (Jokic et al., 2018). However, other studies suggest that individuals with higher score of time perspective will underestimate time as they perceived time to pass more quickly (Zimbardo and Boyd, 1999). We posit the following hypotheses:

H3b: Time perspective will have a moderating effect on the relation between the individual states and time estimation. The relationship between individual states and time estimation will be stronger for individuals with greater time perspective. Time will then tend to be overestimated.

This article proposes a research model that uses the complexity of a utilitarian online task as a direct effect on time estimation. It integrates implicit psychophysiological measures to represent the individual states as an internal mechanism that can mediate the relationship: cognitive load, valence and arousal. The model also integrates individual traits of impulsivity proposed by Barratt et al. (1999) and time perspective proposed by Zimbardo and Boyd (2015) as a moderating effect on the relationship between the individual states and time estimation.

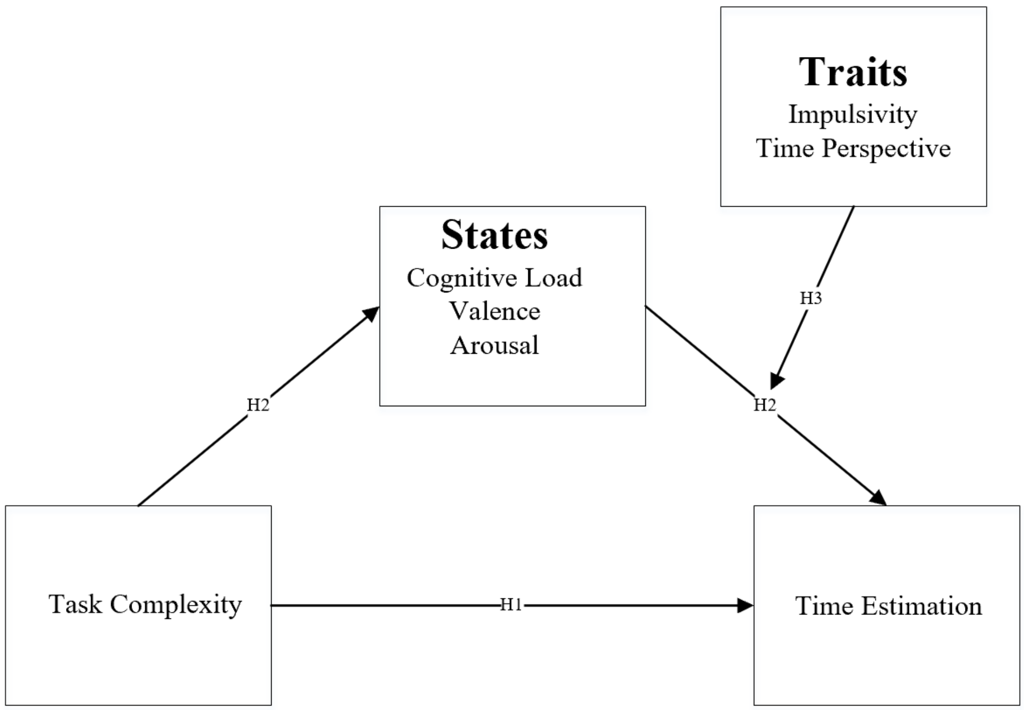


Figure 1. Proposed Research Model

Method

Experimental design

A within-subject laboratory experiment was conducted. Fifty-three participants (24 men, 29 women) with an age range between 18 and 64 years (mean age: 32 years; S.D. = 13.11) participated in the study. Participants were recruited externally by a third-party recruitment service and each received a monetary compensation. The experiment was approved by the Research Ethics Committee of our institution. The experimental factor was manipulated following Terai et al. (2008), the low complexity task consisted of finding a specific information on a banking website and the high complexity tasks consisted of applying for a credit card on a banking website by filling out his personal information on a form. The tasks were randomized to control for ordering effect. We chose to use the verbal estimation as the method estimation and a retrospective paradigm (estimating the time of the task after completing the task) as they are the more convenient method to evaluate the time interval for longer duration tasks (Grondin, 2010).

Procedure

As illustrated in Figure 2, when first arrived at the laboratory experiment, participants were greeted and invited to leave their personal belongings in a locker such as their watch, cell phone, wallet, keys, etc. The reasoning behind leaving the personal belonging of the participant was that they could not check the time by any means while doing the experiment. They were then invited to fill a consent form. Before the experiment began, the participant was brief with a small scenario containing all the basic information the participant needed to complete the tasks. Once ready, the participant proceeds into a baseline which lasted for 90 seconds to have measurements of the participant at rest before the interacting with any task of the experiment. The participant was tasked to count the number of white squares he sees on the screen (Jenning et al., 1992). After the baseline, the participants proceeded into completing the various tasks of the experiment. The tasks were categorized as either high complexity or low complexity by the index from the study of Terai et al. (2008), the low complexity task consisted to find a specific information on a banking website page and the high complexity consisted filling out an online credit card application form. The choice of tasks used in our study is crucial to maximize ecological validity. Hence, we chose to use online banking tasks as it is a utilitarian task that most people around the world use (Martins et al., 2014). Online banking offers a variety of services ranging from providing information, to submitting forms online. All the tasks were counterbalance. After each task's completion, the participants were asked to estimate the time of the task. At the end of the experiment, the participant was instructed to fill out a questionnaire composed of measurement scales of impulsivity and time perspective traits which are respectively the Barratt Impulsiveness Scale (Barratt et al., 1999) and the Zimbardo Time Perspective Inventory (Zimbardo and Boyd, 2015).

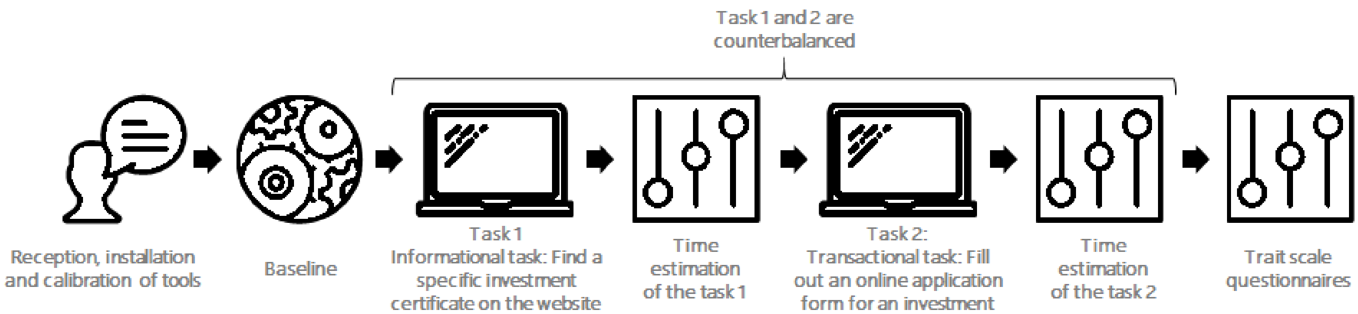


Figure 2. Experiment Timeline

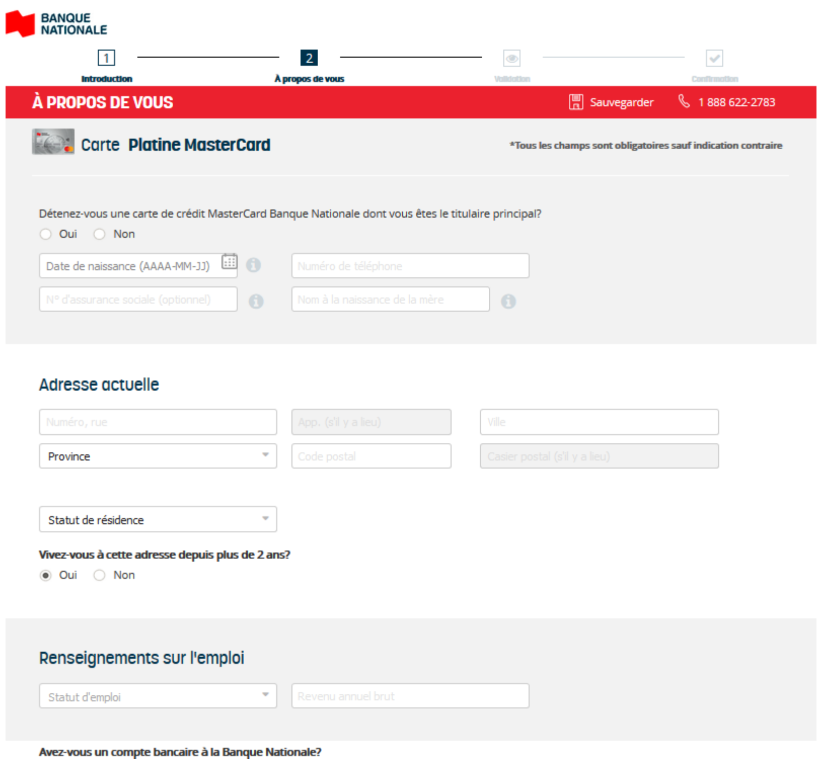


Figure 3. A high complexity task during which the participant had to enter his personal information in order to apply for a credit card.

Figure 4. A low complexity task where the participant had to find a specific information on the page.

Apparatus and Measures

We used Google Chrome version 67.0.3396.99 web browser to display the banking interfaces and they were presented through the software Tobii Pro (Stockholm, Sweden). The task stimulus was presented on a computer monitor with a 1920X1080 resolution.

Explicit Measurement

For our dependent variable, the participants were not informed during the experiment that had to estimate the time on any of tasks nor to pay any attention on time. The participant was asked how long he thought the task lasted in number of seconds. We then calculated the difference between the participant time estimation on the task and the real time of the task (delta).

The Zimbardo Time Perspective Inventory (ZTPI) is a scale consisting of 56 items ranging from 1 (rarely/never) to 5 (almost always) which are grouped into 5 dimensions: Past-negative (PN), past-positive (PP), present hedonistic (PH), present fatalistic (PF) and future. Each dimension represent different aspects of the person's time perspective such as : “I often think about the bad things that have happened to me in the past” (past-negative), “Happy memories of good times spring readily to mind” (past-positive), “I take risks to put excitement in my life” (present hedonistic), “Because things always change, one cannot foresee the future” (present fatalistic) and “I am able to resist temptations when I know that there is work to be done” (future). This scale will provide us with that participant’s characteristic on his time perspective (Zimbardo and Boyd, 2015). For our study, we decided to use the total score to measure the time perspective trait. A higher total score mean that the individual has a high trait in time perspective.

We first pretest the questionnaire with 12 subjects before the experiment to test for the validity and reliability of the scale. We found that the cronbach alpha of the dimensions of the construct was low. To do so, we did a factor analysis with 12 subjects before the experiment by looking at the inter-item correlation matrix. The cronbach alpha of the questionnaire for the Zimbardo Time Perspective Inventory with 12 pretest subjects for the dimensions of past-negative, past-positive, present hedonistic, present fatalistic and future were respectively: α = 0.850, α = 0.697, α = -0.088, α = 0.671 and α = 0.591. We then identified the items that have a weak correlation in the matrix. We eliminated all items with a negative correlation and a correlation lower than 0.4. We then did another factor analysis without the removed item and we calculated the cronbach alpha of each dimension to make sure it is over 0.7. As a result, we reduced the number of items of the questionnaire from 56 items to 29 items. The cronbach alpha of the reduced questionnaire for the Zimbardo Time Perspective Inventory for the dimensions of past-negative, past-positive, present hedonistic, present fatalistic and future were respectively: α = 0.920, α = 0.827, α = 0.678, α = 0.777 and α = 0.779. To calculate the score for every dimension, we kept the way it was presented in the literature. We computed the average score of every dimension.

The table below presents a summary of the cronbach alpha of every dimension of the ZTPI scale.

Table 1. Cronbach Alpha of the ZTPI

Dimensions	Cronbach Alpha in the literature (Zimbardo and Boyd, 2015)	Cronbach Alpha by pre-testing with 12 subjects	Cronbach Alpha of the reduced questionnaire (n=12)	Cronbach Alpha of the reduced questionnaire (n=53)
Past-negative	$\alpha = 0.820$	$\alpha = 0.850$	$\alpha = 0.920$	$\alpha = 0.858$
Past-positive	$\alpha = 0.800$	$\alpha = 0.697$	$\alpha =0.827$	$\alpha = 0.800$
Present-hedonistic	$\alpha = 0.790$	$\alpha = -0.088$	$\alpha = 0.678$	$\alpha = 0.779$
Present fatalistic	$\alpha = 0.740$	$\alpha = 0.671$	$\alpha = 0.777$	$\alpha = 0.680$
Future	$\alpha = 0.770$	$\alpha = 0.591$	$\alpha = 0.779$	$\alpha = 0.740$

The Barratt Impulsiveness Scale (BIS-10) consists of 34 items ranging 1 (occasionally) to 4 (Always) which are grouped into 3 different dimensions: motor impulsivity, cognitive impulsivity, difficulty of planification in time or anticipation. The scoring can be made by doing a sum score of all items together or by dimensions. The higher the score, the higher the person will have a self-rate assessment of being impulsive (Barratt et al., 1999). For our study, we chose to use the total sum score to measure the impulsivity trait. A higher score mean that the individual has a high trait in impulsivity.

We also did a 12 subjects pretest before the experiment to test for the validity and reliability of the scale. We found that the cronbach alpha of the Barratt Impulsiveness Scale with a pretest of 12 subjects for the dimensions of motor impulsivity, cognitive impulsivity and difficulty of planification were respectively: α = 0.760, α = 0.363 and α = 0.387. We used the same reducing method as previously stated for the Zimbardo Time Perspective Inventory. We eliminated all items with a negative correlation and a correlation lower than 0.4. We then did another factor analysis without the removed item and we calculated the cronbach alpha of each dimension to make sure it is over 0.7. Thus, we reduced the scale from 34 items to 21 items. The cronbach alpha of the reduced questionnaire for the Barratt Impulsiveness Scale for the dimensions of motor impulsivity, cognitive impulsivity and difficulty of planification were respectively: α = 0.807, α = 0.746 and α = 0.752.

The table below presents a summary of the cronbach alpha of every dimension of the scale.

Table 2. Cronbach Alpha of BIS

Dimensions	Cronbach Alpha in the literature (Barrat et al., 1999)	Cronbach Alpha by pre-testing with 12 subjects	Cronbach Alpha of the reduced questionnaire (n=12)	Cronbach Alpha of the reduced questionnaire (n=53)
Motor impulsivity	α = 0.790	α = 0.760	α = 0.807	α = 0.737
Cognitive impulsivity	α = 0.560	α = 0.363	α =0.746	α = 0.680
Difficulty of planification	α = 0.640	α = 0.387	α = 0.752	α = 0.731

Implicit measurement

Observational measures were also used in addition to self-reported measures. Three types of psychophysiological variables were used to assess the participant's emotional states: emotional valence, emotional arousal, and cognitive load.

Psychophysiological measures are defined as "an unobtrusive and implicit way to determine the user's affective or cognitive state on the basis of mind-body relations" (Dirican and Göktürk, 2011, p.1362). Psychophysiological measures, also known as implicit measures, are unconscious or automatic phenomenon that the individual is not necessarily conscious about them (Ortiz de Guinea et al., 2014). In contrast, explicit measures represent "a phenomenon that occurs within individuals" awareness, and as such, individuals can report on them" (Ortiz de Guinea et al., 2014). While explicit measures such as self-reported questionnaire offer a great way to measure the user experienced retrospectively (Bargas-Avila and Hornbæk, 2011), the use of psychophysiological measures is becoming more popular in human computer interactions (HCI) research (Ortiz de Guinea and Webster 2013; Riedl and Léger, 2016) as psychophysiological measures was proven to offer greater insights on what the user really experiences during a given task (Georges et al., 2017; Courtemanche et al., 2017). In fact, the method can give a richer perspective by providing real-time data as it offers a better temporal resolution (Lourties et al, 2018; Dirican and Göktürk, 2011). It can provide with continuous measures of the experience over time (Hassenzahl and Tractinsky, 2006; Boucsein, 2012). Non-continuous measures such as self-reported scales only give a measure in a precise set of time. As a result, psychophysiological measures can be very useful for time estimation studies as it provides greater precision. It allows to researchers to precisely know what the participants are living right before they are estimating the time of the task. Thus, psychophysical instruments borrowed from neuroscience theories that provide physiological signals such as electrodermal activity, heart rate, eye-tracking and facial expressions can be used to represent constructs such as valence, arousal and cognitive load (Riedl and Léger, 2016; De Guinea et al., 2013). Electrodermal activity (EDA) has been used to measure physiological arousal (Hassenzahl and Tractinsky, 2006; Boucsein, 2012), facial expression has been used to measure emotional valence (Ekman and Friedsen, 1971; Bartless et al., 2004).and eye-tracking has been used to measure cognitive load through pupil dilatation (Laeng et al., 2012).

We can use the pupillometry of the eye tracker to measure the dilatation of the pupil which can be inferred into cognitive load. Literature has shown that the increase of the diameter of the pupil correlated with an increase of the cognitive load (Laeng et al., 2012; Ahlstrom and Friedman-Berg, 2006). The size of the pupil can range from .2mm to .8mm (Kramer, 1991). The more dilated the pupil is, the more difficult the task is (Beatty, 1982). To measure cognitive load, Tobii Technology (Sweden) was used to track the participant's visual attention during the experiment. We decided to use this instrument for two reasons. First, Eye-tracking technology is useful to measure the level of attention and cognitive load the participant is experiencing during the experiment. Thus, we use the eye-tracker Tobii to measure cognitive load with the use of the dilation of the pupil. It should be noted that pupil dilatation can be affected by the light conditions because the reflex of the pupil (Kramer, 1991). Hence, using the eye-tracker outdoor can cause bias (Adams, 2007). The experiment was run in an indoor laboratory setting in order to control such bias. Second, the instrument is non-intrusive. Thus, it allows us to collect real-time data, and it allows the participants to perform all the tasks in a more realistic way. A 9 points (3 x 3) calibration grid was used to calibrate the participant and it was repeated until acceptable accuracy was reached. The fixation threshold used was of 200ms (Holmqvist et al, 2011).

Previous study has proven that facial micro-expression is a good indicator of the level of valence (Loijens et al., 2015). Thus, facial expression can be analyzed to detect facial muscle movements in order infer emotional valence (Bartlett et al., 2004). To calculate the valence score, the emotional valence that the participant could live throughout the experience could have ranged from negative emotion (unpleasant) to positive emotion (pleasant). We used FaceReader software (Noldus, Wageningen, Netherlands) to measure emotional valence for two main reasons. First, it allows us to record facial expression and micro-expressions of the participants throughout the experiment (Abadi et al., 2013; Ekman and Friesen, 2003). Hence, a score between -1 to +1 was generated with FaceReader software (Ekman and Friesen, 2003; Ekman et al., 1987). Secondly, as the FaceReader software analyze in real time, it has good temporal resolution. It allows us to have real-time recording which is important for a time estimation study. Furthermore, as previously stated, FaceReader software is non-intrusive which allows the participants to interact with the interface in a more realistic manner. To do the analysis with FaceReader software, a webcam and Media Recorder software (Noldus, Wageningen, Netherlands) were used to record to facial emotion of the participant during the experiment. The setting used for the recording was a frequency rate of 30 frames per second and a resolution of 800x600. To make sure everything was properly synchronized between all apparatus, Observer XT (Noldus, Wageningen, Netherlands) was used as suggested by Léger et al (2014).

Arousal is associated with the intensity of an emotion (ranging from deactivated to activate). Past studies have shown that electrodermal activity (EDA) is an accurate indicator of arousal (Hassenzahl and Tractinsky, 2006; Lang et al., 1993; Boucsein, 2012). To measure arousal, Biopac technology (Goleta, USA) was used. Biopac technology allows us to attach sensor to the hand palm of the participant (near the eccrine gland) to collect sweat on the surface of the skin (Lang, 1995). To analyze the data, Acqknowledge software (Goleta, USA) was used to extract the data (sample rate of mp150 at 500 Hz). Arousal is then modelled with a standardized score with an average score of Z (z=$\frac{EDA\ Value - EDA\ Average}{EDA\ Standard\ Deviation}$) (Boucsein, 2012). Acqknowledge Software (Biopac, Goleta, USA) was used to clean EDA data and extracts arousal metric. FaceReader software (Noldus, Wageningen, Netherlands) was used to analyze micro-facial expressions and calculate emotional valence. Finally, event markers were added to different subtasks and as well as area of interests (AOIs) using Tobii Studio. Observer XT (Noldus, Wageningen, Netherlands) was used to synchronize all the recordings during the experiment. To triangulate all the metrics together, we converted all the data from each system and we used the software CUBE HX (Montréal, Canada) (Leger et al., 2018).

Table 3. Operationalization of the Variables Types of Measure

Measures	Instruments	Variables
Task duration	Self-reported questionnaire used on Qualtrics (Seattle, USA)	Objective time (real time in seconds) Subjective time (estimated time in seconds)
Time perspective	The Zimbardo Time Perspective Inventory (ZTPI) (Zimbardo and Boyd, 2015)	Sum score of the reduced scale Items evaluated on a 5-point Likert scale 5 dimensions: Past-negative (PN), past-positive (PP), present hedonistic (PH), present fatalistic (PF) and future.
Impulsivity	The Barratt Impulsiveness Scale (BIS-10) (Barratt et al., 1999)	Sum score of the reduced scale Items evaluated on a 4-point Likert scale 3 different dimensions: motor impulsivity, cognitive impulsivity, difficulty of planification in time or anticipation.

Emotional valence	Recorded with MediaRecorder 2 (Wageningen, Netherlands) Analyzed with: Facereader (Wageningen, Netherlands)	Facial expression score (-1 to 1): valence, neutral, happy, sad, angry, surprised, scared, disgusted
Emotional arousal	Biopac (Goleta, USA)	Electrodermal amplitude: Standardized score Eda
Cognitive load	Tobii Technology (Stockholm, Sweden)	Pupil dilatation (in millimeter)

Analysis

We proceeded with the statistical analysis using the software SAS 9.4 (Cary, USA). We made few transformations in our data set. First, our implicit measures were adjusted for baseline to control for the individual’s resting measurements. In the case of EDA, we wanted to have measures where the participants were not doing any task. The adjusted values were calculated from the difference between the implicit measures collected and the computed average of the corresponding participant’s baseline. Secondly, we first made sure that our data set met the criteria of having a normalized and non-correlated data in order to have a valid test. We used the rule of thumb of (-1.5<sk<1.5 and/or 1.5<ku<4.5) presented by Hair (2006) to verify the normality of the data set and we did a correlation matrix we the rule of thumb of (-0.5>r<0.5) to verify that all metrics are non-correlated. If the data was not normalized, we adjusted using ln, square root, and multiplicative inverse transformation.

Direct effects have been tested using simple linear regressions. Our analysis of our model has been tested using Model 14 of the PROCESS macro as presented by (Hayes, 2017. p.591) in SPSS. Model 14 allows us to test for the mediation effects of the individual states on the relationship of task complexity and time estimation and as well as the moderating effects of individual traits on the relationship of individual states and time estimation. We used bootstrapping method of ab to derive a confidence interval as well as an estimated standard error, for both 95% and 90% confidence interval (Hayes, 2017). 2000 bootstrap samples have been used.

Model 14 allows us to test our analysis model. Which is a mediation model with also a moderator. Model 14 let us analyze the mediating effect of cognitive load, valence or arousal on the relationship between task complexity and time estimation. Furthermore, Model 14 also let us analyze the moderating effect of impulsivity or time perspective between the relationship of valence and time estimation.

To determine if the variables have a positive or negative effect on the relationship, we looked at the beta (β) of the relationship. If the beta was positive, it means that the variable has a positive effect on the relationship and vice versa. In addition, the effects must be significative in order to determine whether or not there was a mediating or moderating role. We also did three separate analysis for all 3 states.

Results

The table 4 present the means, minimums and maximums of all variables for low and high complexity tasks.

Table 4. Descriptive Data

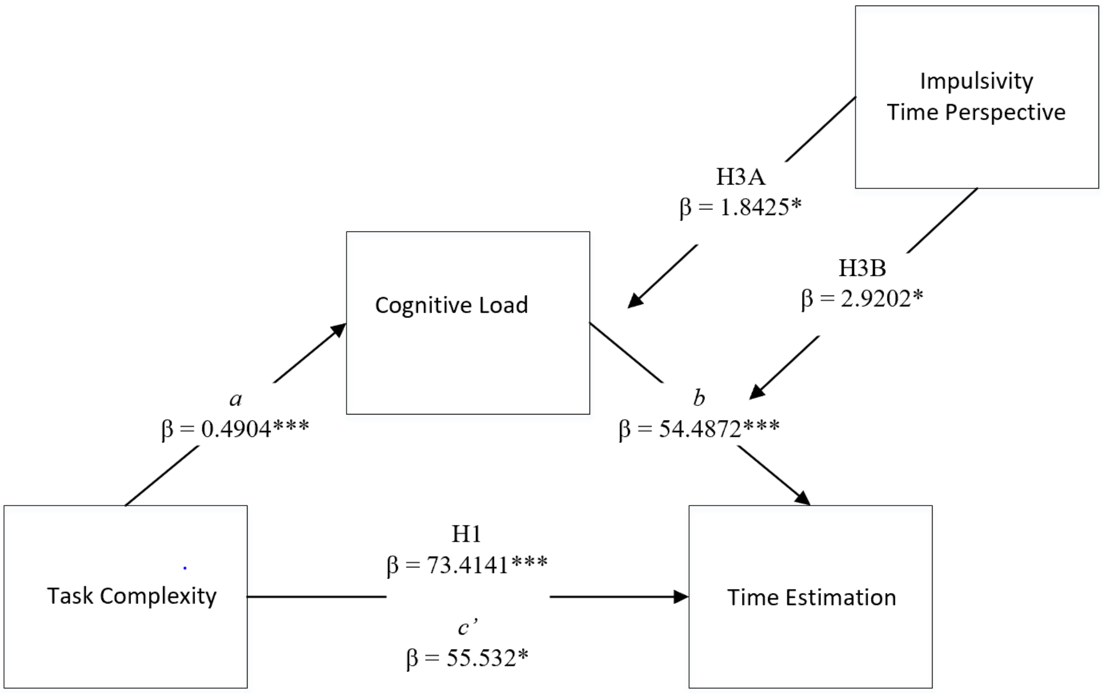
Variables	Low complexity			High complexity		
	Mean	Min	Max	Mean	Min	Max
Time estimation	-19.734	-675.000	356.00	-4.462	-675.00	356.00
Cognitive load	-0.113	-3.035	3.238	-0.130	-3.035	3.199
Arousal	0.369	-91.077	31.476	0.564	-91.077	31.476
Valence	-0.064	-0.958	0.891	0.056	-1.576	0.729
Time perspective	90.869	65.000	105.000	91.081	65.000	105.000
Impulsivity	33.463	16.000	55.000	32.640	16.000	55.000

Hypothesis testing

Hypotheses 1 postulate that the task complexity (high or low) has a positive effect on the time estimation of the individual. Simple linear regressions show that task complexity has a positive significant effect on time estimation ($t=4.07$, $p =< 0.0001$, $\beta = 73.4141$). In other words, an individual will estimate the time of a complex task higher than a simpler task, supporting H1.

Hypothesis 2a-2c postulate the mediating effect of individual states (cognitive load, arousal and valence) on the relationship of task complexity and time estimation. Three separate analyses were done using all three individual states with the two traits.

As shown in Figure 5, in order to test H2a, the indirect effect of the task complexity has a positive influence on cognitive load (*a*) ($t = 7.29$, $p =< 0.001$, $\beta= 0.4904$). Moreover, cognitive load has an influence on time estimation (*b*) ($t = 3.9$, $p =< 0.001$, $\beta= 54.4872$). For the direct effect, both variables have an influence on time estimation (*c'*) ($t = 2.93$, $p < 0.05$, $\beta = 55.532$). The indirect effect (*ab*) is 28.431. The total effect is 83.963. The mediation effect size is 0.364. The effect of the mediation is only partial as the estimate of the direct effect of task complexity on time estimation is 73.4141 and that the estimate of the mediating effect of cognitive load is 55.532. With a 95% bootstrap confidence interval, the interval estimate is 16.14 to 54.76, showing a significant indirect effect. Overall, we conclude that cognitive load toward the relationship of task complexity and time estimation is a partial mediator, supporting H2a.



Note: Results are significant at * p < 0.05, ** p < 0.001, ***P < 0.0001.

Figure 5. Cognitive Load Model Results

As shown in Figure 6, in order to test H2b, the indirect effect of the task complexity does not have a significant effect on arousal (*a*) (t = -1.12, p = 0.2627, β = -0.15). Moreover, arousal does not have a significant effect on time estimation (*b*) (t = -0.57, p = 0.5666, β = -3.3495). For the direct effect, both variables have an influence on time estimation (*c'*) (t = 3.9, p < 0.0001, β = 69.2077). The indirect effect (*ab*) is 0.502425. The total effect is 69.71. The mediation effect size is -0.022. As the indirect effects (*a* and *b*) are not significative and that the direct effect (*c'*) is still significative, we conclude that arousal toward the relationship of task complexity and time estimation is not a mediator. Therefore, H2b is not supported.

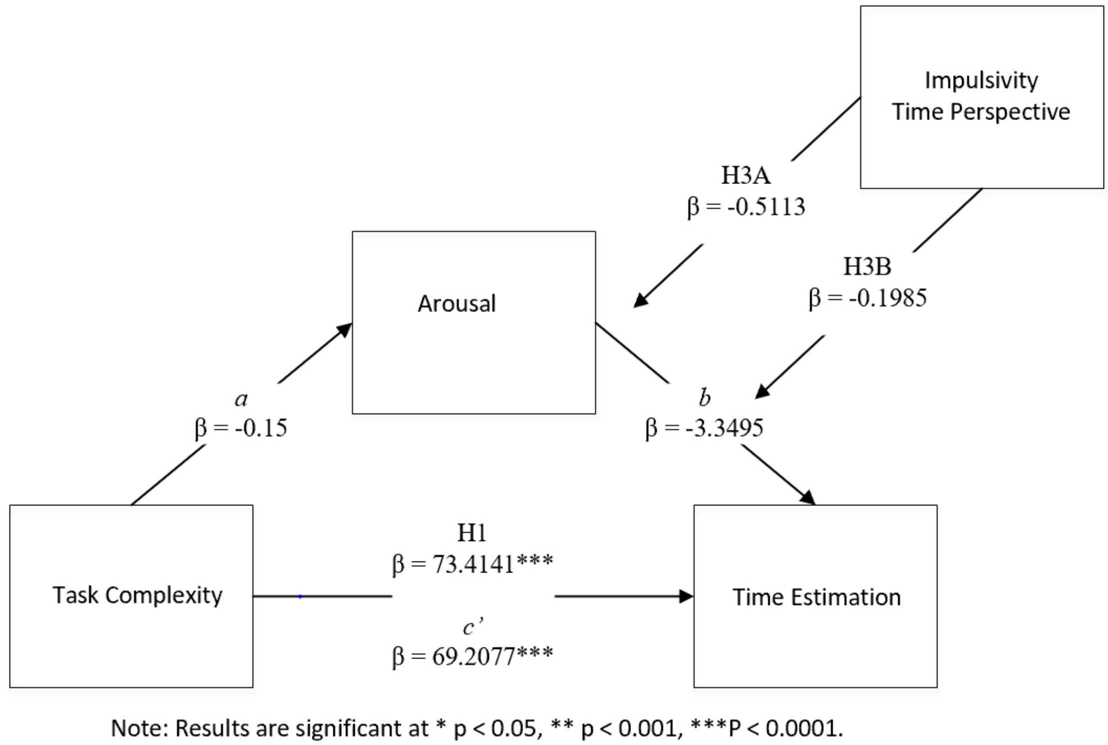


Figure 6. Arousal Model Results

As shown in Figure 7, in order to test H2c, the indirect effect of the task complexity does not have a significant effect on valence (*a*) (t = -0.44, p = 0.6581, β = -0.01356). However, valence does have a significant effect on time estimation (*b*) (t = -3.97, p <= 0.0001, β = -139.63). For the direct effect, both variables have an influence on time estimation (*c'*) (t = -4.47, p < 0.0001, β = 78.6872). The indirect effect (*ab*) is 1.8934. The total effect is 80.5806. The mediation effect size is -0.93272. As the indirect effects are not significative and that the direct effect (*c'*) is still significative, we conclude that valence toward the relationship of task complexity and time estimation is not a mediator. Therefore, H2c is not supported.

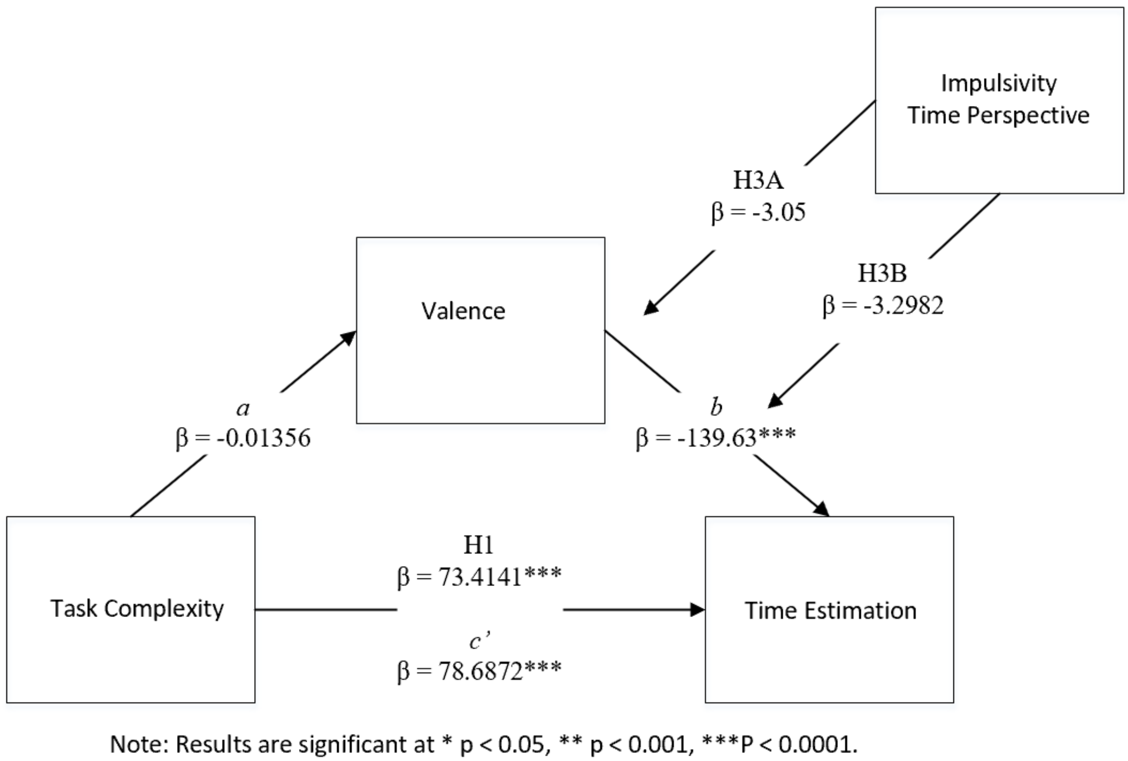


Figure 7. Valence Model Results

Hypothesis 3a-b postulate moderating effect on the relationship of individual traits (time perspective and impulsivity) and time estimation. We postulated that the higher impulsivity or time perspective score will lead to a stronger relationship between individual traits and time estimation. Three separate analyses were done using all three individual states with the two traits.

In the impulsivity moderation analysis of the cognitive load model as previously shown in Figure 5, to test H3a, the impulsivity has a significative moderating effect on the relationship of cognitive load and time estimation ($t = 1.32$, $p < 0.05$, $\beta = 1.8425$). In other words, a higher impulsivity score leads to a stronger effect on the relationship of cognitive load and time estimation. Therefore, we conclude that impulsivity toward the relationship of cognitive load and time estimation is a moderator, supporting H3a. In the time perspective analysis of the cognitive load model shown in Figure 5, the time perspective has a significative moderating effect on the relationship of cognitive load and time estimation ($t = 1.72$, $p < 0.05$, $\beta = 2.9202$). In order word, a higher time perspective score will lead to a stronger effect on the relationship of cognitive load and time estimation. Therefore, we concluded that time perspective toward the relationship of cognitive load and time estimation is a moderator, supporting H3a.

In the impulsivity moderation analysis of the arousal model as previously shown in Figure 6, to test H3b, impulsivity does not have a significative moderating effect on the relationship of arousal and time estimation ($t = -0.95$, $p = 0.3438$, $\beta = -0.5113$). Therefore, we concluded that impulsivity toward the relationship of arousal and time estimation is not a moderator. H3a is not supported for the arousal model. In the time perspective analysis in the arousal model shown in Figure 6, the time perspective does not have a significative moderating effect on the relationship of arousal and time estimation ($t = -0.37$, $p = 0.7127$, $\beta = -0.1985$). Therefore, we concluded that time perspective toward the relationship of cognitive load and time estimation is not a moderator. H3b is not supported for the arousal model.

In the impulsivity moderation analysis of the valence model as previously shown in Figure 7, impulsivity does not have a significative moderating effect on the relationship of valence and time estimation ($t = -0.75$, $p = 0.4548$, $\beta = -3.05$). Therefore, we concluded that impulsivity toward the relationship of valence and time estimation is not a moderator. H3a is not supported for the valence model. In the time perspective analysis shown in Figure 7, the time perspective does not have a significative moderating effect on the relationship of valence and time estimation ($t = -0.78$, $p = 0.438$, $\beta = -3.2982$). Therefore, we concluded that time perspective toward the relationship of cognitive load and time estimation is not a moderator. H3b is not supported for the valence model.

To summarize, results show that task complexity has a positive effect on time estimation (H1). Furthermore, the cognitive load model showed that cognitive load mediates positively the relationship between task complexity and time estimation (H2a). The relationship between individual states and time estimation is stronger for individuals who are more impulsive or greater time perspective trait in the cognitive load model (H3a &

H3b). However, no significant mediation effect was found for emotional arousal and emotional valence (H2b & H2c).

Hypothesis	Description	Conclusion
H1	The complexity of the utilitarian task will positively influence the participant's time estimation. The time of a complex task will be overestimated in comparison to a simpler task.	Supported
H2a	Cognitive load mediates the relationship between task complexity and time perception	Supported
H2b	Emotional arousal mediates the relationship between task complexity and time perception.	Not Supported
H2c	Emotional valence mediates the relationship between task complexity and time perception.	Not Supported
H3a	Impulsivity will have a moderating effect on the relation between the individual states and time estimation. The relationship between individual states and time estimation will be stronger for more impulsive individuals.	Supported for cognitive load
H3b	Time orientation will have a moderating effect on the relation between the individual states and time estimation. The relationship between individual states and time estimation will be stronger for individuals with greater time orientation..	Supported for cognitive load

Figure 8. Summary of Results

Discussion

The analysis of our results showed that the complexity of the task (low complexity or high complexity) affects the time estimation of the users when interacting with utilitarian interfaces (H1). A high complexity task will be estimated higher than a low complexity task. This relationship can be mediated by an individual state. Indeed, cognitive load shown to have significant mediation effect on the relationship (H2a). When cognitive load increases, the participant will tend to overestimate the time. However, the mediating effect of emotional arousal and emotional is not supported on the relationship (H2b&c). Moreover, individual traits of impulsivity and time perspective show significant results to have a moderating effect on the relationship of cognitive load and time estimation (H3a&b). An individual who scores higher on the impulsivity or time perspective traits will lead to a stronger effect on the relationship of cognitive load and time estimation.

This study has theoretical implications. First, the current literature on time estimation has strong theoretical foundation. However, the tasks used in most studies lack ecological validity as they use monotonous stimuli. In this study, we tried to find if there is any difference in time estimation in the current literature when using real-world task because past studies showed that the type of task influence the time estimation of the individual (Zakay and Block, 1997). A strong ecological validity is important for a study in order to reflect as much as possible the real world (Schmuckler, 2001). Hence, for our experiment we chose to use utilitarian banking interfaces because they are commonly used by the population (Martins et al., 2014), Those interfaces were split into two levels of complexity (low and high complexity) depending on the nature of the objective of the task describe by Terai et al. (2008). The level of complexity was considered low when the participant was tasked to look and read specific information on a banking website. On the other hand, the level of complexity was considered high when the participant was tasked to fill out an online investment application form. Thus, our study added the component of using different level of complexity of utilitarian tasks in the literature. The findings in this study suggest that high complexity task will be estimated longer than low complexity task. Hence, time will be perceived to go slower when users interact with a complex utilitarian task in comparison to a simpler one. The results of this study are similar with the current time estimation literature. Indeed, in the retrospective paradigm, past studies also found that a high complexity task will be overestimated in comparison with a low complexity task (Zakay and Block, 1997; Ornstein, 1975). The attentional-gate model (AGM) notably explains this phenomenon that the attention of the participant will be directed on the task instead of keeping track of time as the difficulty of the task increases. Therefore, the amount of attention on time is distorted. Thus, we contributed by adding on task complexity in the time estimation literature and by using a more realistic task.

Second, our study shows no results that emotional arousal and emotional valence mediate the relationship between task complexity and time estimation. Those results go against some previous studies where researchers found that complex tasks result in stronger negative emotion (Anshel and Martins, 1996). Moreover, study suggests that performing difficult maze puzzles will reduce performance and emotion (Huber, 1985). In the emotion and time estimation literature, previous studies found that that the increase of arousal lead to an overestimation of time (Angrilli et al, 1997; Droit-Volet and Meck, 2007). In addition, researchers suggest that an increase of emotional valence will increase time estimation (Boltz, 1994; Delay and Mathey, 1985; Rai, 1975). The results of our study found no significative difference in task complexity and arousal or valence when we tested for the indirect effect. An explanation for these results would be that web design induce a target emotion (Kim and Moon, 1998). In addition, the visual of the interface also influence the time perceived on the individual (Gorn et al., 2004). Since the utilitarian interfaces we used were relativity very similar in design, it could possibly have affected the level of emotion of the user. As a result, there was no significant difference in emotions between a complex or simple task. Gorn et al. (2004) study suggests that the screen colour of a web page influence the user's perception of time because it induces a specific level of emotion. In the case of our study, the screen colour for both tasks' complexity was mostly red and white. Therefore, the level of emotion between both tasks would have been relatively the same level. Thus, we contributed by finding that emotions don't not have a mediating role on time estimation. Those findings are different from what we can find in the current literature on time estimation.

Finally, results show that impulsivity and time perspective traits moderate the relationship between cognitive load and time estimation. A higher score of impulsivity or time perspective will lead to stronger relationship of cognitive load and time estimation. Similar results were also found in previous studies. Past studies suggest that individuals who score higher on impulsivity traits will have an increased of time estimation (Jokic et al., 2018). Indeed Jokic, et al., (2018) found in there that individuals who score higher on impulsivity tend to overestimate the waiting time. Furthermore, past studies on impulsivity found that impulsive individuals tend to overestimate time (Glicksohn et al., 2006; Moreira et al., 2016). Although the literature on time estimation and impulsivity still needs a better theoretical foundation (Wittmann and Paulus, 2008). In addition, a higher time perspective traits score will lead to an overestimation of time (Jokic et al., 2018). An individual with higher present hedonistic and present fatalistic on passage of time tend to have higher overestimation of the waiting time internal. Thus, we contributed by finding expanding Jokic et Al (2008) research by finding that all time perspective traits and impulsivity traits have a moderating effect on time estimation and not only some traits like in previous studies.

Overall, our study shows similar results with the current literature and our study helped by improving the ecological validity of it. These findings contribute to strengthen the current literature and as well as filling the literature gap on time estimation while interacting with utilitarian interfaces, thus advancing knowledge in the human-computer interaction (HCI) literature.

Furthermore, this study also has managerial implications notably in the field of user experience and interface design. As online interaction is becoming more popular in most industries (D'Orazio, and Shotton, 2018), it is important to understand how users perceive the flow of time when interacting with those interfaces. A user who feels that the process takes too much time to finish will abandon it (Delgado, 2018). As a result, the chance to convert the user is lessened if the interface is not optimized to make the user feels that the process is going quickly. The ecological validity of this study was high as users were asked to interact with a banking website as if they would have done in a real-life situation. First, this study shows the importance to make the task as simple as possible because the user will perceive the time to go faster. Some studies found the perceived quickness of the interface which led to a greater likelihood that recommending the website to a friend (Gorn et al., 2004). A Jupiter Media Metrix consumer survey found that 40% of online consumers would go more often on a page if it was faster (Gorn et al., 2004; Pastore, 2001). Second, this study points out the importance to reduce the cognitive load on the user as an increase of cognitive load of the user will lead to a higher perception of time. Thus, the user will perceive that the time will go slower. Some studies on perceived waiting time found that the perception of a slow process will have an impact on the overall satisfaction of the setting when wait time was high such as in restaurants (Jones and Peppiatt, 1996), supermarkets (Tom and Lucey 1997), hospital (Dnsky and Miles 1997), and airports (Taylor, 1994). Third, individual traits such as impulsivity and time perspective influence the time estimation of a user. Interface designers should take advantage of this knowledge to design interfaces based on certain individual characteristics of a user depending of the goal of the interface. Overall, this study points out the importance for UX designers to make tasks as simple as possible in order to reduce the cognitive load on the user. As a result, the user will perceive that the time will go faster. This study also shows for interface designers that time estimation can be manipulated, and it is not a fix value. For example, breaking down one big task into multiple simple tasks can help the user feel that time is going faster rather than asking him to do one big and complex task.

Three limitations of this study need to be acknowledged. First, even though we counterbalanced the tasks, the weakness with the retrospective paradigm to estimate a time internally is to make sure that the answers are not biased (Block and Zakay, 1997). Indeed, as Grondin (2007) mentioned, once the participant has to estimate the time of the first task, he will most likely be aware of the subsequent time estimation. Thus, future research should limit their experiment to only one task to not induced any bias when using the retrospective paradigm to estimate time. Second, our study only used utilitarian banking interfaces. As they are a lot more utilitarian type of interfaces and hedonistic type interfaces, it can be difficult to inter our results to all types of interfaces. Thus, more study should be conducted of time estimation of different types of interfaces to ensure a stronger theoretical foundation. Finally, time perspective trait scale was administered at the end of the experiment. Since the participant had to estimate time interval before filling out the scale. The participant could have been biased on his answer as the participant had to think about time throughout the experiment.

Conclusion

In conclusion, this study shows that the level of complexity of a utilitarian task influence the time estimation on the individual. A task that is considered low complexity is more underestimated in comparison to high complexity task. Furthermore, cognitive load mediates this relationship. A higher task complexity will increase the cognitive load of the individual which will lead to a higher time estimation. Moreover, individual traits such as impulsivity and time perspective moderate the relationship of cognitive load and time estimation. When an individual score a higher impulsivity or time perspective score, the relationship between cognitive load and time estimation is stronger. Overall results show similar finding with the current literature on time estimation. This study provides a stronger ecological validity by using real-world banking interfaces. Thus, strengthening the current literature. It can be interesting the to use the prospective paradigm or different types of interfaces in future studies to see if similar results are found in the current literature.

References

ABADI, M.K., STAIANO, J., CAPPELLETTI, A., ZANCANARO, M. and SEBE, N. 2013. Multimodal engagement classification for affective cinema. In *2013 Humaine Association Conference on Affective Computing and Intelligent Interaction* IEEE, 411-416.

ADAMS, R. 2007. Decision and stress: cognition and e-accessibility in the information workplace. *Universal access in the information society 5*, 363-379.

AGARWAL, R. and KARAHANNA, E. 2000. Time flies when you're having fun: Cognitive absorption and beliefs about information technology usage. *MIS quarterly*, 665-694.

AGARWAL, R. and PRASAD, J. 1999. Are individual differences germane to the acceptance of new information technologies? *Decision sciences 30*, 361-391.

AHLSTROM, U. and FRIEDMAN-BERG, F.J. 2006. Using eye movement activity as a correlate of cognitive workload. *International Journal of Industrial Ergonomics 36*, 623-636.

AHN, H.-K., LIU, M.W. and SOMAN, D. 2006. Memory for Time: A Cognitive Model of Retrospective Duration and Sequence Judgments. *Available at SSRN 897933*.

AL-WABIL, A. and AL-SALEH, M. 2011. Modeling users in web transactional tasks with behavioral and visual exploration patterns. In *International Conference on Human-Computer Interaction* Springer, 260-264.

ALBERT, W. and TULLIS, T. 2013. *Measuring the user experience: collecting, analyzing, and presenting usability metrics*. Newnes.

ALLAN, L.G. 1979. The perception of time. *Perception & Psychophysics 26*, 340-354.

ANGRILLI, A., CHERUBINI, P., PAVESE, A. and MANFREDINI, S. 1997. The influence of affective factors on time estimation. *Perception & Psychophysics 59*, 972-982.

ANSHEL, M.H. and MARTIN, M.B. 1996. Effect of divergent self-monitoring strategies on motor performance and emotion as a function of alternating task complexity. *Journal of sports sciences 14*, 233-242.

ARAPAKIS, I., JOSE, J.M. and GRAY, P.D. 2008. Affective feedback: an investigation into the role of emotions in the information seeking process. In *Proceedings of the 31st* *annual international ACM SIGIR conference on Research and development in information retrieval* ACM, 395-402.

ATKINSON, R. 1999. Project management: cost, time and quality, two best guesses and a phenomenon, its time to accept other success criteria. *International journal of project management 17*, 337-342.

BAILEY, N. and ARENI, C.S. 2006. When a few minutes sound like a lifetime: Does atmospheric music expand or contract perceived time? *Journal of Retailing 82,* 189-202.

BALDAUF, D., BURGARD, E. and WITTMANN, M. 2009. Time perception as a workload measure in simulated car driving. *Applied ergonomics 40*, 929-935.

BARGAS-AVILA, J.A. and HORNBÆK, K. 2011. Old wine in new bottles or novel challenges: a critical analysis of empirical studies of user experience. In *Proceedings of the SIGCHI conference on human factors in computing systems* ACM, 2689-2698.

BARNDT, R.J. and JOHNSON, D.M. 1955. Time orientation in delinquents. *The Journal of Abnormal and Social Psychology 51*, 343.

BARRATT, E.S., STANFORD, M.S., DOWDY, L., LIEBMAN, M.J. and KENT, T.A. 1999. Impulsive and premeditated aggression: a factor analysis of self-reported acts. *Psychiatry research 86*, 163-173.

BARTLETT, M.S., LITTLEWORT, G., LAINSCSEK, C., FASEL, I. and MOVELLAN, J. 2004. Machine learning methods for fully automatic recognition of facial expressions and facial actions. In *2004 IEEE International Conference on Systems, Man and Cybernetics (IEEE Cat. No. 04CH37583)* IEEE, 592-597.

BEATTY, J. 1982. Task-evoked pupillary responses, processing load, and the structure of processing resources. *Psychological bulletin 91*, 276.

BERLIN, H., ROLLS, E. and KISCHKA, U. 2004. Impulsivity, time perception, emotion and reinforcement sensitivity in patients with orbitofrontal cortex lesions. *Brain 127*, 1108-1126.

BERLIN, H.A. and ROLLS, E.T. 2004. Time perception, impulsivity, emotionality, and personality in self-harming borderline personality disorder patients. *Journal of personality disorders 18*, 358-378.

BHATTACHERJEE, A. 2001. Understanding information systems continuance: an expectation-confirmation model. *MIS quarterly*, 351-370.

BISSON, N., TOBIN, S. and GRONDIN, S. 2008. Remembering the duration of joyful and sad musical excerpts: Assessment with three estimation methods. *NeuroQuantology 7*.

BLEWETT, A.E. 1992. Abnormal subjective time experience in depression. *The British Journal of Psychiatry 161*, 195-200.

BLOCK, F. and GELLERSEN, H. 2010. The impact of cognitive load on the perception of time. In *Proceedings of the 6th Nordic Conference on Human-Computer Interaction: Extending Boundaries* ACM, 607-610.

BLOCK, R. and ZAKAY, D. 2004. Prospective and retrospective duration judgments: An executive-control process. *Acta neurobiologiae experimentalis 64*, 319-328.

BLOCK, R.A. 1992. Prospective and retrospective duration judgment: The role of information processing and memory. In *Time, action and cognition* Springer, 141-152.

BLOCK, R.A., HANCOCK, P.A. and ZAKAY, D. 2010. How cognitive load affects duration judgments: A meta-analytic review. *Acta psychologica 134*, 330-343.

BLOCK, R.A. and REED, M.A. 1978. Remembered duration: Evidence for a contextual-change hypothesis. *Journal of Experimental Psychology: Human Learning and Memory 4*, 656.

BLOCK, R.A. and ZAKAY, D. 1996. Models of psychological time revisited. *Time and mind 33*, 171-195.

BLOCK, R.A. and ZAKAY, D. 1997. Prospective and retrospective duration judgments: A meta-analytic review. *Psychonomic bulletin & review 4*, 184-197.

BOLTZ, M.G. 1994. Changes in internal tempo and effects on the learning and remembering of event durations. *Journal of Experimental Psychology: Learning, Memory, and Cognition 20*, 1154.

BONIWELL, I. and ZIMBARDO, P. 2003. Time to find the right balance. *The Psychologist*.

BOUCSEIN, W. 2012. *Electrodermal activity*. Springer Science & Business Media.

BRANCO, P., FIRTH, P., ENCARNAÇÃO, L.M. and BONATO, P. 2005. Faces of emotion in human-computer interaction. In *CHI'05 Extended Abstracts on Human factors in computing systems* ACM, 1236-1239.

BROWN, S.W. 1985. Time perception and attention: The effects of prospective versus retrospective paradigms and task demands on perceived duration. *Perception & Psychophysics 38*, 115-124.

BROWN, S.W. and BOLTZ, M.G. 2002. Attentional processes in time perception: Effects of mental workload and event structure. *Journal of Experimental Psychology: Human Perception and Performance 28*, 600.

BUCHWALD, C. and BLATT, S.J. 1974. Personality and the experience of time. *Journal of Consulting and Clinical Psychology 42*, 639.

BUHUSI, C.V. and MECK, W.H. 2005. What makes us tick? Functional and neural mechanisms of interval timing. *Nature Reviews Neuroscience 6*, 755.

BURLE, B. and CASINI, L. 2001. Dissociation between activation and attention effects in time estimation: implications for internal clock models. *Journal of Experimental Psychology: Human Perception and Performance 27*, 195.

BURNSIDE, W. 1971. Judgment of short time intervals while performing mathematical tasks. *Perception & Psychophysics 9*, 404-406.

BYSTRÖM, K. and JÄRVELIN, K. 1995. Task complexity affects information seeking and use. *Information processing & management 31*, 191-213.

CAMPBELL, D.J. 1988. Task complexity: A review and analysis. *Academy of management review 13*, 40-52.

CAMPBELL, D.J. and GINGRICH, K.F. 1986. The interactive effects of task complexity and participation on task performance: A field experiment. *Organizational behaviour and human decision processes 38*, 162-180.

CAMPBELL, W.K., BONACCI, A.M., SHELTON, J., EXLINE, J.J. and BUSHMAN, B.J. 2004. Psychological entitlement: Interpersonal consequences and validation of a self-report measure. *Journal of personality assessment 83*, 29-45.

CHAU, P.Y., HU, P.J.-H., LEE, B.L. and AU, A.K. 2007. Examining customers' trust in online vendors and their dropout decisions: an empirical study. *Electronic Commerce Research and Applications 6*, 171-182.

CHILDERS, T.L., CARR, C.L., PECK, J. and CARSON, S. 2001. Hedonic and utilitarian motivations for online retail shopping behaviour. *Journal of Retailing 77*, 511-535.

COLOMBETTI, G. 2005. Appraising valence. *Journal of consciousness studies 12*, 103-126.

COMPEAU, D.R. and HIGGINS, C.A. 1995. Computer self-efficacy: Development of a measure and initial test. *MIS quarterly*, 189-211.

COURTEMANCHE, F., LÉGER, P.-M., DUFRESNE, A., FREDETTE, M., LABONTÉ-LEMOYNE, É. and SÉNÉCAL, S. 2018. Physiological heatmaps: a tool for visualizing users' emotional reactions. *Multimedia Tools and Applications 77*, 11547-11574.

DANCKERT, J.A. and ALLMAN, A.-A.A. 2005. Time flies when you're having fun: Temporal estimation and the experience of boredom. *Brain and cognition 59*, 236-245.

DE GUINEA, A.O., TITAH, R. and LÉGER, P.-M. 2013. Measure for measure: A two study multi-trait multi-method investigation of construct validity in IS research. *Computers in Human Behavior 29*, 833-844.

DE GUINEA, A.O., TITAH, R. and LÉGER, P.-M. 2014. Explicit and implicit antecedents of users' behavioral beliefs in information systems: A neuropsychological investigation. *Journal of Management Information Systems 30*, 179-210.

DE GUINEA, A.O. and WEBSTER, J. 2013. An investigation of information systems use patterns: Technological events as triggers, the effect of time, and consequences for performance. *MIS quarterly*, 1165-1188.

DELAY, E.R. and MATHEY, M.E. 1985. Effects of ambient noise on time estimation by humans. *Perceptual and motor skills 61*, 415-419.

DELGADO, M. 2018. 6 Steps for Avoiding Online Form Abandonment. TheManifest.

DENG, Z., LU, Y., WEI, K.K. and ZHANG, J. 2010. Understanding customer satisfaction and loyalty: An empirical study of mobile instant messages in China. *International Journal of Information Management 30*, 289-300.

DIRICAN, A.C. and GÖKTÜRK, M. 2011. Psychophysiological measures of human cognitive states applied in human computer interaction. *Procedia Computer Science 3*, 1361-1367.

DOOB, L.W. 1971. Patterning of time.

D'ORAZIO, V. and SHOTTON, L. 2010. Digital Business Transformation: A Financial Services Perspective Model. Gartner.

DRAAISMA, D. 2004. *Why life speeds up as you get older: How memory shapes our past*. Cambridge University Press.

DRAKE, C. and BOTTE, M.-C. 1993. Tempo sensitivity in auditory sequences: Evidence for a multiple-look model. *Perception & Psychophysics 54*, 277-286.

DROIT-VOLET, S., FAYOLLE, S., LAMOTTE, M. and GIL, S. 2013. Time, emotion and the embodiment of timing. *Timing & Time Perception 1*, 99-126.

DROIT-VOLET, S. and GIL, S. 2009. The time–emotion paradox. *Philosophical Transactions of the Royal Society of London B: Biological Sciences 364*, 1943-1953.

DROIT-VOLET, S. and GIL, S. 2016. The emotional body and time perception. *Cognition and Emotion 30*, 687-699.

DROIT-VOLET, S. and MECK, W.H. 2007. How emotions colour our perception of time. *Trends in cognitive sciences 11*, 504-513.

DROIT-VOLET, S., BRUNOT, S. and NIEDENTHAL, P. 2004. BRIEF REPORT Perception of the duration of emotional events. *Cognition and Emotion 18*, 849-858.

DROIT-VOLET, S., TOURRET, S. and WEARDEN, J. 2004. Perception of the duration of auditory and visual stimuli in children and adults. *Quarterly Journal of Experimental Psychology Section A 57*, 797-818.

EARLEY, P.C. 1985. Influence of information, choice and task complexity upon goal acceptance, performance, and personal goals. *Journal of Applied Psychology 70*, 481.

EFFRON, D.A., NIEDENTHAL, P.M., GIL, S. and DROIT-VOLET, S. 2006. Embodied temporal perception of emotion. *Emotion 6*, 1.

EGGER, S., REICHL, P., HOßFELD, T. and SCHATZ, R. 2012. “Time is bandwidth”? Narrowing the gap between subjective time perception and Quality of Experience. In *2012 IEEE international conference on communications (ICC)* IEEE, 1325-1330.

EGGES, A., KSHIRSAGAR, S. and MAGNENAT-THALMANN, N. 2003. A model for personality and emotion simulation. In *International Conference on Knowledge-Based and Intelligent Information and Engineering Systems* Springer, 453-461.

EISLER, H., EISLER, A.D. and HELLSTRÖM, Å. 2008. Psychophysical issues in the study of time perception. *Psychology of time*, 75-109.

EKMAN, P. and FRIESEN, W.V. 1971. Constants across cultures in the face and emotion. *Journal of personality and social psychology 17*, 124.

EKMAN, P. and FRIESEN, W.V. 2003. *Unmasking the face: A guide to recognizing emotions from facial clues*. Ishk.

EKMAN, P., FRIESEN, W.V., O'SULLIVAN, M., CHAN, A., DIACOYANNI-TARLATZIS, I., HEIDER, K., KRAUSE, R., LECOMPTE, W.A., PITCAIRN, T. and RICCI-BITTI, P.E. 1987. Universals and cultural differences in the judgments of facial expressions of emotion. *Journal of personality and social psychology 53*, 712.

FECICA, A.M. and STOLZ, J.A. 2008. Facial affect and temporal order judgments: Emotions turn back the clock. *Experimental psychology 55*, 3-8.

FRAISSE, P. 1967. *Psychologie du temps*. Presses universitaires de France.

FRAISSE, P. 1984. Perception and estimation of time. *Annual review of psychology 35*, 1-37.

FRANKENHAEUSER, M. 1959. Estimation of time: An experimental study.

FRIBERG, A. and SUNDBERG, J. 1995. Time discrimination in a monotonic, isochronous sequence. *The Journal of the Acoustical Society of America 98*, 2524-2531.

GEORGES, V., COURTEMANCHE, F., SÉNÉCAL, S., LÉGER, P.-M., NACKE, L. and POURCHON, R. 2017. The adoption of physiological measures as an evaluation tool in UX. In *International Conference on HCI in Business, Government, and Organizations* Springer, 90-98.

GIBBON, J., CHURCH, R.M. and MECK, W.H. 1984. Scalar timing in memory. *Annals of the New York Academy of sciences 423*, 52-77.

GIL, S., NIEDENTHAL, P.M. and DROIT-VOLET, S. 2007. Anger and time perception in children. *Emotion 7*, 219.

GLICKSOHN, J. 2001. Temporal cognition and the phenomenology of time: A multiplicative function for apparent duration. *Consciousness and Cognition 10*, 1-25.

GLICKSOHN, J., LESHEM, R. and AHARONI, R. 2006. Impulsivity and time estimation: Casting a net to catch a fish. *Personality and individual differences 40*, 261-271.

GOPHER, D. and DONCHIN, E. 1986. Workload: An examination of the concept.

GORN, G.J., CHATTOPADHYAY, A., SENGUPTA, J. and TRIPATHI, S. 2004. Waiting for the web: how screen color affects time perception. *Journal of marketing research 41*, 215-225.

GREENWALD, M.K., COOK, E.W. and LANG, P.J. 1989. Affective judgment and psychophysiological response: dimensional covariation in the evaluation of pictorial stimuli. *Journal of psychophysiology*.

GRONDIN, S. 2010. Timing and time perception: a review of recent behavioral and neuroscience findings and theoretical directions. *Attention, Perception, & Psychophysics 72*, 561-582.

GRONDIN, S. and PLOURDE, M. 2007. Judging multi-minute intervals retrospectively. *Quarterly Journal of Experimental Psychology 60*, 1303-1312.

GWIZDKA, J. 2010. Distribution of cognitive load in web search. *Journal of the American Society for Information Science and Technology 61*, 2167-2187.

HACKMAN, J.R. 1969. Toward understanding the role of tasks in behavioral research. *Acta psychologica 31*, 97-128.

HACKMAN, J.R. and OLDHAM, G.R. 1976. Motivation through the design of work: Test of a theory. *Organizational behaviour and human performance 16*, 250-279.

HAIR, J.F. 2006. *Multivariate data analysis*. Pearson Education India.

HANCOCK, P.A. and MESHKATI, N. 1988. *Human mental workload*. North-Holland Amsterdam.

HANCOCK, P.A. and SZALMA, J.L. 2008. *Performance under stress*. Ashgate Publishing, Ltd.

HARRISON, A.W. and RAINER JR, R.K. 1992. The influence of individual differences on skill in end-user computing. *Journal of Management Information Systems 9*, 93-111.

HART, S.G. 1975. Time estimation as a secondary task to measure workload.[attention sharing effect on operator performance].

HASSENZAHL, M. and TRACTINSKY, N. 2006. User experience-a research agenda. *Behaviour & Information Technology 25*, 91-97.

HAYES, A.F. 2017. *Introduction to mediation, moderation, and conditional process analysis: A regression-based approach*. Guilford Publications.

HEMMES, N.S., BROWN, B.L. and KLADOPOULOS, C.N. 2004. Time perception with and without a concurrent nontemporal task. *Perception & Psychophysics 66*, 328-341.

HICKS, R.E., MILLER, G.W., GAES, G. and BIERMAN, K. 1977. Concurrent processing demands and the experience of time-in-passing. *The American journal of psychology*, 431-446.

HICKS, R.E., MILLER, G.W. and KINSBOURNE, M. 1976. Prospective and retrospective judgments of time as a function of amount of information processed. *The American journal of psychology*, 719-730.

HOKANSON, J.E. and BURGESS, M. 1964. Effects of physiological arousal level, frustration, and task complexity on performance. *The Journal of Abnormal and Social Psychology 68*, 698.

HOLMQVIST, K., NYSTRÖM, M., ANDERSSON, R., DEWHURST, R., JARODZKA, H. and VAN DE WEIJER, J. 2011. *Eye tracking: A comprehensive guide to methods and measures*. OUP Oxford.

HORNIK, J. 1984. Subjective vs. objective time measures: A note on the perception of time in consumer behaviour. *Journal of consumer research 11*, 615-618.

HORNIK, J. 1992. Time estimation and orientation mediated by transient mood. *The Journal of Socio-Economics 21*, 209-227.

HUBER, V.L. 1985. Effects of task difficulty, goal setting, and strategy on performance of a heuristic task. *Journal of Applied Psychology 70*, 492.

JENKINS, J.M. and OATLEY, K. 1996. Emotional episodes and emotionality through the life span. In *Handbook of emotion, adult development, and aging* Elsevier, 421-441.

JENNINGS, J.R., KAMARCK, T., STEWART, C., EDDY, M. and JOHNSON, P. 1992. Alternate cardiovascular baseline assessment techniques: Vanilla or resting baseline. *Psychophysiology 29*, 742-750.

JOKIC, T., ZAKAY, D. and WITTMANN, M. 2018. Individual Differences in Self-Rated Impulsivity Modulate the Estimation of Time in a Real Waiting Situation.

JONES, P. and PEPPIATT, E. 1996. Managing perceptions of waiting times in service queues. *International Journal of Service Industry Management 7*, 47-61.

KAHNEMAN, D. 1973. *Attention and effort*. Citeseer.

KANDEL, E.R., SCHWARTZ, J.H., JESSELL, T.M., BIOCHEMISTRY, D.O., JESSELL, M.B.T., SIEGELBAUM, S. and HUDSPETH, A. 2000. *Principles of neural science*. McGraw-hill New York.

KELLARIS, J.J. and KENT, R.J. 1992. The influence of music on consumers' temporal perceptions: does time fly when you're having fun? *Journal of consumer psychology 1*, 365-376.

KEOUGH, K.A., ZIMBARDO, P.G. and BOYD, J.N. 1999. Who's smoking, drinking, and using drugs? Time perspective as a predictor of substance use. *Basic and applied social psychology 21*, 149-164.

KIM, J. and MOON, J.Y. 1998. Designing towards emotional usability in customer interfaces—trustworthiness of cyber-banking system interfaces. *Interacting with computers 10,* 1-29.

KIRSCHNER, F., PAAS, F. and KIRSCHNER, P.A. 2009. A cognitive load approach to collaborative learning: United brains for complex tasks. *Educational psychology review 21*, 31-42.

KONONOWICZ, T.W., VAN RIJN, H. and MECK, W.H. 2018. Timing and Time Perception. *Stevens' Handbook of Experimental Psychology and Cognitive Neuroscience, Learning and Memory 1*, 453.

KOWAL, K.H. 1987. Apparent duration and numerosity as a function of melodic familiarity. *Perception & Psychophysics 42,* 122-131.

KRAMER, A.F. 1991. Physiological metrics of mental workload: A review of recent progress. *Multiple-task performance*, 279-328.

LAENG, B., SIROIS, S. and GREDEBÄCK, G. 2012. Pupillometry: A window to the preconscious? *Perspectives on psychological science 7*, 18-27.

LAKE, J.I., LABAR, K.S. and MECK, W.H. 2016. Emotional modulation of interval timing and time perception. *Neuroscience & Biobehavioral Reviews 64*, 403-420.

LAMOTTE, M., CHAKROUN, N., DROIT-VOLET, S. and IZAUTE, M. 2014. Metacognitive questionnaire on time: Feeling of the passage of time. *Timing & Time Perception 2,* 339-359.

LAND, M.F. and HAYHOE, M. 2001. In what ways do eye movements contribute to everyday activities? *Vision research 41*, 3559-3565.

LANE, R.D., CHUA, P.M. and DOLAN, R.J. 1999. Common effects of emotional valence, arousal and attention on neural activation during visual processing of pictures. *Neuropsychologia 37,* 989-997.

LANG, P.J. 1984. Cognition in emotion: Concept and action. *Emotions, cognition, and behaviour*, 192-226.

LANG, P.J. 1995. The emotion probe: studies of motivation and attention. *American psychologist 50*, 372.

LANG, P.J., GREENWALD, M.K., BRADLEY, M.M. and HAMM, A.O. 1993. Looking at pictures: Affective, facial, visceral, and behavioral reactions. *Psychophysiology 30*, 261-273.

LASANE, T.P. and O'DONNELL, D.A. 2006. Time orientation measurement: A conceptual approach. In *Understanding behaviour in the context of time* Psychology Press, 24-43.

LATHAM, G.P. and YUKL, G.A. 1975. A review of research on the application of goal setting in organizations. *Academy of Management Journal 18*, 824-845.

LEE, S.M. and CHEN, L. 2010. The impact of flow on online consumer behaviour. *Journal of Computer Information Systems 50*, 1-10.

LEE, Y., CHEN, A.N. and ILIE, V. 2012. Can online wait be managed? The effect of filler interfaces and presentation modes on perceived waiting time online. *MIS quarterly*, 365-394.

LÉGER, P.-M., DAVIS, F.D., CRONAN, T.P. and PERRET, J. 2014. Neurophysiological correlates of cognitive absorption in an enactive training context. *Computers in Human Behavior 34*, 273-283.

LEWIN, K. 1952. Field theory in the social sciences: Selected theoretical papers by Kurt Lewin (selected by D. Cartwright). *London: Tavistock Publications*.

LOCKE, E.A., SHAW, K.N., SAARI, L.M. and LATHAM, G.P. 1981. Goal setting and task performance: 1969–1980. *Psychological bulletin 90*, 125.

LOIJENS, L., KRIPS, O., KUILENBURG HV, U.M. and IVAN, P.F. 2015. 6.1 Reference Manual. *Noldus Information Technology bv www. noldus. com*.

LOURTIES, S., LÉGER, P.-M., SÉNÉCAL, S., FREDETTE, M. and CHEN, S.L. 2018. Testing the Convergent Validity of Continuous Self-Perceived Measurement Systems: An Exploratory Study. In *International Conference on HCI in Business, Government, and Organizations* Springer, 132-144.

MARTINEZ, M.B. 1991. Testing models of time estimation. In *Time, action and cognition* Springer, 173-176.

MARTINS, C., OLIVEIRA, T. and POPOVIČ, A. 2014. Understanding the Internet banking adoption: A unified theory of acceptance and use of technology and perceived risk application. *International Journal of Information Management 34*, 1-13.

MCCLAIN, L. 1983. Interval estimation: Effect of processing demands on prospective and retrospective reports. *Perception & Psychophysics 34*, 185-189.

MIRHOSEINI, S.M.M., LÉGER, P.-M. and SÉNÉCAL, S. 2017. The influence of task characteristics on multiple objective and subjective cognitive load measures. In *Information Systems and Neuroscience* Springer, 149-156.

MIZUNO, K., TANAKA, M., YAMAGUTI, K., KAJIMOTO, O., KURATSUNE, H. and WATANABE, Y. 2011. Mental fatigue caused by prolonged cognitive load associated with sympathetic hyperactivity. *Behavioral and brain functions 7*, 17.

MOELLER, F.G., BARRATT, E.S., DOUGHERTY, D.M., SCHMITZ, J.M. and SWANN, A.C. 2001. Psychiatric aspects of impulsivity. *American journal of psychiatry 158*, 1783-1793.

MOREIRA, D., PINTO, M., ALMEIDA, F. and BARBOSA, F. 2016. Time perception deficits in impulsivity disorders: A systematic review. *Aggression and violent behaviour 27*, 87-92.

NAKAMURA, J. and CSIKSZENTMIHALYI, M. 2014. The concept of flow. In *Flow and the foundations of positive psychology* Springer, 239-263.

NAVON, D. and GOPHER, D. 1979. On the economy of the human-processing system. *Psychological Review 86*, 214.

NEURINGER, C. and HARRIS, R.M. 1974. The perception of the passage of time among death-involved hospital patients. *Suicide and Life-Threatening Behavior 4*, 240-254.

NOULHIANE, M., MELLA, N., SAMSON, S., RAGOT, R. and POUTHAS, V. 2007. How emotional auditory stimuli modulate time perception. *Emotion 7*, 697.

O'BRIEN, E.H., ANASTASIO, P.A. and BUSHMAN, B.J. 2011. Time crawls when you're not having fun: Feeling entitled makes dull tasks drag on. *Personality and Social Psychology Bulletin 37*, 1287-1296.

ORNSTEIN, R.E. 1975. On the experience of time.

OZKARA, B.Y., OZMEN, M. and KIM, J.W. 2017. Examining the effect of flow experience on online purchase: A novel approach to the flow theory based on hedonic and utilitarian value. *Journal of Retailing and Consumer Services 37*, 119-131.

PAAS, F.G. and VAN MERRIËNBOER, J.J. 1994. Instructional control of cognitive load in the training of complex cognitive tasks. *Educational psychology review 6*, 351-371.

PATTEN, C.J., KIRCHER, A., ÖSTLUND, J., NILSSON, L. and SVENSON, O. 2006. Driver experience and cognitive workload in different traffic environments. *Accident Analysis & Prevention 38*, 887-894.

PLUCK, G., LEE, K.-H., LAUDER, H.E., FOX, J.M., SPENCE, S.A. and PARKS, R.W. 2008. Time perspective, depression, and substance misuse among the homeless. *The Journal of psychology 142*, 159-168.

POYNTER, D. 1989. Judging the duration of time intervals: A process of remembering segments of experience. In *Advances in psychology* Elsevier, 305-331.

PREDEBON, J. 1996. The effects of active and passive processing of interval events on prospective and retrospective time estimates. *Acta psychologica 94*, 41-58.

PREDEBON, J. 1996. The relationship between the number of presented stimuli and prospective duration estimates: The effect of concurrent task activity. *Psychonomic bulletin & review 3*, 376-379.

PROCTOR, R. and VAN ZANDT, T. 1994. Sensory input. *Human Factors in Simple and Complex Systems. Boston: Allyn & Bacon*, 81-86.

RAI, S. 1975. Effects of environmental noises on estimation of duration. *Perceptual and motor skills*.

REVANG, M. 2018. Defining a Good User Experience With the Gartner User Experience Model. Gartner.

RIEDL, R. and LÉGER, P.-M. 2016. Fundamentals of NeuroIS. *Studies in Neuroscience, Psychology and Behavioral Economics. Springer, Berlin, Heidelberg*.

RUSSELL, J.A. 1980. A circumplex model of affect. *Journal of personality and social psychology 39*, 1161.

RUTKOWSKI, A.-F., SAUNDERS, C., VOGEL, D. and VAN GENUCHTEN, M. 2007. “Is it already 4 am in your time zone?” Focus immersion and temporal dissociation in virtual teams. *Small group research 38*, 98-129.

SAHAY, S. 1997. Implementation of information technology: a time-space perspective. *Organization studies 18*, 229-260.

SARKER, S. and SAHAY, S. 2004. Implications of space and time for distributed work: an interpretive study of US–Norwegian systems development teams. *European Journal of Information Systems 13*, 3-20.

SAWYER, T.F., MEYERS, P.J. and HUSER, S.J. 1994. Contrasting task demands alter the perceived duration of brief time intervals. *Perception & Psychophysics 56*, 649-657.

SCHACHTER, S. and SINGER, J. 1962. Cognitive, social, and physiological determinants of emotional state. *Psychological Review 69*, 379.

SCHMUCKLER, M.A. 2001. What is ecological validity? A dimensional analysis. *Infancy 2*, 419-436.

SCHNEIDER, W. and SHIFFRIN, R.M. 1977. Controlled and automatic human information processing: I. Detection, search, and attention. *Psychological Review 84*, 1.

SHARMA, S., DURAND, R.M. and GUR-ARIE, O. 1981. Identification and analysis of moderator variables. *Journal of marketing research 18*, 291-300.

SIMEN, P., RIVEST, F., LUDVIG, E.A., BALCI, F. and KILLEEN, P. 2013. Timescale invariance in the pacemaker-accumulator family of timing models. *Timing & Time Perception 1*, 159-188.

SKADBERG, Y.X. and KIMMEL, J.R. 2004. Visitors' flow experience while browsing a Web site: its measurement, contributing factors and consequences. *Computers in Human Behavior 20*, 403-422.

SPIELBERGER, C.D. 2010. State-Trait anxiety inventory. *The Corsini encyclopedia of psychology*, 1-1.

STARKEY, K. 2017. Time and work: A psychological perspective. In *Time, work and organization* Routledge, 35-56.

TAATGEN, N., ANDERSON, J.R., DICKISON, D. and VAN RIJN, H. 2005. Time interval estimation: Internal clock or attentional mechanism?

TAATGEN, N.A., VAN RIJN, H. and ANDERSON, J. 2007. An integrated theory of prospective time interval estimation: The role of cognition, attention, and learning. *Psychological Review 114*, 577.

TAN, W.-K., LEE, P.-W. and HSU, C.-W. 2015. Investigation of temporal dissociation and focused immersion as moderators of satisfaction–continuance intention relationship: Smartphone as an example. *Telematics and Informatics 32*, 745-754.

TAYLOR, S.A. and BAKER, T.L. 1994. An assessment of the relationship between service quality and customer satisfaction in the formation of consumers' purchase intentions. *Journal of Retailing 70*, 163-178.

TERAI, H., SAITO, H., EGUSA, Y., TAKAKU, M., MIWA, M. and KANDO, N. 2008. Differences between informational and transactional tasks in information seeking on the web. In *Proceedings of the second international symposium on Information interaction in context* ACM, 152-159.

THOMAS, E.A. and WEAVER, W.B. 1975. Cognitive processing and time perception. *Perception & Psychophysics 17*, 363-367.

TOM, G. and LUCEY, S. 1997. A field study investigating the effect of waiting time on customer satisfaction. *The Journal of psychology 131*, 655-660.

TREISMAN, M. 1963. Temporal discrimination and the indifference interval: Implications for a model of the" internal clock". *Psychological Monographs: General and Applied 77*, 1.

TSE, P.U., INTRILIGATOR, J., RIVEST, J. and CAVANAGH, P. 2004. Attention and the subjective expansion of time. *Perception & Psychophysics 66*, 1171-1189.

TWENGE, J.M., CATANESE, K.R. and BAUMEISTER, R.F. 2003. Social exclusion and the deconstructed state: time perception, meaninglessness, lethargy, lack of emotion, and self-awareness. *Journal of personality and social psychology 85*, 409.

UNDERWOOD, G. 1975. Attention and the perception of duration during encoding and retrieval. *Perception 4*, 291-296.

VAN DEN BROEK, M., BRADSHAW, C. and SZABADI, E. 1992. Performance of impulsive and non-impulsive subjects on two temporal differentiation tasks. *Personality and individual differences 13*, 169-174.

VAN DER HEIJDEN, H. 2004. User acceptance of hedonic information systems. *MIS quarterly*, 695-704.

VAN MERRIENBOER, J.J. and AYRES, P. 2005. Research on cognitive load theory and its design implications for e-learning. *Educational Technology Research and Development 53*, 5-13.

VAN MERRIËNBOER, J.J., KIRSCHNER, P.A. and KESTER, L. 2003. Taking the load off a learner's mind: Instructional design for complex learning. *Educational psychologist 38*, 5-13.

WAKEFIELD, R.L. and WHITTEN, D. 2006. Mobile computing: a user study on hedonic/utilitarian mobile device usage. *European Journal of Information Systems 15*, 292-300.

WANG, Q., YANG, S., LIU, M., CAO, Z. and MA, Q. 2014. An eye-tracking study of website complexity from cognitive load perspective. *Decision support systems 62*, 1-10.

WATT, J.D. 1991. Effect of boredom proneness on time perception. *Psychological Reports 69*, 323-327.

WEBSTER, J. and MARTOCCHIO, J.J. 1992. Microcomputer playfulness: Development of a measure with workplace implications. *MIS quarterly*, 201-226.

WIMMER, B., WÖCKL, B., LEITNER, M. and TSCHELIGI, M. 2010. Measuring the dynamics of user experience in short interaction sequences. In *Proceedings of the 6th Nordic Conference on Human-Computer Interaction: Extending Boundaries* ACM, 825-828.

WITTMANN, M., LELAND, D.S., CHURAN, J. and PAULUS, M.P. 2007. Impaired time perception and motor timing in stimulant-dependent subjects. *Drug & Alcohol Dependence 90*, 183-192.

WITTMANN, M. and PAULUS, M.P. 2008. Decision making, impulsivity and time perception. *Trends in cognitive sciences 12*, 7-12.

WOEHRLE, J.L. and MAGLIANO, J.P. 2012. Time flies faster if a person has a high working-memory capacity. *Acta psychologica 139*, 314-319.

WU, J.-J. and CHANG, Y.-S. 2005. Towards understanding members' interactivity, trust, and flow in online travel community. *Industrial Management & Data Systems 105*, 937-954.

YAMADA, Y. and KAWABE, T. 2011. Emotion colors time perception unconsciously. *Consciousness and Cognition 20*, 1835-1841.

ZAKAY, D. 1992. On prospective time estimation, temporal relevance and temporal uncertainty. In *Time, action and cognition* Springer, 109-117.

ZAKAY, D. 1993. Time estimation methods—do they influence prospective duration estimates? *Perception 22*, 91-101.

ZAKAY, D. and BLOCK, R.A. 1997. Temporal cognition. *Current directions in psychological science 6*, 12-16.

ZAKAY, D. and BLOCK, R.A. 2004. Prospective and retrospective duration judgments: an executive-control perspective. *Acta neurobiologiae experimentalis 64*, 319-328.

ZAKAY, D. and FALLACH, E. 1984. Immediate and remote time estimation—A comparison. *Acta psychologica 57*, 69-81.

ZAKAY, D. and SHUB, J. 1998. Concurrent duration production as a workload measure. *Ergonomics 41*, 1115-1128.

ZEDECK, S. 1971. Problems with the use of" moderator" variables. *Psychological bulletin 76*, 295.

ZIMBARDO, P.G. and BOYD, J.N. 2015. Putting time in perspective: A valid, reliable individual-differences metric. In *Time perspective theory; review, research and application* Springer, 17-55.

Conclusion

L’objectif de ce mémoire était de quantifier le temps perçu par l’utilisateur lorsqu’il interagit avec des interfaces utilitaires selon le niveau de difficulté de la tâche (difficile ou facile). Plus précisément, ce mémoire a permis d’identifier que les tâches qui sont classifiées comme « faciles » ont été, en moyenne, plus sous-estimées que les tâches qui sont classifiées comme « difficiles ». De plus, un second objectif était d’identifier des facteurs implicites tels que l’émotion vécue durant l’expérience et des facteurs explicites tels que les traits de personnalité qui viendraient influencer la relation entre la complexité de la tâche et le temps perçu. Les résultats dans les études sur la littérature actuelle sur la perception du temps ont un manque de validité écologique parce que les études utilisent beaucoup de stimuli qui proviennent de la psychologie classique et qui sont monotones. Il y a une lacune dans la littérature et ce mémoire cherche à remplir ce vide en utilisant des tâches qui reflètent la réalité. Ce mémoire a permis d’avoir une meilleure compréhension de l’impact de la difficulté d’une interface bancaire sur la perception du temps, ainsi que les perceptions et le comportement des utilisateurs qui influencent cette relation.

Une expérience en laboratoire intrasujet a été réalisée en trois temps, soit à l’été 2018, l’automne 2018 et en hiver 2019 avec un total 53 participant. Les participants devaient soit trouver une information spécifique ou faire une demande d’application en ligne d’un prêt hypothécaire sur un site bancaire. Chaque participant a été recruté par une agence externe. Les signaux physiologiques des participants lors du processus de complétion des tâches ont été collectés par un électrocardiographe et un oculomètre. Ces données implicites ont permis d’obtenir l’expérience que le participant ait vécue de manière inconsciente durant l’expérience. Les traits individuels des participants ont été collectés par des questionnaires. Cette collecte de données a permis à l’étudiant de ce mémoire de rédiger un article complémentaire.

Ce chapitre rappelle les questions de recherche de ce mémoire et présente les principaux résultats de l'article. La contribution de ce mémoire, les limites de cette étude et les pistes de recherches futures sont aussi présentées.

Rappel des questions de recherche et des principaux résultats

Les résultats de l'article ont permis de répondre aux deux questions de recherches de ce mémoire :

Dans quelle mesure la complexité de l'interface influence la perception du temps lors qu'un utilisateur doit interagir avec des interfaces utilitaires?

Dans quelle mesure les états physiologiques et traits psychométriques influencent la relation entre la complexité de l'interface et de la perception du temps?

Découlant de ces questions, trois hypothèses ont été formulées afin de répondre aux questions de recherche de ce mémoire.

Premièrement, H1 énonçait que la complexité de la tâche (difficile ou facile) allait avoir une différence au niveau du temps d'estimation. Les résultats de cette étude ont pu supporter cette hypothèse. En effet, les résultats ont montré qu'une tâche facile est en moyenne plus sous-estimée qu'une tâche difficile. Ces résultats concordent avec la littérature que les tâches complexes sont surestimées en comparaison aux tâches peu complexes (Ornstein, 1975; Zakay et Block, 1997). Ce phénomène peut être expliqué par le *attentional-gate model* (AGM) qui postule que l'attention du participant va être dirigée sur la tâche au lieu du temps lorsque la tâche devient complexe. Par conséquent, le participant prêtera moins attention au temps. Ces résultats supportent donc H1.

Deuxièmement, H2 postulait que la charge cognitive (H2A), l'activation (H2B) et la valence (H2C) ont un rôle de médiateur dans la relation de la complexité de la tâche et de l'estimation du temps. Les résultats de cette étude ont pu supporter quelques-unes de ces hypothèses. Effectivement, les résultats ont montré que la charge cognitive a un effet de médiation sur la relation de la complexité de la tâche et de la perception du temps. Lorsque la tâche devient plus difficile, la charge mentale du participant augmente. Par conséquent, l'estimation du temps est surestimée. Les résultats trouvés par l'étude sont similaires à la littérature. En effet, les études précédentes suggèrent que la complexité d'une tâche influence la charge mentale d'un individu (Mirhoseini, Léger et Sénécal, 2017). La charge mentale augmente lorsque la complexité d'une tâche augmente (Wang *et al.*, 2014). De plus, le temps va être surestimé lorsque la charge cognitive augmente (Block, Hancock et Zakay, 2010). Ces résultats supportent ainsi H2A. Cependant, les résultats ont montré qu'il n'y a pas d'effet de médiation en ce qui concerne l'activation et la valence sur la relation de la complexité de la tâche et de la perception du temps. Ainsi, les résultats ne concordent pas avec la littérature. Une étude suggère que le niveau de difficulté d'une tâche engendre des émotions spécifiques dépendant du type de tâche (Arapakis, Jose et Gray, 2008). En addition, ces études suggèrent qu'une augmentation de l'activation vécue influence la perception du temps à la hausse (Angrilli et al, 1997; Droit-Volet et Meck, 2007). Qui plus est, des études antérieures ont démontré que la valence a un rôle sur la perception du temps. En effet, ces études ont trouvé qu'une augmentation de la valence entraîne une surestimation du temps (Boltz, 1994; Delay et Mathey, 1985; Rai, 1975). Une raison qui peut expliquer qu'il n'y a pas eu de différence significative entre la complexité de la tâche et le niveau d'activation émotionnelle ou de valence émotionnelle est que le design d'une interface provoque un certain niveau d'émotion (Kim et Moon, 1998). Par conséquent, comme le design des deux interfaces était relativement similaire à cause qu'ils provenaient du même site, il n'y a donc pas de différence perçue au niveau de l'émotion vécue. De plus, le design de l'interface a une influence sur la perception du temps de l'individu (Gorn *et al.*, 2004). H2B et H2C ne sont donc pas supportés.

Troisièmement, H3 postulait que les traits individuels tels que l'impulsivité (H3A) et l'orientation temporelle (H3B) ont un effet de modération sur la relation de la charge mentale et de l'estimation du temps. Les résultats de cette étude ont trouvé un effet significatif de modération des traits d'impulsivité sur la relation et de l'orientation temporelle. En effet, un individu qui a des traits élevés d'impulsivité ou d'orientation temporelle va faire augmenter la relation de la charge mentale et du temps d'estimation. Les résultats supportent H3A et H3B. Ces résultats sont similaires avec la littérature actuelle. En effet, les études antérieures ont trouvé qu'un individu impulsif va surestimer le temps (Glicksohn, Leshem et Aharoni, 2006; Moreira *et al.*, 2016). Des études précédentes ont trouvé qu'un individu qui a des traits d'orientation temporelle va au aussi surestimer le temps (Jokic, Zakay et Wittmann, 2018).

Contributions du mémoire

D'un point de vue théorique, les résultats de ce mémoire contribuent à combler le manque dans la littérature sur la perception du temps en ajoutant de la validité écologique. La validité écologique est un facteur important pour une étude en laboratoire, car elle permet de refléter plus précisément la réalité (Schmuckler, 2001). Les études antérieures sur la perception du temps ont beaucoup utilisé de tâches de la psychologie classique qui était simple et monotone. Ces tâches ne reflètent nécessairement pas la réalité. De ce fait, l'étude de ce mémoire a employé des tâches bancaires, car ces interfaces utilitaires sont utilisées par une grande majorité de la population (Martins, Oliveira et Popovič, 2014). L'étude permet donc aussi contribuer à la littérature sur l'interaction humain-machine avec l'aspect d'interface bancaire en ligne. Comprendre l'impact des différents types d'interfaces bancaires sur la perception du temps ainsi que les facteurs qui influencent cette relation est donc crucial pour faire avancer la littérature. Les résultats principaux de ce mémoire mettent de l'avant l'importance sur l'expérience vécue et les traits individuels des utilisateurs lorsqu'ils interagissent avec les interfaces bancaires. Ces résultats concordent avec ceux des études antérieures sur la perception du temps. Premièrement, ces études ont montré que plus la tâche est difficile, plus le temps est surestimé. (Zakay et Block, 1997). Deuxièmement, la charge mentale a un effet de médiateur sur la relation de la complexité de la tâche et perception du temps. Le temps va être surestimé lorsque la charge mentale augmente. Ces résultats sont similaires avec la littérature (Block, Hancock et Zakay, 2010). Troisièmement, cette étude a démontré que des traits tels que l'impulsivité et d'orientation de temps va avoir un effet de modérateur sur la relation de complexité de la tâche et de la perception du temps. Une personne qui a des traits élevés d'impulsivité ou d'orientation du temps va rendre la relation de complexité de la tâche et de la perception du temps encore plus forte (Glicksohn, Leshem et Aharoni, 2006; Jokic, Zakay et Wittmann, 2018; Moreira et al., 2016). Les résultats de ce mémoire sont différents de ceux que l'on retrouve dans la littérature actuelle. Effectivement, ce mémoire a démontré que les émotions n'ont pas un effet de médiateur sur la relation de la complexité de la tâche et perception du temps. Des études antérieures suggèrent qu'un utilisateur qui vit de fortes émotions va plus surestimer le temps (Boltz, 1994; Delay et Mathey, 1985; Ornstein, 1975; Rai, 1975).

Les implications pratiques de ce mémoire permettent aux designers d'interfaces bancaires d'obtenir plus d'informations et d'avoir une meilleure compréhension de l'impact de la complexité des interfaces utilitaires sur la perception du temps et les facteurs qui influencent la relation entre les deux. La perception du temps est un enjeu important pour les concepteurs d'interfaces pour les prendre plus agréables et pour que l'utilisateur se sente plus productif (Florian Block et Gellersen, 2010). À l'aide des résultats de cette étude, les développeurs d'interfaces pourraient améliorer les interfaces bancaires actuelles pour les rendre plus agréables aux utilisateurs notamment pour les faire sentir que le processus va plus rapidement qu'en réalité. Les résultats de ce mémoire contribuent sur les points à faire attention lorsqu'on conçoit une interface bancaire telle que l'importance de rendre la tâche la moins complexe possible dans le but de faire sentir à l'utilisateur que le temps passe plus rapidement. Les développeurs devront aussi faire attention de ne pas rendre la tâche trop complexe, car cela fait augmenter la charge mentale de l'utilisateur, ce qui fait augmenter la perception du temps. Un individu qui est de base impulsive ou qui a une orientation de temps élevé va aussi voir le temps passer plus lentement que la moyenne.

Limites du mémoire et pistes de recherches futures

Quelques limitations doivent être prises en considération en ce qui concerne les résultats de ce mémoire. En premier lieu, l'étude a utilisé des interfaces bancaires pour mener l'étude. En effet, les deux tâches de cette étude que les participants devaient accomplir étaient sur un site web bancaire. Ainsi, les recherches futures devraient se concentrer sur un contexte différent pour généraliser cette étude. Il serait intéressant de voir si les résultats s'appliquent à d'autres types d'interfaces utilitaires ou hédoniques. Deuxièmement, le paradigme d'estimation utilisé pour l'étude est le paradigme rétrospectif, dans lequel le participant n'est pas prévenu à l'avance qu'il devra estimer un intervalle de temps après avoir accompli la tâche. La faiblesse de cette méthode est que les résultats peuvent être biaisés, car le participant va être conscient qu'il va devoir estimer un intervalle de temps après la complétion de la première tâche. Par conséquent, les recherches futures devraient se concentrer uniquement sur une seule tâche ou minimiser le nombre de tâches pour ne pas induire ce biais.

Pour conclure, plus de recherche sur la perception du temps avec différents types d'interfaces doit être réalisée dans le but d'obtenir une meilleure compréhension de l'interaction des tâches utilitaires et la perception du temps. Par exemple, les futurs projets pourraient utiliser des interfaces hédonistes comme les jeux vidéo pour étudier la perception du temps. De plus, il serait aussi intéressant de reproduire la même étude, mais sous le paradigme prospectif, dans lequel le participant sait à l'avance qu'il doit estimer un intervalle de temps avant de débuter la tâche. Il serait intéressant de voir si ce paradigme mènerait à des résultats de ceux obtenus.

Bibliographie

Allan, Lorraine G (1979). « The perception of time », Perception & Psychophysics, vol. 26, no 5, p. 340-354.

Atkinson, Roger (1999). « Project management: cost, time and quality, two best guesses and a phenomenon, its time to accept other success criteria », *International journal of project management*, vol. 17, no 6, p. 337-342.

Barratt, Ernest S, Matthew S Stanford, Lynn Dowdy, Michele J Liebman et Thomas A Kent (1999). « Impulsive and premeditated aggression: a factor analysis of self-reported acts », Psychiatry research, vol. 86, no 2, p. 163-173.

Bisson, Nicolas, Simon Tobin et Simon Grondin (2008). « Remembering the duration of joyful and sad musical excerpts: Assessment with three estimation methods », NeuroQuantology, vol. 7, no 1.

Block, Richard A, Peter A Hancock et Dan Zakay (2010). « How cognitive load affects duration judgments: A meta-analytic review », Acta psychologica, vol. 134, no 3, p. 330-343.

Block, Richard A et Dan Zakay (1997). « Prospective and retrospective duration judgments: A meta-analytic review », Psychonomic bulletin & review, vol. 4, no 2, p. 184-197.

Boltz, Marilyn G (1994). « Changes in internal tempo and effects on the learning and remembering of event durations », Journal of Experimental Psychology: Learning, Memory, and Cognition, vol. 20, no 5, p. 1154.

Boucsein, Wolfram (2012). Electrodermal activity, Springer Science & Business Media.

Brown, Scott W (1985). « Time perception and attention: The effects of prospective versus retrospective paradigms and task demands on perceived duration », Perception & Psychophysics, vol. 38, no 2, p. 115-124.

Brown, Scott W (2008). « Time and attention: Review of the literature », Psychology of time, p. 111-138.

Davis, Melissa, W. Roy Schulte et Elizabeth Golluscio (2018). « Make your customer engagement hub real time with continuous intelligence », Gartner.

Delay, Eugene R et Mianne E Mathey (1985). « Effects of ambient noise on time estimation by humans », Perceptual and motor skills, vol. 61, no 2, p. 415-419.

Delgado, Michelle (2018). « 6 Steps for Avoiding Online Form Abandonment », TheManifest.

D'Orazio, Vittorio et Laurie Shotton (2018). « Digital Business Transformation: A Financial Services Perspective Model », Gartner.

Drake, Carolyn et Marie-Claire Botte (1993). « Tempo sensitivity in auditory sequences: Evidence for a multiple-look model », Perception & Psychophysics, vol. 54, no 3, p. 277-286.

Droit-Volet, Sylvie et Sandrine Gil (2016). « The emotional body and time perception », Cognition and Emotion, vol. 30, no 4, p. 687-699.

Droit-Volet, Sylvie et Warren H Meck (2007). « How emotions colour our perception of time », Trends in cognitive sciences, vol. 11, no 12, p. 504-513.

Droit-Volet, Sylvie, Sophie Brunot et Paula Niedenthal (2004). « BRIEF REPORT Perception of the duration of emotional events », Cognition and Emotion, vol. 18, no 6, p. 849-858.

Droit-Volet, Sylvie, Stéphanie Tourret et John Wearden (2004). « Perception of the duration of auditory and visual stimuli in children and adults », Quarterly Journal of Experimental Psychology Section A, vol. 57, no 5, p. 797-818.

Eisler, Hannes, Anna D Eisler et Åke Hellström (2008). « Psychophysical issues in the study of time perception », Psychology of time, p. 75-109.

Fraisse, Paul (1967). Psychologie du temps, Presses universitaires de France.

Fraisse, Paul (1984). « Perception and estimation of time », Annual review of psychology, vol. 35, no 1, p. 1-37.

Glicksohn, Joseph, Rotem Leshem et Rotem Aharoni (2006). « Impulsivity and time estimation: Casting a net to catch a fish », Personality and Individual Differences, vol. 40, no 2, p. 261-271.

Gorn, Gerald J, Amitava Chattopadhyay, Jaideep Sengupta et Shashank Tripathi (2004). « Waiting for the web: how screen colour affects time perception », Journal of marketing research, vol. 41, no 2, p. 215-225.

Grondin, Simon et Marilyn Plourde (2007). « Judging multi-minute intervals retrospectively », Quarterly Journal of Experimental Psychology, vol. 60, no 9, p. 1303-1312.

Heinig, Ian (2018). « 5 Tips for Designing the Perfect Web Form », TheManifest.

Hicks, Robert E, George W Miller et Marcel Kinsbourne (1976). « Prospective and retrospective judgments of time as a function of amount of information processed », The American journal of psychology, p. 719-730.

Hornik, Jacob (1984). « Subjective vs. objective time measures: A note on the perception of time in consumer behaviour », Journal of consumer research, vol. 11, no 1, p. 615-618.

Jokic, Tijana, Dan Zakay et Marc Wittmann (2018). « Individual Differences in Self-Rated Impulsivity Modulate the Estimation of Time in a Real Waiting Situation ».

Kim, Jinwoo et Jae Yun Moon (1998). « Designing towards emotional usability in customer interfaces—trustworthiness of cyber-banking system interfaces », *Interacting with computers*, vol. 10, no 1, p. 1-29.

Kononowicz, Tadeusz W, Hedderik Van Rijn et Warren H Meck (2018). « Timing and Time Perception », Stevens' Handbook of Experimental Psychology and Cognitive Neuroscience, Learning and Memory, vol. 1, p. 453.

Laeng, Bruno, Sylvain Sirois et Gustaf Gredebäck (2012). « Pupillometry: A window to the preconscious? », Perspectives on psychological science, vol. 7, no 1, p. 18-27.

Lake, Jessica I, Kevin S LaBar et Warren H Meck (2016). « Emotional modulation of interval timing and time perception », Neuroscience & Biobehavioral Reviews, vol. 64, p. 403-420.

L'Hostis, Aurelie (2018). « The State Of Digital Banking, 2018 », Forrester.

Loijens, L, O Krips, Uyl Md Kuilenburg Hv et P FaceReader Ivan (2015). « 6.1 Reference Manual », Noldus Information Technology bv www. noldus. com.

Martins, Carolina, Tiago Oliveira et Aleš Popovič (2014). « Understanding the Internet banking adoption: A unified theory of acceptance and use of technology and perceived risk application », International Journal of Information Management, vol. 34, no 1, p. 1-13.

Mirhoseini, Seyed Mohammad Mahdi, Pierre-Majorique Léger et Sylvain Sénécal (2017). « The influence of task characteristics on multiple objective and subjective cognitive load measures », dans *Information Systems and Neuroscience*, Springer, p. 149-156.

Moreira, Diana, Marta Pinto, Fernando Almeida et Fernando Barbosa (2016). « Time perception deficits in impulsivity disorders: A systematic review », Aggression and violent behaviour, vol. 27, p. 87-92.

Nah, Fiona Fui-Hoon (2004). « A study on tolerable waiting time: how long are web users willing to wait? », *Behaviour & Information Technology*, vol. 23, no 3, p. 153-163.

Orlando, Salvatore (2019). « The differences between traditional and online banking », Expatica.

Ornstein, Robert E (1975). « On the experience of time ».

Rai, SN (1975). « Effects of environmental noises on estimation of duration », Perceptual and motor skills.

Revang, Magnus (2018). « Defining a Good User Experience With the Gartner User Experience Model », Gartner.

Sawyer, Thomas F, Peter J Meyers et Stacy J Huser (1994). « Contrasting task demands alter the perceived duration of brief time intervals », Perception & Psychophysics, vol. 56, no 6, p. 649-657.

Schmuckler, Mark A (2001). « What is ecological validity? A dimensional analysis », Infancy, vol. 2, no 4, p. 419-436.

Thomas, Ewart AC et Wanda B Weaver (1975). « Cognitive processing and time perception », Perception & Psychophysics, vol. 17, no 4, p. 363-367.

Tse, Peter Ulric, James Intriligator, Josée Rivest et Patrick Cavanagh (2004). « Attention and the subjective expansion of time », Perception & psychophysics, vol. 66, no 7, p. 1171-1189.

Wang, Qiuzhen, Sa Yang, Manlu Liu, Zike Cao et Qingguo Ma (2014). « An eye-tracking study of website complexity from cognitive load perspective », *Decision support systems*, vol. 62, p. 1-10.

Wittmann, Marc, David S Leland, Jan Churan et Martin P Paulus (2007). « Impaired time perception and motor timing in stimulant-dependent subjects », Drug & Alcohol Dependence, vol. 90, no 2, p. 183-192.

Wittmann, Marc et Martin P Paulus (2008). « Decision making, impulsivity and time perception », Trends in cognitive sciences, vol. 12, no 1, p. 7-12.

Woehrle, James L et Joseph P Magliano (2012). « Time flies faster if a person has a high working-memory capacity », Acta psychologica, vol. 139, no 2, p. 314-319.

Zakay, Dan et Richard A Block (1997). « Temporal cognition », Current directions in psychological science, vol. 6, no 1, p. 12-16.

Zakay, Dan et Joseph Shub (1998). « Concurrent duration production as a workload measure », Ergonomics, vol. 41, no 8, p. 1115-1128.

Zimbardo, Philip G et John N Boyd (2015). « Putting time in perspective: A valid, reliable individual-differences metric », dans Time perspective theory; review, research and application, Springer, p. 17-55.