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Concevoir des gestuelles appropriées : l'importance et les défis liés à l'évaluation de gestuelles sur interface utilisateur mobile

par

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Sommaire

Les concepteurs d'applications mobiles doivent savoir prendre des décisions de design qui affecteront positivement les utilisateurs. Il est donc primordial de comprendre comment, au niveau émotionnel, cognitif et perceptuel, ces utilisateurs vont réagir aux différentes gestuelles retrouvées dans les applications.

Ce mémoire par articles étudie donc l'impact et l'importance que les gestuelles tactiles ont sur l'expérience des utilisateurs d'applications mobiles. En se basant sur la littérature qui se concentre sur l'évaluation des gestuelles de façon explicite et souvent réalisée sur ordinateur, une étude en laboratoire a été réalisée avec 20 participants afin de tester les réactions implicites des utilisateurs d'appareils mobiles.

Basée sur la théorie «Task-technology fit» (Goodhue & Thompson, 1995) et la méthode d'analyse «Stimulus-Organism-Response» (Russell & Mehrabian, 1974), notre recherche permet d'abord d'analyser les impacts cognitifs et émotionnels des gestuelles sur les utilisateurs. Elle permet également de comprendre les rôles de différentes mesures implicites et explicites qui affectent les préférences des utilisateurs face aux gestuelles.

Les résultats de notre étude montrent l'importance d'avoir une bonne compréhension des impacts que peuvent avoir certains éléments dans le design d'applications mobiles à travers l'analyse des réactions des utilisateurs face à ces gestuelles. Les résultats de ce mémoire contribuent également à la littérature en interaction humain-machine. Finalement, ce mémoire propose des lignes directrices pour faciliter les choix de gestuelles lors du design d'applications mobiles.

Mots clés : Expérience utilisateur · Gestuelles tactiles · Design d'interaction mobile · S-O-R · Médiation · Préférences · Mesures psychophysiologiques

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Liste des abréviations

EDA : « *Electrodermal activity* »

HCI : « *Human-Computer Interaction* »

IHM : Interaction Humain-Machine

MIS: *«Management Information System »*

OS: *« Operating system »*

SOR: *« Stimulus-Organism-Response »*

UX: Expérience utilisateur

UX: *« User experience »*

Avant-propos

Suite à l'autorisation de la direction administrative du programme de Maîtrise ès Sciences en Gestion de HEC Montréal, ce mémoire est rédigé sous formes d'articles dans le domaine de l'expérience utilisateur. Il contient deux articles scientifiques qui se complètent l'un l'autre.

Un consentement signé des co-auteurs a été obtenu afin de présenter les articles qui constituent ce mémoire.

Le premier article porte sur l'exploration des différentes gestuelles disponibles sur certaines applications mobiles et s'efforce de déterminer l'impact de ces gestuelles sur l'expérience des utilisateurs. L'article a été soumis pour publication et présentation à la conférence *HCI International 2019* et y a été accepté. Cette conférence se déroulera à Orlando (Floride) à la fin du mois de juillet 2019.

Le second article est construit sur les commentaires obtenus lors de la révision de l'article 1 et il analyse plus profondément le rôle des gestuelles. L'article étudie la relation entre les gestuelles et les préférences des utilisateurs et ce en analysant l'effet médiateur possible de différentes variables implicites et explicites telles que la valence émotionnelle, l'activation émotionnelle, la charge cognitive et la facilité d'utilisation perçue. L'article est rédigé en vue d'être éventuellement soumis à *l'International Journal of Human–Computer Interaction*.

Remerciements

Je n'aurais pu réaliser ce projet sans l'aide et le soutien de plusieurs personnes que j'aimerais remercier de tout mon cœur.

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Chapitre 1 : Introduction

Aujourd'hui, les gestuelles sur interface mobile tactile suscitent beaucoup de questionnements par rapport à l'impact qu'ils ont sur les utilisateurs (Choi *et al.,* 2016). Avec l'innovation de l'écran tactile initiée par Apple, aujourd'hui les écrans tactiles sont perçus comme nécessaires pour les téléphones intelligents. Avec les possibilités grandissantes de gestuelles disponibles pour interface mobile (Villamor *et al.*, 2010), les choix de design de ces technologies deviennent de plus en plus importants. Effectivement, aujourd'hui, près de 70% des ménages canadiens possèdent au moins un téléphone intelligent (Passport, 2018). Il est donc important de bien comprendre si les gestuelles tactiles ont un impact sur les utilisateurs et le cas échéant, de saisir comment leur expérience va en être affectée. Il est également nécessaire d'utiliser des méthodes adéquates pour évaluer cette expérience parfois difficile à évaluer (Phifer & Valdes, 2016).

Les entreprises qui proposent des interfaces utilitaires doivent rendre l'expérience la plus plaisante possible pour leurs clients afin de les inviter à réutiliser leurs plateformes (Burton *et al.,* 2003). Avec les transformations numériques des dernières décennies, l'expérience des clients change rapidement et les entreprises doivent donc s'ajuster au même rythme (Soopramanien, 2011). Par exemple, dans le domaine bancaire au Canada, le nombre de transactions effectuées sur appareil mobile a grandement augmenté au cours des dernières années, soit de 5% en 2012 à 23% en 2018. On perçoit donc vraiment bien la transformation du numérique mobile au Canada (Statista, 2018).

Tous les aspects de design des interfaces mobiles sont importants afin d'assurer aux utilisateurs la meilleure expérience possible. L'évaluation des gestuelles n'a pas suscité beaucoup d'intérêt au niveau de la recherche, car elles ne constituent qu'une infime partie du design de l'interface. Par contre, comme le montre la littérature, ces petits détails peuvent avoir un impact sur les intentions comportementales d'utilisation, le plaisir perçu (Dou & Sundar, 2016), la frustration des utilisateurs (Warr & Chi, 2013), l'absorption cognitive (Choi et al., 2016) ainsi que sur la performance face à une tâche (Bragdon *et al.*, 2011).

Finalement, bien que certaines recherches aient démontré les impacts des gestuelles sur les utilisateurs, la littérature est très limitée au niveau du type de mesures à récolter pour bien comprendre l'expérience des utilisateurs.

Question de recherche

L'étude de l'interaction entre l'humain et la machine connaît un intérêt grandissant. D'abord peu étudiée, les professionnels tentent de plus en plus de comprendre l'impact des différentes gestuelles tactiles sur l'expérience des utilisateurs. Afin de prendre des décisions adéquates lors du design de gestuelles pour applications mobiles, il devient crucial d'en comprendre l'impact réel.

Ce mémoire par articles explore si les gestuelles tactiles peuvent avoir un impact sur l'utilisateur dans un contexte d'application mobile en milieu bancaire. En d'autres mots, ce mémoire explore les gestuelles sur des interfaces utilitaires où les tâches sont orientées vers un objectif. Dans un premier temps, une méthode d'évaluation des gestuelles mobiles a été développée afin de déterminer, à travers la charge cognitive et la valence émotionnelle ressentie, si les gestuelles tactiles influencent l'expérience des utilisateurs. Cette charge cognitive est mesurée à l'aide de la pupillométrie qui mesure le diamètre de la pupille et la valence émotionnelle est mesurée à l'aide d'un logiciel de reconnaissance d'émotions faciales.

Dans un deuxième temps, ce mémoire tente d'explorer et d'analyser l'impact que les différentes gestuelles sur application mobile ont sur les réactions des utilisateurs. Ce mémoire explore ensuite quelles réactions émotionnelles implicites ou explicites affectent la préférence des utilisateurs envers une gestuelle ou l'autre. Des données psychométriques (valence et activation émotionnelle) ainsi que la perception des utilisateurs (facilité d'utilisation) sont évaluées. Également, un court questionnaire permet de déterminer les combinaisons de gestuelles et de cas d'utilisation préférées par les utilisateurs.

La première partie de ce mémoire tentera dans l'article 1 de répondre à la question suivante :

Q1 : Est-ce que la gestuelle combinée à différents cas d'utilisation affecte l'expérience des utilisateurs ?

La seconde partie du mémoire se base sur les résultats de l'article 1 et tente de répondre à la question suivante :

Q2 : Quel est l'impact des réactions émotionnelles implicites et explicites lors de l'utilisation des gestuelles sur la préférence des utilisateurs envers celles-ci ?

Objectifs de l'étude

L'objectif de ce mémoire est d'explorer si l'impact du choix des gestuelles, dans le design d'une application mobile dans un contexte bancaire, modifie l'expérience observée et vécue par les utilisateurs. Du point de vue pratique, les résultats de ce mémoire basés sur l'expérience réelle des utilisateurs peuvent contribuer à diriger le processus de création des designers en expérience utilisateur (UX) et aux experts de l'industrie.

Du point de vue théorique, ce mémoire a pour ambition de contribuer à élargir la littérature sur les interactions humain-machine en explorant le sujet des gestuelles sur application mobile. Les résultats de ce mémoire contribueront à combler un manque dans la littérature au niveau de l'étude de l'impact des différentes gestuelles mobiles.

Structure du mémoire

Les deux prochains chapitres de ce mémoire présenteront les résultats obtenus lors de cette étude. Il faut noter qu'une seule collecte de données a été réalisée pour l'ensemble du mémoire ; ainsi le design expérimental et la méthode restent les mêmes pour les deux prochains chapitres. Tout d'abord, le chapitre 2 présentera le premier article qui a été accepté et publié à la conférence *HCI International 2019*, une conférence scientifique sur le thème de l'interaction humain-machine. À la suite de la correction de ce mémoire, certaines modifications ont été apportées au chapitre 2. La version originale se retrouve dans les actes de la conférence HCI International 2019[1].

L'article de ce chapitre présente une recherche de type exploratoire qui précède l'analyse des résultats présentés dans l'article 2. Ainsi, le chapitre 3 présentera le deuxième article qui est en cours de préparation pour soumission au *International Journal of Human-Computer Interaction.* Pour conclure, le chapitre 4 présentera une synthèse des résultats des deux articles précédents en répondant aux questions de recherche ainsi qu'en présentant des contributions dans le domaine de l'expérience utilisateur et le domaine du design. Finalement, nous présenterons les limites de l'étude ainsi que les suggestions pour des recherches futures.

Informations sur les articles

La collecte de données pour ce mémoire a été effectuée dans le laboratoire du Tech3Lab. Les résultats de cette collecte ont permis de rédiger deux articles portant sur ces données. Le premier article a été rédigé durant la session d'automne 2018 grâce à une bourse de la Chaire de recherche industrielle CRSNG-Prompt en expérience utilisateur. La deuxième phase d'analyse a été réalisée durant l'hiver 2019.

Résumé du premier article

L'objectif de cet article est d'explorer la manière dont les utilisateurs réagissent à certaines gestuelles sur application mobile tel que le glissement de gauche à droite (swipe), le défilement vertical (vertical Scrolling), le défilement latéral (lateral scrolling) et les boutons gauche/droite (tap) lors de différents cas d'utilisation. Plus précisément, cet article tente de déterminer si la gestuelle combinée à différents cas d'utilisation affecte l'expérience des utilisateurs. En nous appuyant sur la théorie de l'adéquation tâche-technologie, nous nous intéressons plus particulièrement au degré d'alignement entre les gestuelles et chaque cas d'utilisation sur mobile. Nous supposons que certaines gestuelles

[1] Beauchesne A., Sénécal S., Fredette M., Chen S.L., Demolin B., Di Fabio ML., Léger PM. (2019) User-Centered Gestures for Mobile Phones: Exploring a Method to Evaluate User Gestures for UX Designers. In: Marcus A., Wang W. (Eds) Design, User Experience and Usability. HCII 2018. Lecture Notes in Computer Science, vol. 1158. Springer, Cham

sont mieux alignées avec certains cas d'utilisation, car elles nécessitent moins d'effort cognitif que d'autres. En d'autres termes, certaines gestuelles peuvent devenir si naturelles pour les utilisateurs qu'ils ne doivent pas consciemment investir d'efforts pour les accomplir. Également, nous émettons l'hypothèse que les types de cas d'utilisation affectent la valence émotionnelle des gestuelles. Pour atteindre l'objectif de cette étude, une expérience de laboratoire a été menée avec 20 participants, où la charge cognitive et la valence émotionnelle ont été mesurées. Les résultats suggèrent que la combinaison de gestes et de cas d'utilisation a bel et bien un impact sur la charge cognitive et la valence émotionnelle de l'utilisateur.

Résumé du deuxième article

Le but de cet article d'analyser et d'évaluer l'impact des réactions émotionnelles implicites et explicites lors de l'utilisation des gestuelles sur la préférence des utilisateurs envers celles-ci. L'objectif de cette étude est donc de déterminer quelles réactions des utilisateurs affectent les préférences pour ces gestuelles et quelles variables devraient être utilisées pour analyser ces préférences. En nous basant sur le modèle *Stimulus-Organism-Response*, nous émettons l'hypothèse qu'une mesure perçue, telle que la facilité d'utilisation face aux gestuelles, et des mesures implicites continues telles que l'activation émotionnelle, la valence émotionnelle et la charge cognitive, serviront de médiateur entre les gestuelles présentées et les préférences des utilisateurs.

Une expérience de laboratoire a été menée pour tester ces hypothèses. Vingt (20) participants ont été invités à tester différents prototypes en utilisant différentes gestuelles: le glissement de gauche à droite (swipe), le défilement vertical (vertical Scrolling), le défilement latéral (lateral scrolling) et les boutons gauche/droite (tap). La charge cognitive, la valence émotionnelle et l'activation émotionnelle ont été mesurées tout au long de la tâche. Les participants ont ensuite été invités à indiquer leurs gestuelles préférées. Les résultats suggèrent que les gestuelles influencent l'activation émotionnelle et la facilité d'utilisation perçue. La facilité d'utilisation perçue à également un impact sur les préférences pour les mouvements. Les résultats suggèrent finalement une relation entre les gestuelles et la préférence de celles-ci. En plus de contribuer à la littérature sur l'interaction humain-machine, les résultats contribuent au domaine du design en proposant des guides pour le choix et la conception de gestuelles dans les applications mobiles.

Contributions et responsabilités personnelles

La contribution et les responsabilités personnelles dans la rédaction de chacun des articles sont rapportées dans le tableau récapitulatif suivant (voir Tableau 1). Celui-ci identifie, en pourcentage, ma contribution pour chaque activité du processus de recherche.

Tableau 1 – Contributions dans la rédaction des articles

Activité	Contribution
Définition des requis et des besoins d'affaires du partenaire	Définition de la question de recherche, de la problématique et des besoins d'affaires du partenaire – 80% ● L'équipe du Tech3Lab, Pierre-Majorique Léger et Sylvain Sénécal ont aidé à établir les besoins d'affaires du partenaire et à transformer ceux-ci en objectif précis de recherche. ● Problématique existante apportée par le partenaire du projet.
Revue de la littérature	Revue de littérature sur les gestuelles sur interface mobile – 100% Rédaction de la revue de littérature – 100% ● Corrections et conseils sur les articles apportés par les directeurs de recherche. Justification des choix de design – 80% ● L'équipe technique du Tech3Lab a validé les outils utilisés et se sont assurés de la cohérence de ceux-ci avec les objectifs de recherche préalablement établis.

Conception du design expérimental	Élaboration de la demande au CER et des demandes de changements – 80% • Demande au CER. • Développement des formulaires de compensation et de consentement à partir de modèles préétablis. • L'équipe du laboratoire s'est assurée de suivre ma démarche afin que la demande soit complète. Élaboration et rédaction du protocole d'expérimentation – 90% • L'équipe du Tech3Lab a approuvé et révisé le protocole avant la collecte. Installation de la salle de collecte – 50 % • Test de placement d'équipement avec le partenaire industriel. • Salle installée avec l'aide de l'équipe d'opération. Pré-test des protocoles afin d'assurer la fluidité de l'expérience et la qualité des données – 90% • Soutien par les assistants de recherche.
Conception des prototypes	Élaboration des prototypes utilisés lors de la collecte sur Atomic – 100% • Soutien par une équipe de design du partenaire du projet. • Version finale faite par le partenaire.

Recrutement des participants	Élaboration et rédaction du questionnaire de recrutement – 100% Recrutement et gestion des participants – 50 % ● 50% des participants ont été recrutés à travers le panel par l'équipe du Tech3Lab. ● Le reste des participants ont été recrutés de façon externe par une firme engagée par le partenaire. Administration des compensations – 100 % Création du cartable d'expérience pour le suivi adéquat des participants – 80% ● Le cartable d'expérience a été assemblé par l'équipe du laboratoire.
Collecte de données	Collecte des données – 100% ● Présence à toutes les collectes de données avec l'aide des assistants de recherche tout au long de cette étape.
Extraction des données	Extraction des données psychométriques et oculométriques. Extraction des données recueillies par des questionnaires Qualtrics – 100%
Analyse des données	Analyse des données oculométriques – 100 % Analyse des données psychométriques – 100% Analyse et interprétation des statistiques du mémoire – 100% ● Aide d'un statisticien pour effectuer les tests statistiques sur le logiciel Stata V.14.
Rédaction des articles et du mémoire	Écriture des articles du mémoire – 100% ● Les articles ont été commentés et améliorés suite aux commentaires des directeurs et des coauteurs.

Chapitre 2: Premier article

User-Centered Gestures for Mobile Phones: Exploring a Method to Evaluate User Gestures for UX Designers

Ariane Beauchesne[1], Sylvain Sénécal[1], Marc Fredette[1], Shang Lin Chen[1], Bertrand Demolin[1], Marie-Laure Di Fabio[2], and Pierre-Majorique Léger[1]

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Abstract

The objective of this paper is to explore how users react to certain gestures (e.g., swipe, scroll, or tap) for certain use cases (e.g., how to use a product or service). More specifically, the goal is to explore and suggest guidelines to user experience (UX) designers when choosing gestures for specific use cases on a smartphone application. Building on the Task-technology fit theory, we are specifically interested in the degree of alignment between gestures and each mobile use case. We hypothesize that some gestures are better aligned with certain use cases because they require less cognitive effort than others. In other words, certain gestures are likely to become so natural for users that they do not have to consciously invest effort to accomplish these gestures. Likewise, we hypothesize that the emotional valence of gestures will be affected by the use case. To attain this objective, a lab-experiment was conducted with 20 participants, where cognitive load and emotional valence were measured. Results suggest that the combination of gestures and use cases have an impact on the user cognitive load and valence. These findings contribute to human-computer interaction (HCI) research by providing insights to help user experience (UX) designers select appropriate gestures.

Keywords: Mobile applications design · Usability methods and tools · Guidelines · User experience · Cognitive load

1. Introduction

One of the most important aspects in designing, creating, and developing applications and interfaces is creating something that feels natural for the user (Wigdor & Wixon, 2011). To do so, design teams need to understand their users: how they feel, what they need, and what they think (Ferreira *et al.,* 2015). Therefore, it seems only logical that with user-centered design, products should feel natural in the hands of users. They should be able to use these products to attain their goals effectively, with efficiency and satisfaction (Garrett, 2011; International Standard, 2016). While using a mobile application, the interaction is an important factor for achieving usability and for creating something intuitive for the user. Mobile operating systems and applications each use their own set of guidelines when designing different gestures, making it hard for users to know what gestures to use. In addition, different types of content can be presented in many ways (called use cases): tutorial, choices, text, etc., making it even harder for users to know how to interact with different applications or interfaces.

To reduce the impact of all these different options, choosing appropriate gestures for different types of use cases can simplify the experience for users. External consistency between different platforms is essential to provide a constant experience to users through their daily use of technology (Scapin & Bastien, 1997).

The literature on product development phases shows the importance of including testing and prototyping at the beginning of that process (Walker *et al.*, 2002). Research shows that those tests need to include the input from users from the very beginning to save time, money, and to better understand user preferences and points of view (Snyder, 2003; Svanaes & Seland, 2004). While research in user-centered design is becoming more present in today's design processes, there appears to be a gap in the literature concerning the type of gestures that are more appropriate for different use cases in mobile applications. Understanding the impact of gestures on the success and ease of use of applications is even more important now because user interface design does contribute to the success and the acceptance of applications (Bano & Zowghi, 2015). In addition, theories such as the Task-technology theory suggest that the alignment of tasks, technologies, and users have a real impact on the usability and the performance of a product (Goodhue & Thompson, 1995).

Therefore, the objective of this paper is to explore how users react to four basic gestures for different types of use cases on mobile applications. To attain this objective, a laboratory experiment with implicit measurements using psychophysiological tools such as facial emotions and eye-tracking was performed. Prototypes of different gesture/use case combinations in the online banking context were presented to participants to investigate how gestures affect the user's experience. Based on these results, we present insights to UX designers to help them explore and choose appropriate gestures for specific use cases for smartphones.

2. Theoretical Background and Hypothesis Development

2.1. Task-Technology Fit Theory

Goodhue and Thompson (1995) define the task-technology fit as "the degree to which a technology assists an individual in performing his or her portfolio of tasks" (p. 216). The theory is based on three levels of inputs: task characteristics, technology characteristics and individual characteristics. When interacting together, these factors influence the fit between task and technology and determine its usability and performance (see Figure 1) (Lin & Huang, 2008). This theory has been a central point in management information system (MIS) literature. However, recent literature is now showing that small variations in how the information is presented in touch interfaces can have an impact on the experience of users (Sundar *et al.,* 2014). Building on the task-technology fit theory, we are specifically interested in the degree of alignment between gestures and each mobile use case.

2.2. Use Case

Use cases are defined in literature as a way in which a user interacts with a system (Cockburn, 1999). Here the term is transposed to define it as a way that a user can use the information in the application. In other words, the same information can be presented in different ways on a mobile phone, here called use cases. Moreover, in mobile applications, two formats have emerged to present the information when it does not fit on one page: horizontal or vertical. The use cases can then be presented with these two formats. Little research has tested the effect of the orientation format for mobile phones on users. A study comparing horizontal and vertical tab switching when web browsing showed that horizontal formats (swiping) provide faster and less frustrating results compared to vertical formats (scrolling) (Warr & Chi, 2013). While another study comparing shopping swipe-based interfaces (horizontal) and scroll-based interfaces (vertical) shows that the horizontal interfaces lead to greater cognitive absorption and playfulness (Choi *et al.*, 2016). With the same idea, research based solely on a computer found that adding horizontal swiping affected positively the intentions to use the website (Villamor *et al.*, 2010).

2.3. Gestures

A gesture is an interaction technique that can be defined as "a way of using a physical input/output device to perform a generic task in a human-computer dialogue''(Sundar *et al.*, 2014) (p.112). Touch gestures are now becoming the norm in mobile phones and applications. They first emerged when touch screens became available and users needed to apply these gestures to navigate the content. They were also used to solve the problem of information not fitting on one page, which caused users to have to apply additional gestures to get to the rest of the information (Wobbrock *et al.,* 2009). Research shows that touch interfaces have a real impact on users' level of engagement (Choi *et al.*, 2016). Gestures need to be effective to decrease users' cognitive load while using an application (Warr & Chi, 2013).

At first, mobile gestures were mostly tapping and vertical scrolling (see Table 1) (Villamor *et al.,* 2010). Now horizontal swiping is becoming part of the basic gestures' family. Indeed, more and more applications have followed the popular dating application TINDER® and are now using horizontal swiping to present their content. According to the literature, including horizontal gestures can increase perceived enjoyment and user engagement (Dou & Sundar, 2016). Lateral gestures such as swiping also suggest an increase in cognitive absorption, reuse intentions, and task performance (Choi *et al.*, 2016).

For this study, gestures found in popular utilitarian and hedonic applications have been selected according to basic gestures used for most touch commands (see Table 1. Basic gestures for touch commands).

Furthermore, visual indicators such as arrows or scrolling bars and feedback like nudging can be included in designs to facilitate the comprehension of gestures and thus, create applications that are more usable (Leung *et al.,* 2007; Ruspini *et al.,* 1997).

Table 1 – Basic gestures for touch commands

Swipe	Lateral Scrolling	Vertical Scrolling	Tap
			
Quickly brush surface with fingertip in on direction of the other	Move fingertip horizontally over surface without losing contact	Move fingertip vertically over surface without losing contact	Briefly touch the surface with the fingertip

2.4. Psychophysiological Measures in User Experience

Evaluating user experience when it includes gestures can be a difficult task because its evaluation is not mainly based on performance. Gestures can, for example, be evaluated on the ease of use, the playfulness and the reuse intentions (Choi *et al.*, 2016). For this reason, we chose to not only focus on explicit measures (e.g., self-reported) but also on implicit ones. Implicit measures are able to offer researchers results of the user experience not only after but also during the experience. While explicit non-continuous measures have been much used throughout the past decades in UX studies and are a great way to measure UX (Bargas-Avila & Hornb, 2011), recent research is now showing that psychophysiological measures can provide real-time insightful data (de Guinea *et al.,* 2014; Dirican & Göktürk, 2011; Lourties *et al.,* 2018; Mandryk *et al.,* 2006).

Dirican and Göktürkb define a psychophysiological measure as a "measure [that provides] an unobtrusive and implicit way to determine the user's affective or cognitive state on the basis of mind-body relations" (Dirican & Göktürk, 2011) (p. 1362). While there are some limitations with psychophysiological measures, there are also many advantages (Allanson & Fairclough, 2004; Dirican & Göktürk, 2011). Among others, implicit measures can eliminate the bias of users giving their retroaction on the task. These measures are implicit, unobtrusive, and continuous (Mandryk *et al.*, 2006; Vicente *et al.,* 1987; Wilson & Sasse, 2006).

In this study, using real-time measures was important, because many tasks were performed (20 tasks) and the goal is to recognize gestures that feel natural, are easy and not frustrating for the user. For this reason, we decided to use the following measures: pupil diameter for measuring mental workload and facial emotion to measure emotional valence.

Pupil Diameter

According to Adams (2007) and Harrison *et al.* (2013), the user's cognitive load is an aspect that researchers in HCI and UX tend to neglect. Cognitive load can be defined "as a multidimensional construct representing the cognitive demands associated with performing a specific task" (Xie *et al.*, 2017) (p.2). It plays a key role in evaluating user experience. Research has established the correlation between pupil diameter and cognitive load (Ahlstrom & Friedman-Berg, 2006; Chen *et al.*, 2016; Ganglbauer *et al.,* 2009; Van Orden *et al.,* 2001).

However, pupil dilation can be affected by the light conditions because of the reflex of the pupil (Kramer, 1990) so measuring outdoors might bias the collected data (Adams, 2007). To prevent such bias, this experiment was run in an indoor lab setting.

The pupil can vary in sizes from .2mm to .8mm. Users with low cognitive load have a non-dilated pupil, while users with higher cognitive load have a dilated pupil (Kramer, 1990). The more difficult a task is, the higher the cognitive load (Beatty, 1982). This measure may provide a reliable index to find a relationship between task difficulty and the size of the pupil (Kramer, 1990).

Using the Task-technology fit theory, we are interested to explore the degree of alignment between gestures and use cases. This alignment should bring out better and worse combinations of gestures and use cases. Thus, we posit the following hypothesis:

H1: The alignment between the type of gesture and the use case influences cognitive demand.

Emotional Valence

Studies on facial expressions and emotions have interested many researchers in, among others, psychological and physiological fields. These studies use physiological measures to identify a range of emotions like sadness or anger (Ekman, 1993). Now UX research is also becoming interested in evaluating emotions to further understand users (Staiano *et al.,* 2012). Emotional valence is one of the dimensions of emotions, it ranges between a pleasant emotion and an unpleasant one (Lane *et al.,* 1999). Assessing this dimension is important when trying to measure user experience on a task that should feel natural. To measure emotional valence, facial recognition analysis tools are used to detect facial muscle movements in order to infer emotions (Bartlett *et al.,* 2004).

Again, based on the Task-technology fit theory, we then posit the following hypothesis:

H2: The alignment between the type of gesture and the use case influences emotional valence.

3. Research Method

3.1. Context

This study used mobile utilitarian applications. In other words, the prototypes were tested during use cases that users could come across everyday. Different use cases were used in this study to test the gestures in more than one context. Prototypes were developed based on banking applications. From checking their account to reading articles on retirement savings, online banking is now part of the customers' everyday life. In 2018, around 70% of Americans accessed their bank accounts via a mobile device (EMarketer, 2018). Over the past years, banks began to understand the importance of designing and creating an experience which would fulfil the needs of users. Testing and shedding light on the most natural gestures could greatly improve those everyday interactions with the online banking system. Furthermore, simple banking interactions like the ones used in this test are common not only in banking applications, but also in many others. Choosing simple daily use cases would also ensure faster use case completion for the user.

3.2. Participants

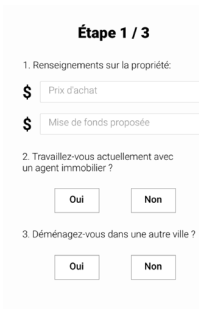
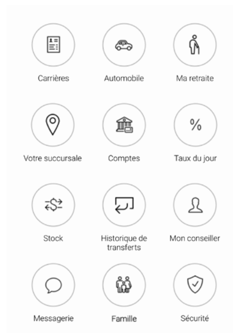
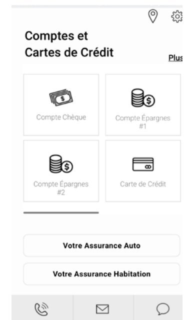
To test our hypotheses, an experiment was conducted. Twenty participants between the ages of 20 and 46 were recruited for this study (Mage =28.7, SD = 8.70; 11 women). Every participant received monetary compensation. Half of the participants were recruited via our school panel while the other half were recruited through an external firm. The second group was recruited externally to ensure a broader age distribution. Participants were pre-screened for glasses, laser eye surgery, astigmatism, epilepsy, neurological and psychiatric diagnoses. This project was approved by the Ethics Committee of our institution.

3.3. Design and Procedure

The experimental design of this study is based on two main within-subject factors: use cases and gestures. Five utilitarian use cases were explored to ensure diversity of content while testing gestures: filling out a form (C1), discovering a tutorial (C2), browsing an application menu (C3), reading a text (C4), and using a dashboard (C5) (see Table 2). For each use case, the four basic mobile gestures were tested. These gestures represent common gestures used in a utilitarian context: swiping (SW), lateral scrolling (LS), vertical scrolling (VS), and tapping (TA) (Table 1). During a one-hour test, participants first performed a baseline task to measure their cognitive and emotional reactions in their normal and calm state. Participants watched a standardized relaxing video to achieve the desired state (Piferi *et al.,* 2000). After, participants performed 20 tasks (each use case with each gesture) on an iPhone 6 Plus in a randomized way. Each use case was performed on a prototype and began with an entry page detailing which type of use case participants were going to perform; then the participants performed the use cases, and closed the application when they were done.

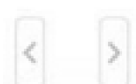
The high-fidelity prototypes necessary to represent the use cases and the gestures were developed on Atomic© and were inspired by use cases found in the banking sector. For the use cases C1, C2, C3 and C4, the content was distributed on three distinct pages, while for the C5, the content was distributed on two pages. Also, C5 was presented in a hybrid design, where only one section of the page was moving when using a gesture. The rest of the page was static. Gestures were signaled with visual indicators to give a hint to the users on which gestures should be used. The same indicators were used for every use case (see Table 3).

Table 2 – 20 prototypes were created on Atomic©. Here is an example of each use case

Filling out a form (C1)[1]	Discovering a tutorial (C2)[2]	Browsing an application menu (C3)[3]	Reading a text (C4)[4]	Using a dashboard (C5)[5]
				

Translation of texts in the images
[1] C1: Step ⅓; 1. Property information; 2. Do you work with a realtor? ; 3. Are you moving to another city?
[2] C2: Take a picture of the front and the back of your check with the camera of your smartphone.
[3] C3 (first three applications only): Career; Car; My retirement.
[4] C4: 4 savings strategies to carry out all your projects. Good savings strategies are actions that will allow you to raise the amounts needed to carry out your projects in the short, medium or long term. Here are some tips to help you build the best strategy for your needs.
[5] C5: Accounts and credit cards; Checking account; Savings account #1; Savings account #2; Credit card; Your car insurance; Your home insurance.

Table 3 – Visual indicators used for each gesture

Gestures' names	Visual indicators	Description
Swiping (SW)		With Swiping, the window changes from left to right or from right to left, allowing the user to see additional information in a different window. For example, one may swipe to access new pages of informations. Each page is seen as a whole and when a user swipes, new pages are presented.
Lateral Scrolling (LS)		With Lateral Scrolling, the window moves left to right or from right to left, allowing the user to see additional information. For example, one may need to scroll right to continue reading a document or see other parts of the page. Pages here are not presented as a whole.
Vertical Scrolling (VS)		With Vertical Scrolling, the window moves up or down, allowing the user to see additional information. For example, one may need to scroll down to continue reading a document or see other parts of the page. Pages here are not presented as a whole.
Tapping (TA)		With Tapping, the window changes from left to right or from right to left, allowing the user to see additional information in a different window. For example, one may tap a button to access new pages of information. Each page is seen as a whole and when a user taps, new pages are presented.

3.4. Experimental Setup and Apparatus

The experiment took place in a laboratory, with controlled lighting, humidity, and temperature. The room was set up so the participant was sitting in front of the phone that was held by a support. Some complementary information was shown on an iPad also held by a support. The participant used the mouse to complete the questionnaire between each use case (see Figure 1. Experimental set-up). The research assistants were sitting in an adjacent room behind a one-way mirror. To communicate with the participant, a microphone was used. Three types of measures were used to capture the cognitive reaction and emotion to a given gesture. A webcam was used to record the image of the participant with Media Recorder (Noldus, Wageningen, Netherlands). The videos were then processed through FaceReader, an automatic facial analysis tool (Noldus, Wageningen, Netherlands) to provide us with emotional valence. Finally, Tobii X-60 eye-tracker (see Figure 2) was used to capture the participants' pupil size and was set under the phone. All of the measures and data were synchronized with Observer XT (Noldus, Wageningen, Netherlands) with the guidelines provided by Léger *et al.* (2014).

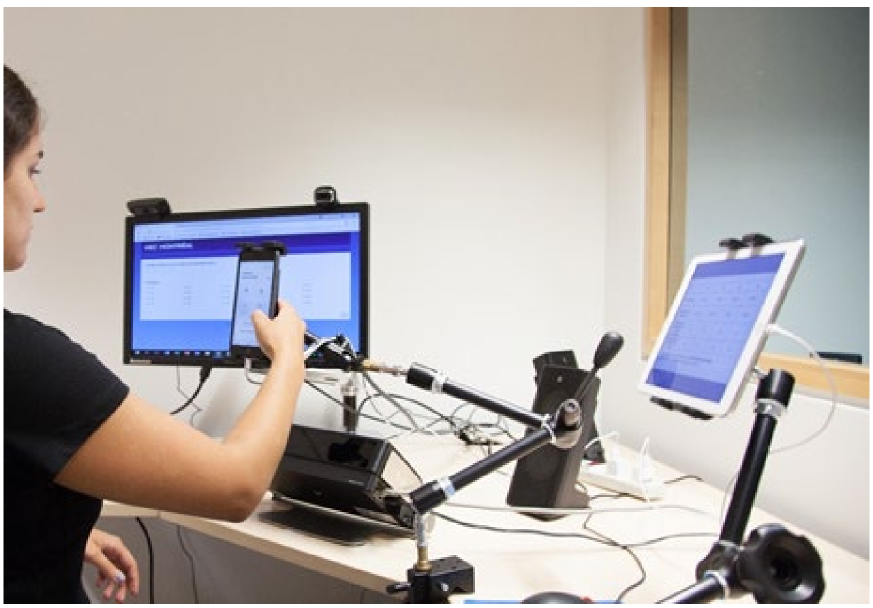


Figure 1 – Experimental set-up

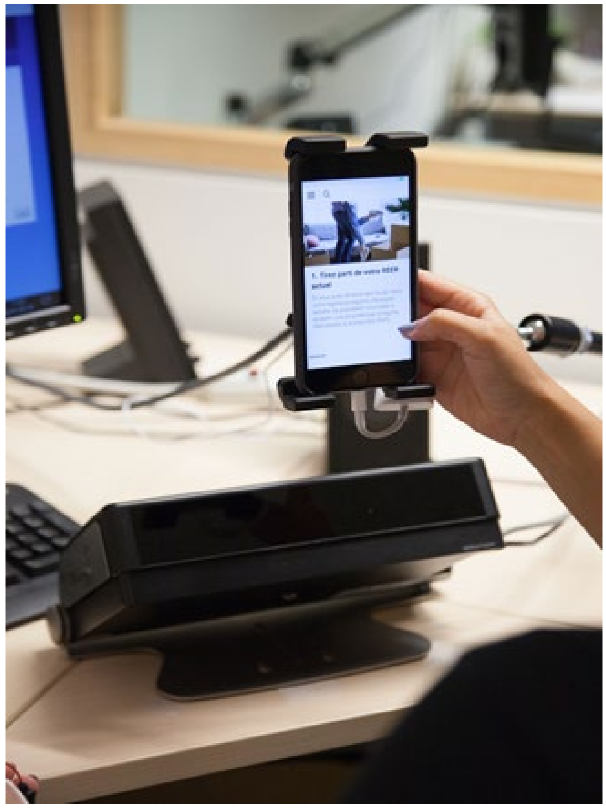


Figure 2 – Tobii X-60 eye-tracker

4. Results and Analysis

In order to explore how users react to certain gestures (e.g., swipe, scroll, or tap) for certain use cases, we compared the implicit behavioral measures. The implicit individual measures were adjusted for baseline. The adjusted values were calculated from the difference between the data collected and the participants' baseline. It was then rescaled to (-1,1) for the entire data set.

Table 4 shows the means of the implicit measures for each combination use cases/gestures for all participants (n=20).

Table 4 – Participants' mean cognitive load and valence

Hypothesis	Use cases	Mean Cognitive Load	Mean Valence
Swiping (SW)	C1	-.10745	-.32227
	C2	-.14379	-.25108
	C3	-.10488	-.24626
	C4	-.1798	-.25284
	C5	-.08656	-.21009
Lateral Scrolling (LS)	C1	-.11869	-.28062
	C2	-.07469	-.26977
	C3	-.07756	-.21539
	C4	-.16407	-.24679
	C5	-.12229	-.21297
Vertical Scrolling (VS)	C1	-.09224	-.28401
	C2	-.08292	-.25817
	C3	-.07823	-.27056
	C4	-.15975	-.2372
	C5	-.07606	-.25596
Tapping (TA)	C1	-.07909	-.26513
	C2	-.12661	-.23434
	C3	-.08842	-.23459
	C4	-.17081	-.19289
	C5	-.10731	-.3286

H1 suggests that the alignment between the type of gestures and the use case influences cognitive demand. Table 5 presents results of an ANOVA with a two-tailed level of significance adjusted for multiple tests comparison with the Holm-Bonferroni method, which was used to test if there is a significant difference between at least two means of a gestures' cognitive load for a specific use case (see Table 5). The degree of freedom (n-1) is presented with the p-values of each test. In other words, the ANOVA tests if there is, for example, a significant difference between at least two means between C1, C2, C3, C4, and C5 for the cognitive load of the swipe gesture. For all four gestures, results suggest that the participants' cognitive load is different for at least two use cases (SW, LS, VS, TA: $p < .0001$). This indicates that H1 is supported and that gestures' cognitive demand depends on the use case.

In order to test H2, which suggests that the alignment between the type of gesture and the use case influences emotional valence, the same statistical test was conducted. Results presented in Table 5 suggest again that for all four gestures users' emotional valence is significantly different for at least two use cases (SW, LS, TA: $p <.0001$; VS: $p = .0009$). Therefore, results show that H2 is supported, suggesting that the gestures' emotional valence is influenced by the use case.

Table 5 – P-values of ANOVA's statistical tests

	Hypothesis	Gestures	Degree of freedom	P-value[a]
At least two values are significantly different for each use cases' cognitive load	H1	Swiping (SW)	4	<.0001
		Lateral Scrolling (LS)	4	<.0001
		Vertical Scrolling (VS)	4	<.0001
		Tapping (TA)	4	<.0001
At least two values are significantly different for each use cases' emotional valence	H2	Swiping (SW)	4	<.0001
		Lateral Scrolling (LS)	4	<.0001
		Vertical Scrolling (VS)	4	.0009
		Tapping (TA)	4	<.0001

Note. N=5
[a]Two-tailed level of significance

5. Discussion and Concluding Comments

This paper is an exploratory attempt to determine if gestures and use cases for mobile applications have an impact on the experience of users. Our results show that gestures emotional valence and cognitive load depend on the use case (H1 & H2). These results suggest that the combination of gestures and use cases have an impact on the user experience. Understanding the best fit between gestures and use case could significantly impact the users' experience when using mobile applications on a smartphone.

This study contributes to user experience, human-computer interaction, and interface design literature in many ways. First, this study explores a subject that has not been investigated so far. The importance of choosing and designing gestures can sometimes be neglected while results clearly show that they can have an impact on user interaction with a mobile application. Second, our research shows a way to use psychophysiological measures to evaluate gestures during an experiment. Overall, knowledge of testing and choosing adequate gestures could help designers and product owners lower the cognitive load of their users and increase their emotional valence, therefore creating a more positive experience overall.

Because this research is exploratory, some limitations need to be acknowledged. Regarding technical limitations, there were inactivated functionalities on the prototypes. For example, a menu icon was added to the design to provide a more realistic interface and some of these icons were inactivated and would not open a menu. It is possible that some participants tried to use them. Also, this study was performed on five use cases in a utilitarian context; further research should address other specific use cases. Furthermore, the same gestures were performed more than once during the test. This may have affected the cognitive load because of learnability. However, to minimize these effects, the combinations of use cases and gestures were performed in a randomized way. Finally, the age of the participants was between 20 and 46 years old. Further research could be done on older population to see if their reactions differ.

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Chapitre 3 : Deuxième article

The effects of different touch gestures on users' emotional responses and how they affect the preferences towards these gestures

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Abstract

The aim of this study is to explore and analyze the impact of using different types of gestures on mobile applications in order to provide guidelines for designers who are choosing which gestures to use for a given application. The objective of this study is to explore which users' reactions affect the preference for these gestures. Using not only explicit measures but implicit ones to capture reactions, we investigate if those implicit reactions impact the users' preferences. Building on the Stimulus-Organism-Response model, we hypothesize that explicit measures such as ease of use with a gesture, and continuous implicit variables like arousal, valence and cognitive load, mediate the relationship between the touch gestures and the preferences for those gestures. A within-subject lab-experiment was conducted to test these hypotheses. Twenty (20) participants were asked to test 20 different prototypes using four different gestures (Swiping, Lateral Scrolling, Vertical Scrolling and Tapping). Participants were then invited to indicate their preferred gesture for the task. Results show that touch gestures influence arousal, valence and perceived ease of use. Perceived ease of use also has an impact on the preferences for the gesture. Results thus suggest a relationship between gesture and gesture preference. In addition to contributing to the Human-Computer-Interaction literature, the findings have implications for the choice and design of touch gestures in mobile applications.

Keywords: S-O-R Mediation Touch gesture Application design User Experience

1. Introduction

Usability testing in product development is an effective way to understand users' needs and thus provide them with better user experience (Nigel, 2008). Evaluating design decisions in the early stages of product development is essential in saving time and in ensuring that the product will meet the users' expectations (Sandars & Lafferty, 2010). Within the human-computer interaction (HCI) field, touch gestures on mobile phones have been part of the picture for several years (Khandkar & Maurer, 2010). The evaluation of those gestures has become a topic of interest in many industries.

Today, the information provided in applications has moved from "vertical only" to other forms of presentations; for example, TINDER®, a popular dating application, brought in the horizontal presentation. Indeed, at first, vertical touch interfaces prevailed, but later on, swipe-based touch interfaces started to emerge in the market (Choi & al., 2016). To our knowledge, few studies have investigated touch gestures for mobile phones (Choi *et al.,* 2016; Dou & Sundar, 2016; Khandkar & Maurer, 2010). More specifically, there is a gap in the literature: very little research has been done on the impact of the stimuli (touch gestures) on the responses of users (Choi *et al.,* 2016; Sundar *et al.,* 2014). The research by Sundar *et al.* (2014), show that using a swipe-based horizontal interface on computers brings a higher level of enjoyment and engagement to the users as compared to other gestures. Based on this research, Choi *et al.* (2016) wanted to test the same effects of interaction on the users, but this time on a mobile shopping application. They found that, yet again, swiping interfaces led to greater cognitive absorption and playfulness (Choi *et al.,* 2016). Another research, based on the cognitive load experienced by the users, shows that the touch gestures in mobile applications affect the experience of the users (Beauchesne & al., 2019). These two last studies show the importance of designing good gestures for the users, since small user interface (UI) design decisions will have an impact on their experience. The latter study shows that there is an association between the stimuli (gestures and use case), the valence and the cognitive load of the users (Beauchesne & al., 2019). Thus, tasks using different gestures elicit changes in the users' experience that result in different behavioral responses. Research shows that these behavioral changes may arise from the users' internal response systems such as valence, cognitive load, and heart rate (Li, *et al*., 2012; Koo & Ju, 2010; Mehrabian and Russell, 1974).

Although these studies show that gestures had an impact on the experience of the users, they mostly measured the experience of users through explicit measuring. To our knowledge, no research has measured changes in the internal experience of the users. In other words, research showing which organisms (i.e., changes of a person's internal state) best explain the responses of the users when presented with different types of stimuli is non existent. Understanding what best explains the link between touch gestures and responses, would help researchers and designers choose the best tools to evaluate such gestures. On the one hand, gesture movement is quick and may be done unconsciously by the users and, on the other hand, gestures are only a small aspect of a user interface design. Therefore, evaluation of these gestures is difficult and must be done differently from studies on computers (Bragdon *et al.,* 2011). It may be important to discover which types of measures will best explain the responses of the users. This paper aims to propose directions and guidelines for the design and development of applications.

Building on the S-O-R model by Mehrabian and Russell (1974), the objective of this paper is to explore the underlying process between performing touch gestures and reporting a preference for one of these gestures. In other words, we investigate potential mediators of this relationship. To answer this, a one-hour lab experiment was conducted with 20 participants. Implicit measures were gathered through psychophysiological tools and explicit measures through questionnaires. Participants tested different prototypes of online banking applications with varied combinations of gestures and use cases.

Results make three contributions to the literature. First, they provide confirmation that gestures do influence the internal reactions of users and the preferences for these gestures. Second, our results show that the ease of use perceived by users has an impact on preferences and thus shows that designers and researchers should try to build gestures that would be as easy as possible for users. Third, the findings of this study may also help designers develop and create applications and interfaces using the correct gestures.

Because studies on touch gestures for smartphones are scarce, these findings contribute to the fields of human-computer interaction, user experience, and information technology.

2. Literature review and hypotheses

The S-O-R framework was initially proposed by Mehrabian and Russell (1974). The authors explain that the S-O-R framework assumes that at a particular moment in time, the environment provides a stimulus (S) that causes changes to a person's internal state (organism O), which in turn elicits a response (R) (see Figure 1; Jacoby, 2002). The organism component is defined as an individual's emotional reactions to an environment (Petrie, 1967). Mehrabian and Russell (1974) first argued that three emotional responses states would be responsible for mediating the responses of an individual. These are pleasure - displeasure, arousal - non-arousal and dominance - submissiveness. However, in another study, Russell & Pratt (1980) modified this framework by keeping only the pleasure and arousal organisms' constructs as it had been shown that the dominance-submissiveness dimension did not add anything of significance to the framework. In the user experience field, the experience of the users that translates as changes in their organisms, is defined and includes not only emotions, but beliefs, perceptions, physical, and psychological behaviours and responses (ISO 9241-220, 2016). Studies are trying to understand the role of the organisms by looking at the users' perceptions such as perceived ease of use and perceived usefulness (Choi *et al.* 2016). It was shown in the literature that those perceptions influence attitude and behavioral intentions towards technology (Agarwal & Karahanna, 2000; Moon & Kim, 2001). Thus, they are of importance when trying to understand responses to a stimulus.

Mehrabian and Russell (1974) proposed that the responses of the users to the stimulus were either an approach (e.g., willingness to stay, desire to explore, increased satisfaction or preferences) or avoidance (e.g., lower satisfaction, boredom, desire to leave). Other behavioral responses were added later, including physical approach, exploration, affiliation, performance, or other verbal and non-verbal communications of preferences (Vieira, 2013).

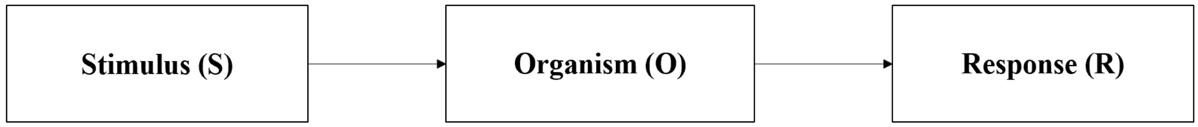


Figure 1 – SOR framework (Mehrabian and Russell, 1974)

Since its introduction, multiple research fields have used the S-O-R framework. Particularly, this framework has been much used and extended in research on marketing (Éthier *et al.,* 2006; Li *et al.,* 2012; Mummalaneni, 2005; Vieira, 2013), information technology (Gatautis, 2016; Gerlach *et al.,* 2015), and human-computer interaction (Ballantine & Fortin, 2009; Sheng & Joginapelly, 2012). In the field of marketing, the framework has been used to study the influence of the physical environment in shopping and customer service (Sherman *et al.*, 1997). Research using the S-O-R framework has now grown from the physical marketplace to the online environment (Ballantine & Fortin, 2009; Éthier *et al*., 2006; Li *et al*., 2012). Research by Ballantine & Fortin (2009) explores the level of interactivity and the amount of information provided to the users as stimuli. Similarly, research by Mummalaneni (2005), shows that the S-O-R framework can also work in an online or virtual environment. They explore the design of websites as the stimulus (Mummalaneni, 2005). Pleasure and arousal were measured through questionnaires to understand the internal reactions of the users. Finally, many behavioral shopping responses were tested (satisfaction, intention of loyalty, amount of time spent, number of items purchased and amount spent).

The S-O-R framework model has mostly been explored with emotional reactions of organisms that are explicitly measured. Self-administered questionnaires based on research are the most common way by which researchers measure the emotions experienced by participants (Li & al., 2012). However, to our knowledge, no other research has attempted to investigate the effects of automatic and unconscious (implicit) organisms' reactions on the responses. An implicit measure is defined as "a measure of attitude that does not require a self-report or conscious introspection''(Cunningham & al, 2009, p.485). The use of physiological measures such as valence and arousal is important as they can bring greater insight into the users' emotional states (Sheng & Joginapelly, 2012). Implicit approach to understand emotional and behavioral beliefs can complement an explicit approach by capturing the real-time reactions of users and by capturing unconscious and automatic processes that take place within the brain (de Guinea *et al.,* 2014).

At the top of the proposed research model (see Figure 2), three measures refer to the internal reactions of the users, i.e., the "O" dimensions: arousal, valence, and cognitive load. We compared implicit measures (i.e., arousal, valence and cognitive load) with explicit measures (i.e., ease of use) to understand the organism's reactions. We extended the classic model by adding cognitive load and ease of use in the organism dimensions to see if other reactions, such as the ones described in the International Standard 2941-220 (2016) would influence the response. In this model, the responses indicate the participants' preferences for the use of certain touch gestures in different cases. It is through a comparison of the two types of measures, that we wish to understand which variables mediate the relationship between the touch gestures and the preferences indicated by users.

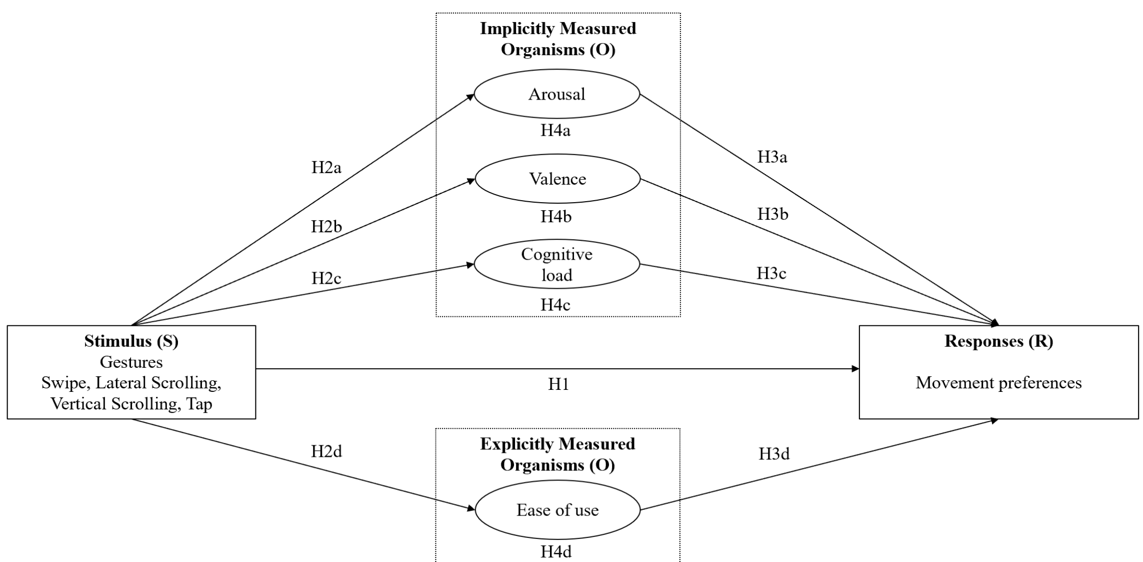


Figure 2 – Proposed research model

2.1. Stimulus (S) : Gesture

An interaction technique is defined by Jacob (1994) as “a way of using a physical input/output device to perform a generic task in a human-computer dialogue’’ (p.1); an example would be the touch gestures first introduced in small devices such as mobile phones. Over the years, several types of touch gestures have been developed (Choi *et al.*, 2016; Villamor *et al.,* 2010). Vertical scrolling is currently the most prevalent in the digital world. However swiping is the touch gesture that is considered the most intuitive as it is closely related to reading a book or other similar gestures in the non-technological world (Sundar *et al.,* 2014). Emanating from pressing buttons on a mobile phone, the “tapping’’ interaction technique is now much used in mobile interfaces (Dou & Sundar, 2016).

Based on the touch gesture reference guide of Villamor *et al*. (2010), four core gestures were chosen as stimuli in our experience (see Table 1): swiping (also known as flick), lateral scrolling (also known as drag), vertical scrolling, and tapping. Swiping is a gesture where the users quickly brush the surface with a fingertip. When swiping, the content disappears completely to give way to new information. Users can swipe backwards to reverse their action. Vertical scrolling and lateral scrolling are interactions where users move a fingertip over the surface of the screen without losing contact. Here, the users are in control and can stop wherever they want on the page. Finally, tapping is an interaction that is achieved by briefly touching the surface of the screen with a fingertip. Gestures are normally combined with visual indicators to enhance the users’ understanding (see Table 2).

Table 1 – Four core gestures tested in this research

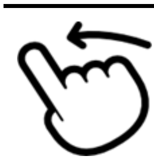
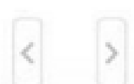
Swipe	Lateral Scrolling	Vertical Scrolling	Tap
			
Quickly brush surface with fingertip in on direction of the other	Move fingertip horizontally over surface without losing contact	Move fingertip vertically over surface without losing contact	Briefly touch the surface with the fingertip

Table 2 – Visual indicators used for each gesture

Gestures' names	Visual indicators	Description
Swiping (SW)		With Swiping, the window changes from left to right or from right to left, allowing the user to see additional information in a different window. For example, one may swipe to access new pages of informations. Each page is seen as a whole and when a user swipes, new pages are presented.
Lateral Scrolling (LS)		With Lateral Scrolling, the window moves left to right or from right to left, allowing the user to see additional information. For example, one may need to scroll right to continue reading a document or see other parts of the page. Pages here are not presented as a whole.
Vertical Scrolling (VS)		With Vertical Scrolling, the window moves up or down, allowing the user to see additional information. For example, one may need to scroll down to continue reading a document or see other parts of the page. Pages here are not presented as a whole.
Tapping (TA)		With Tapping, the window changes from left to right or from right to left, allowing the user to see additional information in a different window. For example, one may tap a button to access new pages of information. Each page is seen as a whole and when a user taps, new pages are presented.

2.2. Response (R) : Movement preference

The S-O-R model suggests that before analyzing anything, there is a need to establish a relation between the stimulus and the response (Jacoby, 2002). In this study, we are trying to predict users' preferences for different gestures. In recent research, touch gestures have been proven to impact cognitive absorption, enjoyment, sense of control, user engagement, and re-use intention (Choi *et al.*, 2016). When testing whether participants preferred one or two-hand gestures, findings suggest that users prefer one-hand gestures (Wobbrock *et al.,* 2009). This study shows that even simple interactions like gestures may have an impact on the preferences of the users. Furthermore, a study by Park & Han (2014) postulates that some gestures are more appropriate than others for different tasks. Users could then prefer some gestures that may seem more appropriate for certain tasks than for others. Other results confirmed this and suggested that designers should take into account the preferences of the users for some gestures (Koskinen *et al.,* 2008). This implies that such gestures can have an impact on the preferences indicated by users. This led us to formulate the following hypothesis:

H1: The type of gestures influences preferences for these gestures.

2.3. Organism (O)

Three components are usually observed when studying emotions: arousal, valence and dominance (Warriner *et al.*, 2013). As suggested by Russell & Pratt (1980), only the arousal and valence components will be used here. Arousal is a state that goes from quietness to arousal; it can be defined as a physiological response to an input (Russell *et al.,* 1989). These input variables such as tasks can vary in timing or in complexity and can affect changes in intensity which users might not be used to (Pribram & McGuinness, 1975). For example, different tasks might bring different internal reactions to users because some tasks could be easier than others or more familiar. Different types of gestures can thus bring different levels of complexity and bring changes to the user's arousal. One of the ways to collect this data is with psychophysiological measures (i.e., blood pressure, respiration rate, heart rate etc.) that measure arousal through reactions of the sympathetic nervous system. For example, secretion of sweat on the palm of a user's non-dominant hand is an effective way to measure arousal (Boucsein, 2012). Arousal can also be measured via self-reported measures where users answer questions on how they feel.

The second common component in the study of emotions is the emotional valence (Warriner *et al.*, 2013), going from unpleasant to pleasant. Arousal and valence, when presented together can bring interesting insights because these measures complement each other well. Indeed, they bring together different emotional dimensions; for example, a user that exhibits a positive valence and a positive arousal will be closer to the excitement emotion. Whereas low arousal and low valence will generate bored or depressed emotions in a user (Russell & Pratt, 1980). So, understanding the level of arousal and valence can help designers or professionals better understand the reactions of their users. Grime *et al.* (2013) stress that arousal and valence do play an important role in understanding the users' interaction with technology. The authors show that different stimuli with different levels of arousal and valence impacted the interactions of users with a computer. Indeed, they presented different levels of arousal and valence to users by using the International Affective Picture System (IAPS) which elicits a specific state of arousal and valence in the users and saw that these different levels had an impact on motor control such as mouse distance, speed and trajectory movement (Grime *et al.,* 2013). Other research studying user experience on websites found that a difference in stimuli like the aesthetics of a website and the perceived usability significantly influenced valence (Seo *et al.,* 2015). This research examined users' perceptions and emotional responses such as valence, arousal, and engagement on different websites and found that differences in their perception can be connected to their valence and engagement (Seo *et al.,* 2015). Different types of gestures can be perceived differently and can thus influence arousal and valence. This leads to the following hypotheses:

H2a: The type of gestures influences user's arousal.

H2b: The type of gestures influences user's valence.

Cognitive load is yet another component used to measure the user's experience while performing a given task. Cognitive load can be defined as "a multidimensional construct representing the load that performing a particular task imposes on the learner's cognitive system" (Paas *et al.*, 2003, p.64). Low cognitive load correlates with low cognitive demand on the learner's cognitive system; long or highly complex tasks constitute a higher cognitive demand (Chen *et al.*, 2012). A study by Choi *et al.* (2016) suggests that changes in the type of gestures presented in an interface impact the levels of cognitive absorption. The authors compared swiping gestures with scroll-based gestures and concluded that the level of perceived cognitive absorption was greater with swiping. Again, another study tested different types of mobile touch-screen interactions and concluded that there were significant differences in the demands for the users' attention (Bragdon *et al.,* 2011). This suggests that different types of gestures could have an impact on the users' cognitive load. Thus, we posit the following hypothesis:

H2c: The type of gestures influences user's cognitive load.

Finally, perceived ease of use is a construct that has been used in many studies and is defined as a "fundamental determinant of user acceptance of information technology" (Adams *et al.*, 1992, p.227). Gestures were shown to have an impact on the perceived ease of use of the tasks. A study by Wobbrock *et al.* (2009) asked participants to measure if a gesture was easy to perform and found significant differences between certain types of gestures. Another study showed that some gestures could be done easily, without the participant looking at his hand, while other gestures did not elicit the same performance by the participants (Bragdon *et al.*, 2011). Additional research supported that the easiness of the tasks was a good way to measure the efficiency of touch gestures (Koskinen *et al.*, 2008; Kühnel *et al.*, 2011). The impact of gestures shows up on implicit measures as well as on self-reported ones. Research also observe that different gestures may present different levels of difficulty. This leads to the following hypothesis:

H2d: The type of gestures influences user's perceived ease of use.

Research by Menon & Kahn (2002) found that the levels of arousal and valence impacted users' behaviors. This research tested the impact of online atmospherics on the degree of valence and arousal. The authors showed that if the users' first encounter with the website brought them more pleasure, then their shopping behaviors would be positively impacted; users would then take part in more arousing activities (i.e., higher responses to promotions, more explorations, etc.). Arousal and valence are therefore two measures that could impact responses. Other research showed that arousal would impact the support for a cause/charity, and thus once again showed that arousal can impact users decisions (Gault & Sabini, 2000). Other studies have demonstrated that the arousal level expectations are a key variable in research on arousal. Indeed, users' ideal level of arousal will depend on the time and the place of the experience (Wirtz *et al.,* 2007). In other words, if someone goes to the cinema to see a thriller, they will not expect the same level of arousal as if they were going to the bank. So, in utilitarian tasks, a neutral level of arousal might be best associated with the user's preferences. Indeed, when using a utilitarian application such as a banking application, we hypothesized that users would expect a neutral level of arousal: they probably will not expect to be happy and excited and will not expect to be angry either. So, if their level of expected arousal is not met during an interaction with a characteristic (e.g. type of gesture), users' preferences would be impacted: users would prefer characteristics that do follow their expected level of arousal. Additionally, research on the impact of emotional valence postulates that negative and positive emotions play important roles in stages of decision making such as evaluating and choosing something (Leone *et al.,* 2005). As valence and arousal seem to impact decisions and reactions of users towards product and experience, it led us to hypothesize that these variables would impact the preferences of different types of gestures:

H3a: Touch gesture preferences are influenced by arousal.

H3b: Touch gesture preferences are influenced by valence.

One research also shows that preferences are influenced by the users' goal, cognitive constraints, and experience (Warren, McGraw, & Van Boven, 2011). This study states that changes in cognitive load will disrupt the way users make their decisions. Other studies argue that decision-making is not only influenced by the emotional system but also by the cognitive one. They thus provide a more analytical and logical side of decision making (Bechara *et al.*, 2000; Lee *et al.,* 2009). Research also indicates that a reduced cognitive load can free up cognitive resources and help users process the information presented to them (Ariely, 2000). This implies that the level of cognitive load can change the way a user processes information. A study on the cognitive load in e-commerce applications first assumes that lower cognitive load will increase users' satisfaction with their shopping experience. It then argues that most usability guidelines already suggest that designers reduce cognitive load of their applications; indeed this helps users' make decisions and comparisons (Schmutz *et al.,* 2009). Thus, we posit the following hypothesis:

H3c: Touch gesture preferences are influenced by cognitive load.

A study by Yoon *et al.* (2015) explored measures of perception of complexity and showed that such measures were in fact related to both behavioral and implicit ones. The study also showed that explicit measures are appropriate tools to predict performance. Another study showed that usability attributes such as the ease of use of an application are a good way to measure the quality of applications (Zhang & Adipat, 2005). Furthermore, the complexity of small design details in interfaces, such as the choice of gestures, can affect user perception of an application. Indeed, it was shown in a study that the menu structure and the navigational keys affected the perceived ease of use as well as the performance of the participants (Ziefle, 2002). The perceived ease of use was also shown to impact the attitudes toward e-commerce platforms (Childers *et al.*, 2001). Furthermore, Koskinen *et al.* (2008) argue that simple hand gestures are preferred over more complex hand-gestures. Because the perceived ease of use "plays a critical role in predicting and determining a user's decision to use an information system" (Hackbarth *et al.,* 2003, p.221), we tested not only explicit measures but also implicit ones. This leads to the following hypothesis:

H3d: Touch gesture preferences are influenced by perceived ease of use.

2.4. Mediation

As explained by Baron & Kenny (1986), "S-O-R model [...], is the most generic formulation of a mediation hypothesis. [The idea is] that the effects of stimuli on behavior are mediated by various transformation processes internal to the organism" (p.1176). Hayes (2013) defines mediation as a "statistical method used to evaluate evidence from studies designed to test hypotheses about how some causal antecedent variable X transmits its effect on a consequent variable Y'' (p.78).

The mediating role of arousal and valence was first introduced through the S-O-R framework of Mehrabian and Russell (1974). It was then used in multiple fields. Consumer responses studies also showed that arousal and pleasure had indirect effects of mediation on the viewing time of advertising (Olney *et al.*, 1991). Research by Sherman *et al.* (1997) argues that the arousal and the valence mediated the relationship between stimuli of a store, such as the design and the ambiance, and the responses of the users which in this case was whether the shopper liked the store environment. This study shows that once more arousal and valence tend to mediate the relationship between store factors and users' responses to the retail environment. Other studies on performance showed that the level of arousal mediated the association between listening to music and performing in a test (Jones *et al.,* 2006). Thus, we propose the following hypotheses for our model:

H4a: Arousal mediates the effect between the gestures and the preferences for these gestures.

H4b: Valence mediates the effect between the gestures and the preferences for these gestures.

A research by Leutner *et al*. (2009) shows that cognitive load mediates the relationship between a stimulus of reading a text on the comprehension of that text. In advertisement marketing, research also showed that cognitive responses, such as cognitive load, mediates the relationship between the messages advertised and the attitudinal message acceptance (Wright, 1973). These studies show that cognitive load tends to mediate the relationship of a task and responses. The following hypothesis is proposed:

H4c: Cognitive load mediates the effect between the gestures and the preferences for these gestures.

Research on comparing gestures designed by experts with some designed by end-users showed that preferences varied with the different types of gestures presented. The authors hypothesized that these differences in preference arose from the complexity of the gestures (Morris *et al.*, 2010). Based on this research, it could be hypothesized that the gestures could play a mediating role in the relationship between the touch gestures and the preferences of the users. Another research also shows that the perceived ease of use mediates the relationship between external variables on usage behaviors, such as attitude, intention to use and the actual use (Burton-Jones & Hubona, 2006). Thus, we posit the following hypothesis on the mediating effects that ease of use can have in our context:

H4d: Reported ease of use mediates the effect between the gestures and the preferences for these gestures.

3. Methodology

3.1. Design and Procedure

To test our hypotheses, a 5 × 4 within-subject full factorial design experiment was conducted within an instrumental context (online banking) with two factors (gestures and use cases). Participants completed all twenty (20) trials on mobile applications prototypes in a randomized order. The use case factor was added to the design to ensure that the gestures could be tested in different contexts. In other words, the prototypes presented different use cases with each gesture to ensure that users experienced gestures in multiple contexts. Because the goal of this paper is to understand the impact of gestures, the average reactions of all use cases for one gesture are computed and presented later in this paper. These use cases can be experienced in current banking applications. We based the five use cases on banking applications as we wished to propose utilitarian tasks[2]. This research was approved by our institution's Research Ethics Committee.

We argue, in this paper, that the banking context is an appropriate context to test applications. Therefore, utilitarian applications, defined as goal-oriented applications, offer an appropriate context in which to test touch gestures. Mobile banking continues to grow every year and according to a survey done in 2018 by Statista, close to 70% of millennials use online banking applications, while 24% of baby boomers also use their mobile phones to make transactions on their bank account (Statista, 2018). Utilitarian

[2] To ensure that there was no effect brought by the use cases, we tested the use cases as a moderator in the model and no significant difference could be observed.

banking applications are indeed common and therefore a good context in which to test utilitarian applications.

The test was conducted in a laboratory setting where users were in one room and observers were in the adjacent room behind a one-way mirror. This experimental set-up enabled researchers to observe the behaviors of the participants during the interaction with the prototypes. Cameras were set-up in the participants' room to record the test, thus enabling researchers to access the data even after the test had ended. Participants then performed the tasks in the test room while the researchers observed their behaviors from the control room (see Figure 3).

Figure 3 – Usability lab control and test room

A research assistant installed the electrodes for electrodermal measurement on their palm. Participants were invited to sit in a desk chair facing a phone that was installed on a desk mount. The research assistant made sure to place the participants in the right position in front of the phone, so their face and eyes could be well captured with a webcam and with Tobii X-60 eye-tracker (see Figure 4).

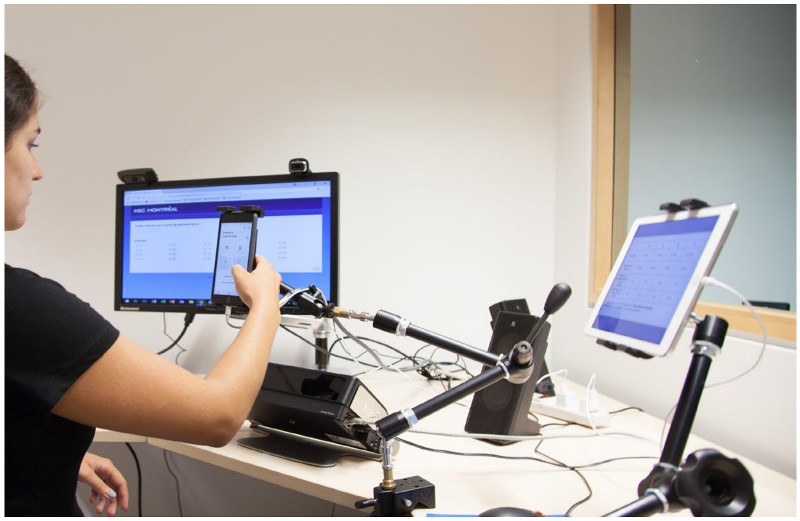


Figure 4 – Experimental set-up

The participants received on-screen desktop instructions on the procedure of the test. Complementary information necessary to complete certain tasks were presented on an iPad. Before beginning the tasks, a calibration for Tobii X-60 pro was conducted where the participants were asked to direct their gaze on certain parts of the phone screen. After that, a baseline was recorded for the physiological signals during a 90 seconds rest period where participants looked at colored squares and were asked to count the number of white squares (Piferi *et al.,* 2000). Subsequently, participants carried out the 20 tasks (e.g., filling out a form) on the iPhone and filled out a short questionnaire on the computer between tasks where they were asked to assess their perceived ease of use of the gestures (see section 4.5).

During the tasks, the researchers observed the different attempts made by the participants for each task. Performing the 20 tasks would take about 30 minutes. Afterwards, the research assistant would remove the electrodes of the participants who would then complete the experiment by signing a compensation form.

3.2. Stimuli

High fidelity prototypes made on Atomic (Wellington, New-Zealand) were created based on different use cases in the banking context. These utilitarian prototypes allowed the participants to test different use cases while employing different gestures (see Figure 5). So, touch gestures were combined with use cases. These use cases corresponded to five different purposes: filling out a form, exploring a tutorial, browsing through an application menu, reading a text and using a dashboard. These five use cases were chosen based on a benchmark done on different banking applications.

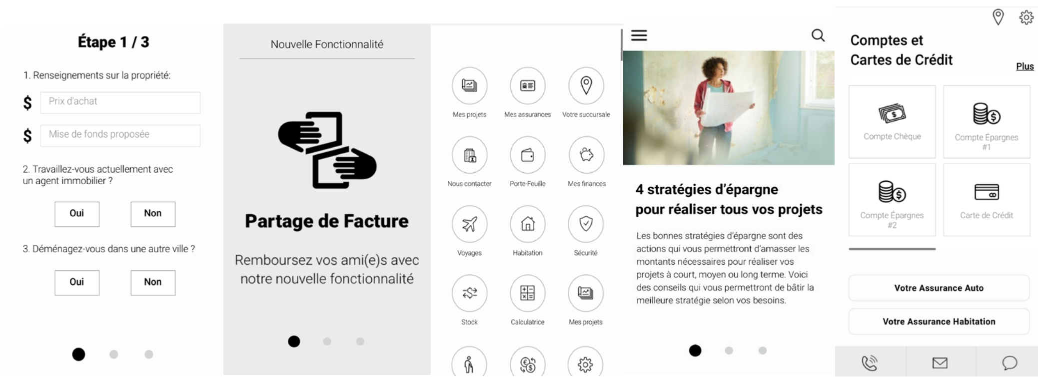


Figure 5 – Images of prototypes presented to the participants[3]

Altogether a twenty (20) task matrix was created to test 4 different gestures with 5 different use cases. The prototypes were composed of two different sections. First, a starting page where the title of the page and the task were presented to the participants (see Figure 6). This first page had a "start'' button from which the participants could access the second part of the prototype. This second part was where the participants could actually perform the task. To limit the variations of cognitive load, simple tasks were created and associated with each use case (Mayer & Chandler, 2001) (see Table 3). The stimuli were presented on an iPhone 6 Plus (Cupertino, CA).

[3] The information in the prototypes was presented in French because the study was performed with a French-speaking sample.

Figure 6 – Page presenting the tasks

Table 3 – Description of tasks for each use case

Use Case	Example of title page	Tasks
Filling out a form	Application for pre-approval of mortgage loan	Fill out the next form and please refer to complementary information on the iPad
Exploring a tutorial	Discover the new features of your banking application	Thank you for reading the following tutorial
Browsing through an application	Discover your banking universe	Access the " (name of application) " application
Reading a text	Four savings strategies to carry out all your projects	Please read and take note of the information at your disposal
Using a dashboard	Discover the homepage of your banking application	Find how you can contact a banking advisor

3.3. Participants

Twenty (20) subjects participated in this experiment. All participants performed the same 20 tasks in a random order to limit the effects of learning the gestures or the use cases. The experimental group was composed of 11 women (*M* age = 30 years, *SD* = 10) and 9 men (*M* age = 27 years, *SD* = 7). Each participant read and signed a consent form where all the tools used during the test were explained. Participants were informed that they could leave the test anytime during the experiment for any reason.

Each participant received a small monetary compensation after the experiment. Participants were also pre-screened for skin allergies, laser vision correction, reading glasses for the computer, astigmatism, epilepsy and neurological or psychiatric diagnoses. Finally, participants needed to be 18 years old or older.

4. Data acquisition and analysis

4.1. Synchronization of apparatus

Multiple tools and equipment were used during this study to measure implicit reactions of the participants. They include an eye-tracker, a facial recognition software and equipment to measure the electrodermal activity on the palm. All of the systems were connected via the local lab network. To synchronized all of these tools together, a data synchronization software called Observer XT (Noldus, Wageningen Netherlands) was used. This software synchronizes the event markers and the recordings of all the data coming from these different softwares. To do so, each event (e.g., beginning of Task 1, end of Task 1, beginning of Task 2, etc.) was marked in Tobii Studio, the eye tracker software. The guidelines for synchronization were provided by Léger *et al.* (2014).

4.2. Valence

Emotional valence can be measured retroactively through self-reported questionnaires as well as continuously measured in real time with tools such as FaceReader (Benta *et al.*, 2009). For this study, the emotional valence was measured throughout the experiment in real time in order to determine its impact on preferences for certain gestures, and also to determine the reciprocal impact of the gestures on the valence. The emotional valence was measured with a facial expression recognition software to analyze the participants' emotions: This tool is called FaceReader™ (Noldus, Wageningen, Netherlands). Another tool, MediaRecorder (Noldus, Wageningen, Netherlands) was used with a webcam to record images of the participants. These recordings were then uploaded and processed automatically in FaceReader software to provide emotional valence. FaceReader measures six basic emotions based on discrete emotion theory: Anger, disgust, fear, happiness, sadness and surprise (Ekman, 1993). The valence then measured by subtracting the intensity of negative emotions from the intensity of positive emotion (Valence = Happy - (Sad + Angry + Scared + Disgusted) (Loijens & Krips, 2018). With a value from 0 to 1, when all of the emotions are added together, the results would be close to one, making it easy to compare the participants emotions. When the valence is negative, the negative emotions outperform the positive emotions. In a utilitarian task, a neutral valence is good and normal (Zimmermann, 2008). Automatic real-time emotional expression recognition has been used by many researchers to express the real-time emotions of participants (Bartlett *et al.,* 2004; Benta *et al.,* 2009; Terzis *et al.,* 2010)

4.3. Electrodermal activity

Arousal can be measured with the electrodermal activity (EDA). Over the years, arousal has mostly been measured with self-reported scales (Russell *et al.*, 1989). However, using data collection tools such as the EDA is another way to measure this variable continuously throughout the test. Studies in multiple areas have used EDA as a measure for arousal, for example, when measuring stress in autistic children (Levine *et al.*, 2012). Other studies have measured the intensity of arousal in hyperactive children (Lazzaro *et al.*, 1999).

The skin conductance was recorded using AcqKnowledge software (Biopac, Goleta, USA). Two Biopac disposable electrodes were attached to the palm of the participants' non-dominant hand. These electrodes were affixed to the skin at the very beginning of the test to establish a small delay before the start of the task. The electrodes were connected to the Biopac MP150 data acquisition systems. The skin conductance is measured by applying a small voltage across the two disposable electrodes. The AcqKnowledge fully automated suite application uses, as timing marks, the event marker from Tobii Studio (see section 4.1) and measures the resulting current that flows between the electrodes. It is the amplitude of the current that is proportional to the skin conductance and it is measured in microsiemens (□S) (www.biopac.com).

4.4. Pupil diameter

Cognitive load can be measured through explicit questionnaires where participants are asked to explain their perception of a variable (O'Donnell & Eggemeier, 1986). However, as explained by Chen *et al.* (2012), these types of measures do interrupt the flow of the tasks and can contribute to an overload of information for the user. By monitoring the participants' cognitive load, the different levels of complexity would appear. Remote eye-tracking has been recognized by multiple studies as being a good option to measure the cognitive load of the users (Klingner *et al.,* 2008; Palinko *et al.,* 2010; Szulewski *et al.,* 2015)

The pupil diameter was recorded at 60 Hz sampling rate (Laeng *et al.,* 2012). Tobii Pro X-60 (Stockholm, Sweden) and Tobii Studio were used to record the experience. The eye-tracker measures the pupil size by measuring the diameter of the pupil and multiplying it with a scaling factor (www.tobiipro.com).

4.5. Explicit measures

After each task, participants were asked to evaluate the ease of use of the movements during the tasks, using a question scaled on seven point such as proposed by other studies on the evaluation of gestures (Choi *et al.*, 2016; Wobbrock *et al.*, 2009). The item was graded from *I strongly disagree* (1) to *I totally agree* (7).

Finally, in order to better understand the implications of choosing different touch gestures when designing an application, we asked participants which touch gestures they preferred for the five use cases. As proposed by Vieira (2013), the responses can include physical approach, exploration, affiliation, performance or other verbal and non-verbal communication of preferences. In this case, it is through an online five (5) item questionnaire that the participants communicated their preferences for each different type of use case. For example, they chose which gestures they preferred when they were presented the *reading a text* use case. The mean gesture preferences are later computed for all participants and for every use case. A value between 0 and 1 is presented in the results section.

Table 4 – Operationalization of the research variables

Research variables	Moment of measurement	Definition	Measure
Mean valence for each gesture for 20 participants	During the tasks	Users' intensity of positive emotions subtracted by the intensity of negative emotions	Facial expression recognition software FaceReader TM (Noldus, Wageningen, Netherlands)
Mean arousal for each gesture for 20 participants	During the tasks	Electrodermal activity of users' palm	Electrodermal amplitude with the AcqKnowledge software (BIOPAC, Goleta, USA)
Mean cognitive load for each gesture for 20 participants	During the tasks	Users' pupil diameter	Pupil diameter with Tobii Pro X-60 (Stockholm, Sweden)
Mean ease of use for each gesture for 20 participants	Right after a task	Users' evaluation of the gestures (Perceived)	Question evaluating the ease of use of the gesture graded from *I strongly disagree* (1) to *I totally agree* (7): The gesture was easy to use (Choi *et al.*, 2016; Wobbrock *et al.*, 2009)
Mean of preferences for each use case for 20 participants (value between 0 and 1)	At the end of all the tasks	Users' preferences at the end of the tasks	Five (5) items questionnaire, one for each use case: One (1) gesture preference for each use case was selected by users

4.6. Statistical analysis

In order to analyze and test if the implicit or explicit measures had a mediation effect on the relationship between the different gestures and responses, we analyzed the data using the statistical software Stata V.14 (College Station, USA).

To compare the data across participants, some manipulations were done to the raw data. First, we calculated the average baseline for each implicit measure (valence, arousal and cognitive load) per subject. This baseline was measured at the beginning of the test where physiological signals were recorded during a 90 seconds rest period where participants looked at colored squares and were asked to count the number of white squares (Piferi *et al.,* 2000). For each observation, we computed the average of the difference between the value of the data and the value of the baseline. In addition, for each task and for every subject, the averages of the valence, arousal, and cognitive load were also computed. To analyze the data for each gesture, the tasks and subjects were combined in order to be able to compare the gestures with one another. In other words, the tasks were grouped per gesture. For example, for the Swipe gesture, the data of the five (5) tasks that presented the Swipe were combined: filling out a form, exploring a tutorial, browsing through an application menu, reading a text and using a dashboard.

There were two types of dependent variables. Continuous variables were the arousal, valence, cognitive load, and ease of use. The preferences of the participants for the gestures, on the other hand, were binary variables. Thus, two types of regressions were computed. To compute the former variables, a multiple linear regression was used. The latter were computed with a logistic regression.

The multiple linear regression first used the touch gesture Tap as a reference. The regression was again computed with other gestures as references to ensure that all combinations of gestures would be available for analysis. Through these regressions, the unstandardized coefficients are presented in the results (section 5.2) with their p-values (level of significance for the bilateral test).[4]

A correction on the standard error of the coefficient by the cluster ID was applied. In other words, to correct our metrics due to the effects of repeated measures by subject, a statistical regression was used with the VCE repetition cluster (Wooldridge, 2010).

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[4] We showed the non standardized coefficient for interpretation. Dividing those coefficients by the standard error, gives us a standardized measure allowing comparison.

For the mediation analysis, because our measures were repeated (20 tasks for each subject) the Preacher and Hayes (2004) methodology could not be used to analyze the mediation of the model. Using the methodology of Baron & Kenny (1986), four steps were analyzed to establish the mediation. The first condition is to show that the causal variable (stimulus) is correlated with the outcome (response). The second condition needs to show that the stimulus is correlated with the mediator variable (organism). The third step should show that the organisms affect the response. The fourth step is to show that if the organisms mediate the relationship between stimulus and responses, the direct relationship between S and R should become zero. If not, a partial mediation could be indicated. Finally, the indirect effects are calculated based on the same methodology proposed by Baron and Kenny (1986): "The indirect effect equals the reduction of the effect of the causal variable on the outcome or the indirect effect equals to total effect minus direct effect" (Kenny, 2018, p.4).

5. Results

5.1. Descriptive statistics

Table 5 presents the descriptive statistics of the four variables tested to understand the reactions of the users. The average for all the observations of the arousal (n=400) is 0.041 (SD = 0.071) with a minimum of -0.172 and a maximum of 0.305. The average emotional valence for all the observations (n=400) is -0.116 (SD = 0.229) with a minimum of -0.703 and a maximum of 0.493. It is interesting to note here that the average emotional valence is negative. This means that the negative emotions are on average stronger than the most positive emotions (Loijens & Krips, 2018). The average of the cognitive load captured all of the observations (n=400) is 0.017 (SD = 0.243) with a minimum of -0.525 and a maximum of 0.907. A negative cognitive load means that the average cognitive load was smaller than the one measured during the baseline. Now, for the explicit measures, the average of the perceived ease of use for all the tasks (n=400) is 5.750 (SD = 1.417) with a minimum of 1 and a maximum of 7.

Table 5 – Descriptive statistics

Variable	Mean	Standard Deviation	Min	Max
Arousal	0.041	0.071	-0.172	0.305
Valence	-0.116	0.229	-0.703	0.493
Cognitive Load	0.017	0.243	-0.525	0.907
Ease of Use	5.750	1.417	1	7

Note: N = 400

5.2. Hypothesis testing

In the research model, Hypothesis 1 suggests that the type of gestures would influence the preferences for these gestures. This hypothesis was tested using a logistic regression and this first hypothesis was supported. Indeed, the touch gestures in the tasks do influence the preferences of these gestures significantly. There were significant differences between these combinations of gestures: Swipe and Lateral scrolling, Swipe and Vertical Scrolling, Swipe and Tap, and Lateral Scrolling and Vertical Scrolling (see Table 6). The preference was higher for the Swipe compared to all three other gestures, and the Vertical Scrolling was preferred to the Lateral Scrolling.

Table 6 – Logistic regression coefficients (P-Values) of combinations for the impact of gestures on preferences (H1)

Gestures	Swipe	Lateral Scrolling	Vertical Scrolling	Tap
Swipe				
Lateral Scrolling	-1.929*** (0.007)			
Vertical Scrolling	-0.909* (0.075)	1.020* (0.077)		
Tap	0.943* (0.086)	-0.986 (0.133)	0.0343 (0.947)	
Preference Mean	0.43	0.10	0.23	0.23

Note: N=20; **** = p<0.001, *** = p<0.01, ** = p<0.05, *=p<0.1

For the implicit measures, there is a significant difference of arousal between Swipe and Vertical Scrolling where the arousal is greater for the Swipe, and between Tap and Vertical Scrolling where the Tap had higher arousal (see Table 7). This means that H2a, that suggest that the type of gestures influences users' arousal, is supported. The gestures did influence the arousal of the participants.

Table 7 – Multiple linear regression coefficients (P-Values) of combinations for the impact of gestures on arousal (H2a)

Gestures	Swipe	Lateral Scrolling	Vertical Scrolling	Tap
Swipe				
Lateral Scrolling	-0.312 (0.188)			
Vertical Scrolling	-0.329* (0.075)	-0.017 (0.930)		
Tap	0.039 (0.809)	-0.289 (0.188)	-0.289* (0.062)	
Arousal Mean	1.87	1.59	1.58	1.85

Note: N=20; **** = $p<0.001$, *** = $p<0.01$, ** = $p<0.05$, *=$p<0.1$

Hypothesis H2b suggests that a relationship exists between the type of gestures and the valence. There is no significant difference between combinations of gestures for the valence. Thus, H2b is not supported: the type of gestures do not impact the participants' valence.

Furthermore, H2c suggests that the type of gestures influenced the user's cognitive load. However, the logistic regression did not show any significant impact of the type of gestures on the participants' cognitive load. We then stopped our analysis of the mediation here for the valence and the cognitive load, because the second condition of the analysis was not met. Therefore, the H3b and H3c hypotheses are not supported: the valence and the cognitive load do not significantly impact the preferences.

The same conclusion goes for Hypothesis H3a, which suggests that touch gesture preferences would be influenced by valence: no significant differences were observed between valence and the preferences for the movements. This concludes automatically that arousal, valence, and cognitive load do not mediate the relationship between gestures and responses. Consequently, Hypotheses H4a, H4b and H4c are not supported.

For the explicit measures, Hypothesis H2d that states that the types of gestures would influence users' perceived ease of use, is supported. Indeed, we see several significant differences in the relationships between different touch gestures and the ease of use (see Table 8). The Swipe, Tap, and Vertical Scrolling are significantly easier to use compared to the Lateral Scrolling.

Table 8 – Multiple linear regression coefficients (P-Values) of combinations for the impact of gestures on ease of use (H2d)

Gestures	Swipe	Lateral Scrolling	Vertical Scrolling	Tap
Swipe				
Lateral Scrolling	-0.488** (0.012)			
Vertical Scrolling	0.212 (0.171)	0.700*** (0.006)		
Tap	0.240 (0.109)	0.728*** (0.005)	0.028 (0.832)	
Ease of use Mean	5.76	5.27	5.97	6.00

Note: N=20 ; **** = p<0.001, *** = p<0.01, ** = p<0.05, *=p<0.1

Hypothesis 3d suggests that touch gestures preferences are influenced by perceived ease of use. The logistic regression shows that ease of use (coefficient = 0.2282, p-value = 0.0012) influences the preferences for the gestures. Thus, H3d is supported.

Finally, Hypothesis H4d suggests that reported ease of use mediates the effect between gestures and preferences for these gestures. Mediation analyses were conducted using the ease of use as mediators and using the preferences as the dependent variable. For the organisms to completely mediate the X-Y relationship, the effect of the stimulus on the responses, when factoring in organisms, should be zero (0). Here the effect is significantly different from zero (see Table 9). Indeed, when comparing the direct and indirect relationships between types of gestures and preferences for these gestures, one observes that the relationships are very similar. This means that the organisms play no significant role in the X-Y relationship and thus the possibility of a mediation is eliminated. H4d is thus not supported.

Table 9 – Logistic regression coefficients (P-Values) of the effect between the gestures and the preferences mediated by the ease of use (H4d)

Gestures	Swipe	Lateral Scrolling	Vertical Scrolling	Tap
Swipe				
Lateral Scrolling	-1.850*** (0.010)			
Vertical Scrolling	0.954* (0.060)	-0.896 (0.116)		
Tap	-0.997* (0.074)	0.853 (0.184)	-0.044 (0.932)	

Note: N=20 ; **** = p<0.001, *** = p<0.01, ** = p<0.05, *=p<0.1

Table 10 presents a summary of our tested hypotheses. Figure 7 presents a review of the proposed research model where the dotted lines present the hypotheses that are not supported in the model, and full lines and stars (*) besides the hypotheses numbers present the hypotheses that are supported in the model.

Table 10 – Summary of conclusions

Hypothesis	Description	Conclusion
H1	The type of gestures influences preferences for these gestures.	Supported
H2a	The type of gestures influences user's arousal.	Supported
H2b	The type of gestures influences user's valence.	Not Supported
H2c	The type of gestures influences user's cognitive load.	Not Supported
H2d	The type of gestures influences user's perceived ease of use.	Supported
H3a	Touch gesture preferences are influenced by arousal.	Not Supported
H3b	Touch gesture preferences are influenced by valence.	Not Supported
H3c	Touch gesture preferences are influenced by cognitive load.	Not Supported
H3d	Touch gesture preferences are influenced by perceived ease of use.	Supported
H4a	Arousal mediates the effect between the gestures and the preferences for these gestures.	Not Supported
H4b	Valence mediates the effect between the gestures and the preferences for these gestures.	Not Supported
H4c	Cognitive load mediates the effect between the gestures and the preferences for these gestures.	Not Supported
H4d	Reported ease of use mediates the effect between the gestures and the preferences for these gestures.	Not Supported

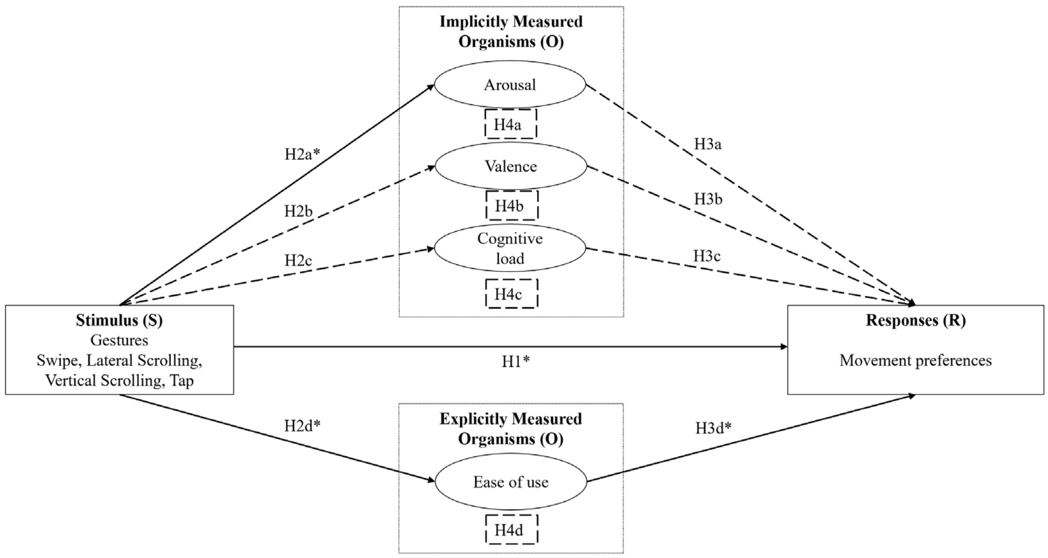

Figure 7 – Proposed research model with conclusions

6. Discussion

The aim of this study was to evaluate the mediating effects of different organisms based on the S-O-R model. The results of this study indicate that neither the implicit measures (arousal, valence, or cognitive load), nor the explicit measure (ease of use) mediate between the touch gestures presented to the participants and their preferences. However, it is interesting to observe that despite the fact that the organisms do not play a role of mediator as such, they still do play an important role. Indeed, there were significant differences between the relationships described in our research model. In other words, the types of gestures did significantly influence the user's arousal (H2a), and the user's perceived ease of use (H2d). Also, the gestures as such significantly impacted the preferences for those gestures (H1). Finally, ease of use plays a significant role in determining the preferences for the gestures (H3d).

These findings have theoretical implications for the understanding of the role of touch gestures in the experience of the users and for measuring such gestures. Investigating the reactions and changes brought by small details of design will provide a comprehensive understanding of the impact of such gestures in the organism. Such understanding is lacking in the current literature (Dou & Sundar, 2016). Our model, however, does not completely correspond with the mediation aspect of the S-O-R framework in the literature. Indeed, this framework has mostly been studied in contexts where the stimulus had a big impact in the environment studied. Studies used anger and anxiety as a stimulus (Russell & Mehrabian, 1974). Other studies, mostly in marketing, have tested responses such as purchasing intentions (Sheng *et al.*, 2012). Literature using the S-O-R framework has many studies on consumers' habits as the response variable (Li *et al.*, 2012). However, to our knowledge, no study tested the relationship between touch gestures and preferences for these gestures, as we have done in our research. The relationship between those two factors might be too correlated, so that the organisms might not play a significant role in explaining the responses.

Our results show that there is no relationship between the organisms and the preferences. This lack of relationship could come from the habits of users. Indeed, as mentioned by

Dou & Sundar (2016), newer gestures could be perceived differently than gestures such as tapping that were first introduced with computers. In other words, the novelty of a gesture could impact the preferences by influencing the users' organisms whereas a familiar gesture would not. Another study shows that the level of habits with a technology should impact the level of intention towards this technology (de Guinea & Markus, 2009).This suggests that preferences might not influence implicitly measured organisms such as cognitive load, arousal and valence but might influence other factors not accounted for in this research. For example, Bragdon *et al.* (2011), hypothesized that prior experience might influence the users' performance and perception. This research studied small design aspects of mobile applications and their interactions with the gestures. Such interactions may be too small to create a strong enough change in the organisms to mediate the relationship with the responses.

However, the results presented in this research do follow some assumptions of the S-O-R framework. Results suggest that touch gestures do impact arousal and valence. Our results thus support the findings by Grimes *et al.* (2013) where level of arousal and valence change when different stimuli are presented to users. Our results go even further by introducing implicitly measured valence and arousal, showing that gestures do influence the arousal and valence of users in real time while using different types of gestures. Our research also shows that although there is no mediation effect in the relationship between touch gestures and preferences, the direct relationship (touch gestures influencing the preferences) exists. Finally, our model shows that there is a relationship between touch gestures and perceived ease of use, and between perceived ease of use and preferences. Once more, it shows the importance of studying even the smallest details in the HCI field of study.

This study also has implications for designers and product owners. Table 11 presents which touch gestures were preferred for each use case. Because the results of this research show that there is no mediation effect of the organisms, the direct responses (i.e., preferences of gestures) is presented for each use case. For use cases, filling out a form, exploring a tutorial, browsing through an application and using a dashboard, the Swipe gesture was preferred over other gestures. The participants however preferred Vertical

Scrolling for the task of reading a text. These results mostly follow findings by Choi *et al*. (2016) and Sundar *et al.* (2014) that also demonstrated better results from swiping interfaces than scrolling interfaces.

Table 11 – Preferred gestures for each use case

Use Case	Preferences
Filling out a form	Swipe
Exploring a tutorial	Swipe
Browsing through an application menu	Swipe
Reading a text	Vertical Scrolling
Using a dashboard	Swipe

Because the organisms tested in this study do not mediate the relationship between touch gestures and preferences, we cannot say which variables best explain preferences; this could be explored in future research.

This paper has several limitations that need to be acknowledged. This study was done in a banking context. To be able to generalize the results to other fields, future research should focus on different industries. Furthermore, this study could only test a limited amount of use cases and gestures. As seen in the gesture reference guide by Villamor *et al.* (2010), many other gestures do exist. Here, we concentrated on four basic gestures that can be found in many mainstream applications such as Facebook, Instagram, Twitter and banking interfaces. Future research could explore different gestures and also different use cases, not only based on the banking system. Moreover, only twenty participants took part in this study. Ten (10) students and ten professionals tested the prototypes. Literature shows that older people could have a hard time adapting to new technology (Bean & Laven, 2003). It would then be interesting if future studies could focus on this segment of the population that is not explored here. Additionally, the user testings were conducted on an iPhone 6 plus, and although no significant differences were raised between participants who owned an iPhone versus another operating system (OS), it would still be interesting to test our hypotheses on other OS or types of devices. Finally, research showed that ratings of ease of use differed from novice to expert, and that expertise affects perception of the users (Ziefle, 2002). In other words, preferences change according to experience; it would, therefore, be interesting to understand participants' prior experience with touch gestures to see if it is correlated with their preferences.

In conclusion, this paper shows the importance of designing appropriate gestures in mobile applications because they have an impact on the internal states of users as well as their preferences towards theses gestures. It is thus important to continue research in this field to better understand the complexity of designing small characteristics.

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Chapitre 4 : Conclusion

L'objectif de ce mémoire par articles était de mieux comprendre l'impact du design de différentes gestuelles sur interface mobile sur l'expérience des utilisateurs. En premier lieu, le deuxième chapitre de ce mémoire explique que la valence émotionnelle et la charge cognitive des utilisateurs face aux gestuelles dépendent des cas d'utilisation combinés à ces gestuelles. Ensuite, dans le troisième chapitre, ce mémoire discute du rôle que jouent les gestuelles sur les utilisateurs sous plusieurs angles : la charge cognitive, la valence émotionnelle, l'activation émotionnelle, la facilité d'utilisation perçue ainsi que la préférence pour certaines gestuelles. Finalement, à l'aide de cette analyse des comportements et de son impact, ce mémoire cherche à proposer des recommandations en format *meilleures pratiques* face à la mise en place de ces gestuelles lors du design d'applications mobiles.

Une expérience en laboratoire inter-sujet a été réalisée à l'été 2018 avec un total de vingt (20) participants. Ceux-ci devaient évaluer un total de 20 prototypes développés en collaboration avec le Mouvement Desjardins (Montréal, Canada), qui présentaient différentes gestuelles combinées à différents cas d'utilisation. Cette recherche a permis de tester nos hypothèses ainsi que de répondre aux questions de recherche. Des questionnaires, un oculomètre, un logiciel d'analyse d'expression faciale et des capteurs électrodermaux ont permis de recueillir les données nécessaires afin de bien comprendre l'expérience des participants. Cette collecte a permis la rédaction des deux articles présentés aux chapitre deux et trois.

Le présent et dernier chapitre présente les principaux résultats des articles de ce mémoire. Les contributions, l'implication, les limites et les recherches futures seront également présentées dans cette dernière section.

Rappel des questions de recherche et principaux résultats

Les résultats des analyses de ce mémoire ont permis de répondre aux questions de recherche suivantes :

Q1 : Est-ce que la gestuelle combinée avec différents cas d'utilisation affecte l'expérience des utilisateurs ?

Le premier article a permis de répondre à cette question de recherche. Deux hypothèses ont été émises face à celle-ci en se basant sur la littérature dans les domaines similaires :

H1 : L'alignement entre le type de gestuelles et le cas d'utilisation influence la charge cognitive.

H2 : L'alignement entre le type de gestuelles et le cas d'utilisation influence la valence émotionnelle.

Les résultats permettent de supporter les deux hypothèses présentées. Effectivement, la charge cognitive et la valence émotionnelle étaient significativement différentes pour plusieurs tâches présentées aux participants. Ainsi, ce mémoire permet de répondre à la question 1 : oui, la gestuelle combinée avec différents cas d'utilisation affecte l'expérience des utilisateurs.

Ensuite, le deuxième article permettait de répondre à la question suivante :

Q2 : Quel est l'impact des réactions émotionnelles implicites et explicites lors de l'utilisation des gestuelles sur la préférence des utilisateurs envers celles-ci ?

Quatre hypothèses ont été formulées dans ce chapitre en se basant également sur la littérature afin de répondre à cette question.

H1 : Les gestuelles dans les tâches influencent la préférence pour ces gestuelles.

Les analyses démontrent que les gestuelles présentées aux participants influencent effectivement leurs préférences pour ces gestuelles. Ainsi l'hypothèse 1 est supportée.

H2 : Les gestuelles influencent l'activation émotionnelle (H2a), la valence émotionnelle (H2b), la charge cognitive (H2c) et la facilité d'utilisation perçue des tâches (H2d).

La deuxième hypothèse se divise en quatre parties selon les différentes données recueillies lors de l'expérience. L'hypothèse postule que les gestuelles influencent les différentes mesures émotionnelles, cognitives et perçues. Effectivement, les données montrent que les gestuelles influencent l'activation émotionnelle ainsi que la facilité d'utilisation perçue lors des tâches. Toutefois, les gestuelles n'ont pas d'influence sur la valence émotionnelle et la charge cognitive des participants. Cela démontre que la valence émotionnelle et la charge cognitive en tant que telles ne permettent pas de bien analyser l'effet de la gestuelle sur les préférences.

H3 : Les préférences sont influencées par l'activation émotionnelle (H3a), la valence émotionnelle (H3b), la charge cognitive (H3c) et la facilité d'utilisation perçue avec les tâches (H3d).

Ensuite, la troisième hypothèse énonçait que les préférences sont influencées par les différentes mesures observées et perçues par les participants. La facilité d'utilisation perçue d'une gestuelle (H4d) influence en effet la préférence accordée à cette gestuelle. Toutefois, l'activation émotionnelle (H3a), la valence émotionnelle (H3b) et la charge cognitive (H3c) n'influencent pas la préférence des participants. Ainsi, aucune des mesures observées n'influence la préférence des participants et seule la mesure perçue explique bien la préférence.

H4 : L'activation émotionnelle (H4a), la valence émotionnelle (H4b), la charge cognitive (H4c) et la facilité d'utilisation perçue (H4d) ont un effet de médiation sur l'effet entre les stimuli (gestuelles des tâches) et la préférence pour ces gestuelles.

Enfin, la quatrième hypothèse posait que chacune de ces mesures joue un rôle de médiateur sur l'effet entre les gestuelles des tâches et la préférence pour ces gestuelles. Les mesures observées ne pouvaient pas jouer un rôle de médiateur puisque l'hypothèse trois n'était pas soutenue. Suite à ceci, seule la facilité d'utilisation perçue pouvait agir en tant que médiateur entre les gestuelles et les préférences. Toutefois, H4d ne joue pas un rôle de médiateur. Bien que des effets existent dans la relation entre les gestuelles, les émotions et les préférences (Hypothèses 1 à 3), ces effets ne sont pas médiateurs et l'hypothèse quatre n'est pas soutenue.

Ainsi, le lien direct entre les gestuelles et les préférences a été analysé afin de déterminer quelles gestuelles étaient préférées pour chaque cas d'utilisation. Le Swipe a été préféré pour quatre cas d'utilisation sur cinq (remplir un formulaire, explorer un tutoriel, découvrir un portail d'application et utiliser un tableau de bord). Finalement, la préférence des utilisateurs pour le cas d'utilisation *Lire un texte* était le Scrolling Vertical.

Contributions et implications

Il existe encore peu de recherche sur l'impact du choix de gestuelles sur interface mobile. Toutefois, comme l'indiquent Choi *et al.* (2016), les gestuelles sont «des caractéristiques essentielles de la conception d'applications et influencent à la fois les attitudes comportementales et les performances des utilisateurs» (p.177). Il est donc important de continuer la recherche dans le domaine.

Ainsi, ce mémoire contribue du point de vue théorique à la littérature de quelques domaines de recherche. D'abord, la contribution se reflète au niveau de l'expérience utilisateur mais également au niveau de la littérature en interaction humain-machine (IHM). En effet, les chapitres deux et trois permettent de mieux comprendre le rôle des gestuelles sur l'utilisateur. C'est également en proposant une méthodologie d'analyse avec l'aide de prototypes, que ce mémoire contribue à la littérature en IHM. Ensuite, ce mémoire contribue à la littérature en expérience utilisateur en explorant l'impact sur les utilisateurs d'une caractéristique de design et ce à l'aide de tests utilisateurs et de mesures utilisées dans ce domaine de recherche (de Guinea *et al.,* 2014; Georges *et al.*, 2017). Les principaux résultats de ce mémoire montrent d'abord que les gestuelles influencent la perception et le vécu des participants autant positivement que négativement. Ensuite, ce mémoire indique que certaines gestuelles sont préférées à d'autres selon différents contextes d'utilisation. Ces résultats concordent avec les conclusions de plusieurs études antérieures sur l'analyse des gestuelles sur interfaces mobiles qui ont montré que les gestuelles avaient également un impact sur des mesures émotionnelles, cognitives et perçues par les utilisateurs (Bragdon *et al.*, 2011; Choi *et al.*, 2016; Warr & Chi, 2013).

Ensuite, au niveau des implications pratiques, les résultats de ce mémoire permettent entre autres d'offrir des recommandations concrètes pour le développement d'applications mobiles. En effet, peu de guides ou de livres blancs existent qui permettent aux designers d'interfaces mobiles de choisir des gestuelles adaptées. Ces résultats permettent donc aux designers en UX de mieux comprendre l'impact de leurs choix de design sur les utilisateurs et offrent un guide afin de soutenir leurs décisions.

Limites et recherches futures

Quelques limites doivent être prises en considération en ce qui a trait à l'étude décrite dans ce mémoire. Des améliorations et possibilités de recherches futures seront également présentées dans cette section.

D'abord, l'étude a été conçue dans un contexte utilitaire bancaire. Il serait donc intéressant d'élargir cette recherche dans des contextes autres que bancaire et même au niveau hédonique. Effectivement, certaines recherches sur les gestuelles en application hédonique montrent des résultats intéressants au niveau de l'amusement et de la rétention d'information (Choi *et al.*, 2016).

De plus, vingt prototypes ont été créés nous permettant de tester cinq cas d'utilisation et quatre gestuelles. Afin d'être capables de généraliser les résultats de cette étude, d'autres recherches pourraient être menées sur d'autres gestuelles comme celles présentées dans le guide de référence des gestuelles par Villamor *et al.* (2010). Également, le test a été réalisé sur un iPhone 6 +. Malgré que nous ayons testé la différence entre les utilisateurs propriétaires d'un iPhone versus un Android et qu'aucune différence ne ressortait entre les deux groupes, il serait tout de même intéressant de tester cette méthodologie sur d'autres systèmes d'opération de téléphone afin de s'assurer que les données soient généralisables.

Une autre limite de cette étude est le fait que nous avons testé les prototypes sur des participants ayant une moyenne d'âge sous les 30 ans. Ainsi, cette étude ne représente pas la population plus âgée qui utilise les technologies comme les applications bancaires, et donc elle ne reflète pas son expérience. En contrôlant pour une moyenne d'âge plus élevée, les résultats représenteraient mieux la population complète d'utilisateurs de téléphone mobile (Bean & Laven, 2003). Finalement, il serait également intéressant de refaire l'expérience en tenant compte des expériences passées des utilisateurs. Ces utilisateurs connaissent-ils bien les gestuelles d'autres applications, et est-ce que leurs expériences passées changent leurs expériences présente ?

Pour conclure, ce mémoire montre l'impact des gestuelles sur les utilisateurs et contribue à la création de ligne directrices pour les designers d'application mobile ainsi que les designers UX. Plusieurs autres recherches doivent être réalisées afin d'avoir une meilleure compréhension sur le sujet. Ces recherches permettraient d'approfondir la littérature sur l'impact réel des gestuelles et permettraient de contribuer davantage au développement de guides pour les designers.

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