Titre :

Expérimentation de la navigation en ville à l'aide d'une application web par des utilisateurs de fauteuil roulant manuel : évaluation à l'aide de nouveaux critères d'utilisabilité

Rapport final produit pour :

Office des personnes handicapées du Québec - Réseau provincial de recherche en adaptation-réadaptation (OPHQ-REPAR)

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Partenaires communautaires :

Adaptavie, offre des activités sportives aux personnes en FRM
ROPH-03 (Regroupement des organismes de défense des personnes handicapées de la région 03), supporte les droits des personnes avec une déficience physique
CAPVISH (Comité d'action des personnes vivant des situations de handicap) à Québec

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Résumé

Contexte : La connaissance de l'accessibilité des itinéraires est indispensable pour que les utilisateurs d'aides à la mobilité roulante puissent se déplacer de manière sûre et efficace. Cependant, les technologies de navigation actuelles ne fournissent guère d'informations adaptées à cette population, comme l'état des trottoirs, le niveau des pentes, les travaux de la voirie en cours. Les objectifs de l'étude étaient de collecter des données sur l'utilisabilité d'une deux applications de navigation puis de concevoir une évaluation de la satisfaction à l'égard d'une technologie géospatiale d'assistance (ÉSTGA). Pour ce faire, ont été réalisées une validation de contenu, la praticabilité, la faisabilité de l'ÉSTGA en 2018-2019, ainsi que les validités de critère, de construit et interculturelle en 2020-2021.
Méthode : Dans la dernière année du projet, un essai sur le terrain filmé et une étude méthodologique ont été menés en parallèle. Trente utilisateurs d'aides à la mobilité roulante ont été filmés en train de planifier et d'effectuer un trajet de 10 minutes en utilisant HERE WeGo. L'ÉSTGA en français, le Computer System Usability Questionnaire et la version anglaise (ESGAT) ont été complétées à la suite de l'expérience terrain. Une grille d'observation vidéo pour coter l'efficacité et l'efficience de HERE WeGo a été complétée à l'aide des vidéos des participants filmés. Des analyses descriptives, de corrélation et de correspondance multiple ont été réalisées.
Résultats : Quatorze hommes et 16 femmes (âge moyen de 45,9 ans) ont essayé HERE WeGo ; 14 étaient des utilisateurs de fauteuil roulant motorisés. L'utilisabilité de l'application était modérée (bonne efficacité, modérée efficacité et assez satisfait). La validité des critères de l'ÉSTGA était bonne ($r=0,598$; $p<0.001$). La validité de construit était moyenne compte tenu des résultats du facteur 1 ($\alpha=0,789$, acceptable), le facteur 2 ($\alpha=0,586$, faible) et le facteur 3 ($\alpha=0,409$, inacceptable). La validité interculturelle (français vs anglais) était modérée ($r=0,861$; $p<0,001$).
Conclusion. Les questionnaires ESGAT-ÉSTGA 1.0 sont désormais disponibles en anglais et en français avec un score moyen total (11 items), un sous-score informatique (moyenne de 5 items) et un sous-score géomatique (moyenne de 6 items). Leur validation doit être poursuivie avec les nouvelles applications de navigation plus adaptées aux aides à la mobilité roulantes.

Mise en contexte

Afin de contrer les barrières environnementales, les utilisateurs de fauteuil roulant et de quadriporteur doivent bien planifier leur déplacement en ville pour vaquer à leurs activités, et dans ce sens, ils seront sensibles à la signalisation de la présence d'obstacles sur les trottoirs, au degré maximal des pentes, au nombre et type de traverses de rue[1].

Actuellement, les systèmes et services de navigation ainsi que les planificateurs d'itinéraires d'usage courant (ex. *Google maps*) ne fournissent pas de données informatives et de trajets adaptés au profil de capacité d'un utilisateur en fauteuil roulant/quadriporteur. Il y a donc un besoin de développer des technologies géospatiales d'assistance mobile qui répondent à leur besoin. En revanche, il n'existe pas non plus d'outils permettant de mesurer la satisfaction des utilisateurs de ces technologies, afin de relever les aspects à améliorer. Finalement, il faudrait aussi quantifier plus objectivement les difficultés rencontrées, ce que l'on nomme également la mesure de l'utilisabilité.

L'utilisabilité correspond au degré selon lequel un produit peut être utilisé pour atteindre des buts déterminés avec efficacité, efficience et satisfaction dans un contexte d'une utilisation spécifique[2]. L'utilisabilité est mesurée par des utilisateurs en situation de handicap dans 68% des études concernant les aides techniques en réadaptation[3]. Alors que dans une méta-analyse sur l'utilisabilité des applications mobiles menée en 2011, seulement 2 études sur 100 examinées avaient été documentées par des personnes ayant une déficience [4]. Ce constat peut paraitre étonnant étant donné l'essor concomitant de la littérature scientifique sur le thème de l'accessibilité, le niveau de soutien législatif et l'intérêt suscité à l'échelle communautaire pour les personnes présentant des déficiences. L'utilisabilité des technologies géospatiales d'assistance demeure méconnue. Comme il n'existait pas de liste des critères d'utilisabilité pour nous aider à les évaluer en vue de les améliorer ou encore à les recommander en clinique le moment venu, un examen de la portée a permis d'identifier une cinquantaine de critères d'utilisabilité pour notre population étude (ex. main libre, confort, contenu informatif).[5]

Il demeure important de s'assurer que les technologies géospatiales d'assistance mobile répondent bel et bien aux besoins et exigences des utilisateurs de fauteuils roulant et de quadriporteur, c'est-à-dire d'augmenter leurs chances de participer le plus activement possible dans la société. Dans ce sens, nous avons formulé quatre **objectifs spécifiques** de recherche réalisées en deux temps :

2018 et 2019

1. Développer et valider un questionnaire sur la satisfaction de la technologie d'assistance géospatiale, en français et en anglais (validation du contenu, faisabilité et applicabilité)

2. Évaluer la satisfaction, l'efficacité et l'efficience d'une technologie d'assistance géospatiale auprès d'utilisateurs permanents (n=3) et temporaires (n=5) de fauteuils roulants à la suite d'un essai filmé dans une zone urbaine dense.

2020 et 2021

3. Évaluer l'utilisabilité d'une application de navigation (application de mobilité) lorsqu'elle est utilisée par des utilisateurs d'aides à la mobilité sur roues dans leur quartier.

4. Évaluer la validité de critère, la validité de construit et la validité interculturelle des versions anglaise et française de l'ESGAT (Evaluation of satisfaction with geospatial assistive technology) et de l'ÉSTGA (Évaluation de la satisfaction à l'égard des technologies d'assistance géospatiale).

Méthodologie pour les objectifs 1 et 2 (2018-2019)

Le devis de cette première étude consistait en une étude méthodologique et un essai filmé sur le terrain.

Pour **développer le questionnaire** sur la satisfaction de la technologie d'assistance géospatiales, la chercheure principale et le professionnel de recherche (CV et FD) se sont basés sur les résultats de deux études précédentes de notre groupe de recherche qui examinaient les critères d'utilisabilité pour l'assistance géospatiale et la mobilité en fauteuil roulant [5, 6] ainsi que sur le QUEST 2.0 [7]. Il existait beaucoup d'éléments de satisfaction. Pour les sélectionner et les combiner nous avons utilisé le COSMIN pour une bonne validité du contenu (p. 7 sur https://www.cosmin.nl/wp-content/uploads/COSMIN-methodology-for-content-validity-user-manual-v1.pdf) c'est à dire:

1. Les éléments inclus sont-ils pertinents pour le concept d'intérêt ?
2. Les éléments inclus sont-ils pertinents pour la population cible d'intérêt ?
3. Les éléments inclus sont-ils pertinents pour le contexte d'utilisation d'intérêt ?
4. Les options de réponse sont-elles appropriées ?

Une étudiante en ergothérapie lors d'un stage de recherche (RG) a amélioré chaque critère et sa formulation, en co-validation avec le chercheur principal, à partir de cette première ébauche du questionnaire. Des changements majeurs par rapport à la version originale ont été apportés, notamment en ce qui concerne les exemples écrits entre parenthèses ; mais le nombre de critères (12) est resté inchangé.

Deux **groupes de discussion** de quatre experts chacun (n=8) ont été recrutés pour évaluer la formulation des items et le système de notation, pour les versions françaises et anglaises. Cinq participants ont été approchés parce qu'ils travaillaient au centre de recherche et trois autres avaient consenti à être approchés pour d'autres projets, après avoir participé à une étude précédente sur la mobilité en fauteuil roulant.

Un **essai sur le terrain** a été mis en place avec d'autres participants, avec la chercheure principale et l'étudiante en ergothérapie (CV et RG). Le même processus de recrutement a été utilisé que pour les groupes de discussion, soit des utilisateurs permanents (n=3) et temporaires (n=5) de fauteuils roulants (cliniciens ou étudiants ayant une certaine expérience de la mobilité manuelle en fauteuil roulant). Cinq parlaient français mais parlaient couramment l'anglais et les trois autres avaient l'anglais comme langue maternelle.

Il a été demandé aux participants de planifier un itinéraire d'environ 5 à 10 minutes entre deux endroits dans la ville de Québec (Canada), en utilisant l'option piétonne de Google Maps avec leur propre appareil mobile. Ils devaient alors s'y rendre tout en étant filmé, puis ils revenaient à leur point de départ.

C'est à l'intérieur, près du point de départ ou de retour au centre de recherche, que les participants en remplissaient le **questionnaire de satisfaction** en français, puis en anglais. Les fichiers vidéo ont été examinés par le coordinateur de la recherche, qui était aveugle à l'essai sur le terrain, afin de remplir une **grille d'observation** et de notation évaluant l'utilisabilité de la technologie d'assistance géospatiale pour chaque participant.

Méthodologie pour les objectifs 3 et 4 (2020-2021)

Le devis de la seconde étude consistait en un essai filmé sur le terrain ainsi qu'une étude méthodologique menés en parallèle.

La **population d'intérêt** consistait en des utilisateurs de fauteuil roulant et de quadriporteur hétérogènes (i.e. de diagnostic, âge et genre variés) se déplaçant par eux-mêmes à l'extérieur de leur domicile et qui sont habituellement actifs dans la communauté. Les critères d'inclusion étaient: 1) être âgé d'au moins 18 ans; 2) se propulser de façon autonome avec un fauteuil roulant (manuel ou motorisé) ou un quadriporteur, i.e. sans assistance humaine, pour un minimum de 20 minutes et 3) être familier avec un téléphone intelligent ou une tablette électronique. Le seul critère d'exclusion était: 1) impossibilité de communiquer en français ou en anglais.

La **taille d'échantillon** finale a été fixée à 30 participants, ce qui est suffisant compte tenu du type d'étude que nous voulons faire (utilisabilité et évaluation des qualités psychométriques d'un questionnaire évaluant la satisfaction envers cette application). Le recrutement a été réalisé avec le soutien de de partenaires communautaires. (Adaptavie, ROPH-03, CAPVISH). Les intervenants de ces quatre organismes ont par la suite sollicité leurs membres pour leur demander de participer au projet et transmettre leurs coordonnées à la coordination de la recherche. Il a également été possible de recruter des personnes en contactant des anciens participants des projets de recherche d'un des co-chercheurs (François Routhier) qui avaient accepté d'être recontactés pour d'autres projets.

Pour **l'essai sur le terrain**, un étudiant gradué, une étudiante au baccalauréat en ergothérapie ou le professionnel de recherche s'est rendu au domicile des participants pour ces expérimentations. Le port du masque pour tous et une distanciation de 2 mètres était respectée sauf pour quelques instants lors des ajustements avec la technologie. Nous invitions les participants à installer une nouvelle application mobile sur leur téléphone (Here WeGo). On lui demandait de planifier un trajet à partir du domicile pour une destination d'environ 10 minutes. Ensuite, on proposait un support pour y déposer le téléphone ou la tablette sur la cuisse ou directement sur le fauteuil/quadriporteur. Ceci était essentiel pour que le participant puisse avoir les mains libres pour manœuvrer. Pour la navigation, on s'assurerait que l'usager démarre seul l'application, que le mode audio fonctionne bien et que l'usager se déplace de façon sécuritaire. Nous pouvions intervenir au besoin s'il y avait des obstacles sur la chaussée ou qu'il fallait revenir en arrière. L'expérimentateur portait au front un support pour téléphone afin de filmer la scène et d'avoir lui aussi les mains libres en cas de problème.

De retour au domicile, il était demandé au participant de compléter trois **questionnaires** dans cet ordre : ESTGA (français), questionnaire d'utilisabilité (CUSQ) [8], ESGAT (anglais) [9]. Également, la **grille d'observation** était cotée pour l'efficacité et l'efficience de l'application de navigation à partir des vidéos, par le stagiaire et le professionnel de façon indépendante, puis ils se sont rencontrés pour faire consensus.

Variables et mesures

La variable dépendante était la mesure détaillée de l'utilisabilité et la variable indépendante le guidage de l'utilisateur par l'application web. Pour mesurer ces variables, nous avons utilisé les instruments de mesure suivants.

La *Grille d'évaluation de l'utilisabilité des technologies d'assistance géospatiale*. Cette grille permet d'examiner l'intervention a posteriori, minute par minute, à l'aide d'extraits vidéos, par ex. : nature des gestes de l'utilisateur, aide requise, motifs pour lesquels le clinicien a dû intervenir, temps de réalisation pour planification et pour navigation, positionnement de l'appareil, utilisation des différents modes d'accès, difficultés rencontrées, niveau d'accord entre l'itinéraire planifié et l'itinéraire expérimenté sur la chaussée.

Le *questionnaire sociodémographique* est inclus au début de l'*ESTGA-ESGAT* et comporte des variables descriptives, par ex. : âge, genre, diagnostic, niveau de scolarité, étude ou travail à temps partiel/complet, type de logement, accessibilité au logis, aides techniques utilisées, services à domicile.

La version de l'*Évaluation de la satisfaction envers une technologie géospatiale d'assistance (ESTGA-ESGAT)* utilisée dans cette étude afin d'évaluer la satisfaction des participants est présentée en annexe. Il est à noter qu'une version améliorée, découlant de notre étude est quant à elle disponible à la fin du deuxième article présenté plus loin en annexe.

Analyses psychométriques de l'ESGAT-ÉSTGA

Pour la consistance interne, une analyse de correspondance multiple a été réalisée. Notre hypothèse est que le construit de la satisfaction repose sur 2 dimensions : géolocalisation et technologie informatique. Afin de mesurer le degré de consistance interne de l'ESTGA (version française), l'outil statistique recommandé est l'alpha de Cronbach. La valeur de cet alpha peut varier de 0 à 1. Cette valeur est affectée par le nombre d'items de l'instrument et le nombre de répondants. Plus ces deux paramètres sont élevés, plus l'exigence pour la valeur de l'alpha est élevée. Des valeurs entre 0,70 et 0,95 sont habituellement raisonnables lorsque l'échelle ou la sous-échelle a plus de 5 items. Un alpha trop élevé (0,90) peut indiquer une redondance de certains items.

Pour la validité de critère, il a été calculé le coefficient de corrélation entre la mesure obtenue (ESTGA, version française) et la mesure de critère (soit le CUSQ). Notre hypothèse est à l'effet que les items concernant la « technologie informatique » de l'ESGAT sont corrélés avec les résultats au CUSQ.

Pour la validité culturelle (i.e. concomitance entre l'ESTGA et l'ESGAT), des analyses de corrélations ont été réalisées sur les résultats aux items formulés en anglais et en français, sur les sous-scores, et le score total.

Résultats

Dans la première étude (objectifs 1 et 2):

Le contenu du questionnaire d'Évaluation de la satisfaction à l'égard de la technologie d'assistance géospatiale (ESGAT) a été développé. L'ESGAT comprend un profil d'utilisateur et son expérience avec la technologie, suivi de 12 critères de satisfaction notés de 1-pas satisfait à 5-très satisfait, ainsi qu'un score global. À la fin, il est demandé aux usagers de choisir les 3 items les plus importants pour eux. La faisabilité et l'applicabilité de ce questionnaire ont été jugée satisfaisantes sur le terrain. L'utilisabilité de l'outil Google Maps piétons a été évaluée comme « modérée » par les utilisateurs de fauteuils roulants manuels puisque le score de satisfaction totale à l'ESGAT était de 3,9/5. Les items avec les scores le plus bas étaient : l'aide à la navigation, la fonction mains libres et la sécurité. La technologie d'assistance géospatiale était efficace (87,5% ont atteint leur destination) mais pas efficiente (37,5 % avaient besoin d'aide).

Les profils des participants ainsi que les résultats détaillés sont présentés sous forme d'article scientifique, disponible en annexe. Il est à noter que les co-chercheurs ont relu et commenté à deux reprises, l'article.

Vincent, C., Girard, R., Dumont, F., Archambault, P., Routhier, F., and Mostafavi, M.A. 2019. Evaluation of satisfaction with geospatial assistive technology (ESGAT): a methodological and usability study. Disability and Rehabilitation: Assistive Technology, June 2020. https://doi.org/10.1080/17483107.2020.1768307

Dans la seconde étude (objectifs 3 et 4):

Quatorze hommes et seize femmes (âge moyen de 45,9 ans) ont essayé HERE WeGo ; 14 étaient des utilisateurs de fauteuils roulants électriques. L'utilisabilité de l'application était modérée (bonne efficacité, efficience modérée et assez satisfait). La validité critère de l'ESGAT était bonne ($r=0,598$; $p<0,001$). La validité de construit était moyenne compte tenu des résultats pour le facteur 1 ($\alpha=0,789$, acceptable), le facteur 2 ($\alpha=0,586$, faible) et le facteur 3 ($\alpha=0,409$, inacceptable). La validité interculturelle (français vs anglais) était modérée ($r=0.861$; $p<0.001$).

Une fois de plus les résultats détaillés se retrouvent en annexe sous forme d'article. Il vient d'être soumis à un journal. Les co-chercheurs ont lu et commenté à deux reprises l'article.

Vincent, C., Levac, S., Dumont, F., Archambault, P., Routhier, F., Mostafavi, M.A. Usability of a navigation application for safe travel with wheeled mobility device and, further validation of the Evaluation of satisfaction with geospatial assistive technology. Disability and Rehabilitation: Assistive Technology. (soumis).

Plan de transfert et d'appropriation des connaissances vers les milieux de pratique

Dans toutes nos publications et moyen de transferts de connaissances, nous recommandons aux cliniciens les éléments suivants pour l'appropriation des connaissances:

1. Pour les utilisateurs de fauteuils roulants manuels jumelés à une technologie d'assistance géospatiale, il est nécessaire de faire un test sur le terrain afin de s'assurer de l'efficacité de la technologie pour éviter ou annoncer des obstacles potentiels tels des travaux, des trottoirs endommagés, l'accessibilité à destination, indications verbales qui arrivent trop tôt ou trop tard, indications erronées, flèche qui n'indique pas la bonne direction, réajustement de l'itinéraire nécessaire et un manque d'indication.

2. Les cliniciens devraient demander à leurs clients utilisant un appareil de mobilité sur roues de tester leurs applications de navigation pour s'assurer de leur sécurité et de compléter l'Évaluation de la satisfaction à l'égard des technologies d'assistance géospatiale (ESGAT 1.0) disponible en français et en anglais.

3. Les cliniciens devraient se renseigner sur la satisfaction de leurs clients en ce qui a trait aux éléments présentés dans le questionnaire de satisfaction, soit des éléments traitant de l'informatique (facilité d'accès, facilité d'apprentissage, fonction mains libres, facilité d'utilisation, transportabilité et apparence) et des éléments traitant de la géomatique (contenu, informations géographiques, efficacité, efficience, aide à la navigation en temps réel, aspect de sécurité).

4. Les cliniciens en réadaptation devraient s'enquérir de l'efficacité de l'application de navigation et prévenir leurs clients des obstacles potentiels tels que : voyager dans la rue pendant une longue partie du trajet et non sur le trottoir; indications verbales qui arrivent trop tôt ou trop tard; indications erronées et les trottoirs endommagés et encombrés.

Pour s'assurer d'un impact du projet dans les milieux de pratique et communautaires et organismes défenseurs des droits des personnes handicapées, il sera acheminé la dernière version de l'ESGAT/ÉSTGA à tous les Organismes dédiés à la mobilité réduite et l'accessibilité universelle, afin de les encourager à tester avec leurs clients, les nouvelles technologies d'assistance géomatiques. Organismes dédiés - Ressources pour personnes handicapées - OnRoule OnRoule.org. Également, l'outil sera disponible sur le site du Cirris dans la section instrument de mesure. https://www.cirris.ulaval.ca/partenaires-et-innovations/produits-de-la-recherche/. Ce rapport sera également disponible à la Bibliothèque et Archives nationales du Québec (BAnQ) et un numéro standard international (ISBN) sera produit ce qui facilitera le partage du document.

Les présentations suivantes ont été faites afin d'informer la clinique et la recherche:

1. Vincent, C., Rebecca, G., Dumont, F., Routhier, F., Archambault, P., Mostafavi, M. Déplacements urbains en fauteuil roulant à des fins de validation du questionnaire « Évaluation de la satisfaction envers une technologie géospatiale d'assistance». 32è Entretiens Jacques Cartier : le rendez-vous

France x Québec - #EJC2019 Mobilité, territoires et « Smart Cities », 5 novembre 2019, Université Laval, Québec. https://www.fourwav.es/view/1474/info/

2. Girard, R., Vincent C. Déplacements urbains en fauteuil roulant à des fins de validation du questionnaire « Évaluation de la satisfaction envers une technologie géospatiale d'assistance (ÉSTGA)». Journée de synthèse des étudiants d'été du CIRRIS, p.31. Institut de réadaptation en déficience physique de Québec, CIUSS/CN, le 9 septembre 2019, Québec, Canada. (Prix de meilleure présentation étudiante du CIRRIS)

3. Vincent, C, *Girard, R, Prémont, ME, Dumont, F. Évaluation d'une aide technique à la navigation en fauteuil roulant en ville : validation de contenu. 26ième XXVIe congrès de la Société Francophone Posture Équilibre et Locomotion (SOFPEL). L'art de se déplacer en ville. Musée des beaux-arts de Montréal, Canada, 4 et 5 décembre 2019, Neurophysiologie clinique, 49 (6) : 415.

4. Simon Richard, Claude Vincent, François Routhier, Mir Abolfazl Mostafavi, Philippe Archambault, Frédéric Dumont, Sophie Levac. Geospatial assistive technology and wheelchair mobility, a mobile app user experience. Poster #5. 2nd COTEC-ENOTHE Congress. Occupational Therapy in Europe. Prague. September 15–18, 2021. Cubex Centre Prague and the City Conference Center. Cubex Centre Prague, Strži 2097/63, 140 00 Prague 4, Czech Republic. Programme | 2nd COTEC-ENOTHE CONGRESS | Ex Ordo

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Annexe 1

Article 1 ; voir ESGAT-ESTGA p. 24

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Evaluation of satisfaction with geospatial assistive technology (ESGAT): a methodological and usability study

Claude Vincent, Rébecca Girard, Frédéric Dumont, Philippe Archambault, François Routhier & Mir Abolfazl Mostafavi

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ORIGINAL RESEARCH

Evaluation of satisfaction with geospatial assistive technology (ESGAT): a methodological and usability study

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ABSTRACT

Purpose: Manual wheelchair users are more vulnerable, in situations such as road crossings, hazardous sidewalks or curbs and crossing of buildings and facilities threshold. Geospatial assistive technology (GAT) can help with route planning. However, it is important to ensure the usability of such products, as well as the satisfaction of persons with reduced mobility. The study's aim was (1) to develop and validate a questionnaire on the satisfaction of GAT, in English and French, and to (2) assess satisfaction, efficacy and efficiency of a GAT with manual wheelchair users following a filmed trial in a dense urban area.

Method: A methodological study was conducted (development of the questionnaire, assessment of its content validity, feasibility and practicability) followed by a trial and post-observations with the videos. Two questionnaires (English, French) were concurrently validated by two groups of experts ($n = 8$), and then field-tested by wheelchair users ($n = 8$), using Google Maps Pedestrian routeing tool.

Results: The Evaluation of satisfaction with geospatial assistive technology (ESGAT) consists in a user profile and their experience with the technology, followed by 12 satisfaction criteria rated from 1-not satisfied to 5-very satisfied. Both questionnaires were rated as feasible and practicable to complete. The usability of Google Maps Pedestrian routeing tool was measured as "moderate" by manual wheelchairs since the total satisfaction score at the ESGAT was 3.9/5 (quite satisfied). The items with the lowest score were navigation assistance, hands-free function and security. The GAT was effective (87.5% have completed their destination) but not efficient (37.5% needed help).

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➤ **IMPLICATIONS FOR REHABILITATION**

For manual wheelchair users paired with geospatial assistive technology:

- A 10 minutes questionnaire was developed and validated to assess their satisfaction after testing aid in an urban area.
- Satisfaction criteria to address are ease of access (service), learnability, hands-free function, ease of use for planning as well for navigating, transportability/ appearance, content, geographic information, effectiveness, efficiency, navigation assistance and security
- A field test is necessary to ensure the effectiveness of the technology in avoiding or announcing potential obstacles such as sidewalk crossing ramp, damaged and congested sidewalk; sidewalk tilt (side slopes); thresholds at destination; verbal indication too soon or too late; incorrect indication; the arrow does not indicate the right direction; readjustment of the route needed; a lack of indication; and human intervention needed.

Introduction

In recent years, digital maps and navigation tools such as Google Maps, Yelp or Waze have completely changed the way we navigate and travel from one point to another. These navigation aids focus particularly on-road data and point of interest information but lack insight on pedestrian infrastructure and wheelchair accessibility [1]. Even websites such as walkscore.com, which model and visualize the routes and walkability of different neighbourhoods, do not include information regarding sidewalks accessibility nor curbs and ramps condition, for example [2]. Wheelchair user's community represents 197,560 individuals in the Canadian population [3] and there is no platform considering the fact they need obstacle-free sidewalks. In order to navigate outdoors, wheelchair users must face environmental challenges such as sidewalks, uneven surfaces, narrow spaces, inoperable or lacking ramps, blocked curbs or sidewalks and bad weather [4]. Wheelchair navigation should point out environmental barriers that can compromise the user's safety and effectiveness. The use of digital maps and navigation tools for users with disabilities

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should be accessible to diverse users with a wide range of physical, sensory and cognitive abilities [5].

To address both needs, several projects in the past few years have consisted of the development of geospatial assistive technologies (GAT), allowing the calculation of personalized itineraries and guidance to assist with wheelchair navigation. Prototypes of specific tools addressing manual wheelchair users' needs, such as MobiliSIG, were implemented [6]. Most recently, Google Maps has made some progress regarding planning and navigation for people who use wheelchairs or other mobility assistive devices for their mobility. They introduced "wheelchair accessible" as a new option proposing routes that are accessible by public transportation. However, this new feature is available only in a few metropolitan cities (London, New York, Tokyo, Mexico City, Boston, and Sydney) [7]. Moreover, Google is in the process of adding new accessibility data worldwide using the *Local guides platform* [8], giving anyone around the globe the opportunity to share accessibility information and features on any location or infrastructure. The gathered data is expected to improve the accessibility information proposed by the Google Maps platform [9]. This platform is the most used in the population to plan a trip by car, bus, bicycle or walking (https://www.statista.com/statistics/865413/most-popular-us-mapping-apps-ranked-by-audience/). Since there are no apps or platforms available for planning a trip in a wheelchair in Quebec city (with local barriers and accessibility features), the present study had to consider the pedestrian access proposed by the Google Maps platform.

So far, there are rather very limited data addressing the usability issue of Google maps for wheelchair users, and this is important for health professionals to know about. Currently, this GAT does not compile the capabilities of the user to use his wheelchair outside before the route planning task. The ISO 9241-11:2018 definition [10] of usability is the "extent to which a system, product or service can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use". Then, the proposed study should include satisfaction, efficacy (effectiveness) and efficiency of the planning and navigation tasks.

It would be beneficial for navigational aid users to be able to indicate their satisfaction after testing this type of technical aid, and it would also be beneficial for clinicians to know if the aid tested is effective and efficient, given that apps are multiplying in the market and that there is no measure in these regards. For those considerations, the study's aim is then twofold: (1) to develop and validate a questionnaire on the satisfaction of GAT, in French and English (content validation, feasibility and practicability); and (2) to assess satisfaction, effectiveness and efficiency of a GAT with manual wheelchair users following a filmed trial in a dense urban area.

Method

A methodological study was carried out and a filmed field trial. For the development and content validity of the questionnaires, the research design described by Lynn [11] was retained. The two stages illustrated by this method were followed. The first stage (development) results in the establishment of the instrument's items, while the second stage (judgement and quantification) evaluates the performance of these items. The research method was complemented by a third stage (technological trial/or field trial), in which the feasibility, practicability and usability of the new questionnaires were tested. Figure 1 shows the steps to develop the questionnaires and to assess its feasibility and practicability. Ethical approval was obtained from the Research Ethics Committee of Centre intégré Universitaire de Santé et de Services Sociaux de la Capitale-Nationale (#2019-1604). Written consent was given by participants at stages 2 and 3.

Development (stage 1)

The construct measure was based on the results of two previous studies (examining the usability criteria for geospatial assistance and wheelchair mobility) and QUEST 2.0. Since all usability questionnaires in the literature have not been validated with the target population (persons with disabilities), we found that only the QUEST was successfully developed for assistive technology and persons with disabilities. However, the QUEST was not developed for informatics aids or geospatial aids. The format of the QUEST was retained for the development of our questionnaire (structure and scoring system); the criteria and nomenclature were selected by the authors, based on previous usability questionnaires made for informatics aids and geospatial aids, making our questionnaire completely new. In this manuscript, the results of the development stage are presented in the Results section.

Practically, to select and combine satisfaction items, the developers used the COSMIN checklist for good content validity, except the fifth criteria of relevance (p. 7 at https://www.cosmin.nl/wp-content/uploads/COSMIN-methodology-for-content-validity-user-manual-v1.pdf): *1 Are the included items relevant for the construct of interest? 2 Are the included items relevant for the target population of interest? 3 Are the included items relevant for the context of use of interest? 4 Are the response options appropriate? 5 Is the recall period appropriate?*

Three publications were analyzed in details: a scoping review about geospatial assistive technologies' usability criteria and measures [4], an explanatory qualitative study with 17 manual wheelchair users regarding the potential usability of existing GATs [12] and the *Quebec User Evaluation of Satisfaction with assistive Technology* (QUEST 2.0) [13]. The research coordinator (FD) made use of these three previous lists of usability and satisfaction criteria [4,12,13] to begin his thought process. He deemed relevant to elaborate our questionnaire's format, in terms of length and rating system, using QUEST 2.0 as a guide (approximately 10 min to fill, with scores and comments). The English version was developed first using both English reference articles [4,12] and the QUEST (available in English and French). For the French version, the French-speaking research team translated the English items using the QUEST and dictionaries when needed.

Judgement and quantification (stage 2)

An occupational therapy student (RG), starting the first draft of the questionnaire, enhanced every criterion and its wording, co-validating with the principal investigator. Major changes from the original version were made, particularly related to the examples written in parentheses; but the number of criteria (12) remained unchanged.

Two focus groups of four experts ($n = 8$) were planned to assess the preliminary questions, the item's wording (criteria and examples) and the rating system, in French as well as in English. The first and second authors led the focus groups, which were audiotaped. The first author had more than 20 years of experience in leading focus groups. The inclusion criteria for participants were: to be bilingual (FR and EN), to be a manual wheelchair user, a therapist, a research or a student in occupational therapy with experience with a manual wheelchair or mobility studies. In

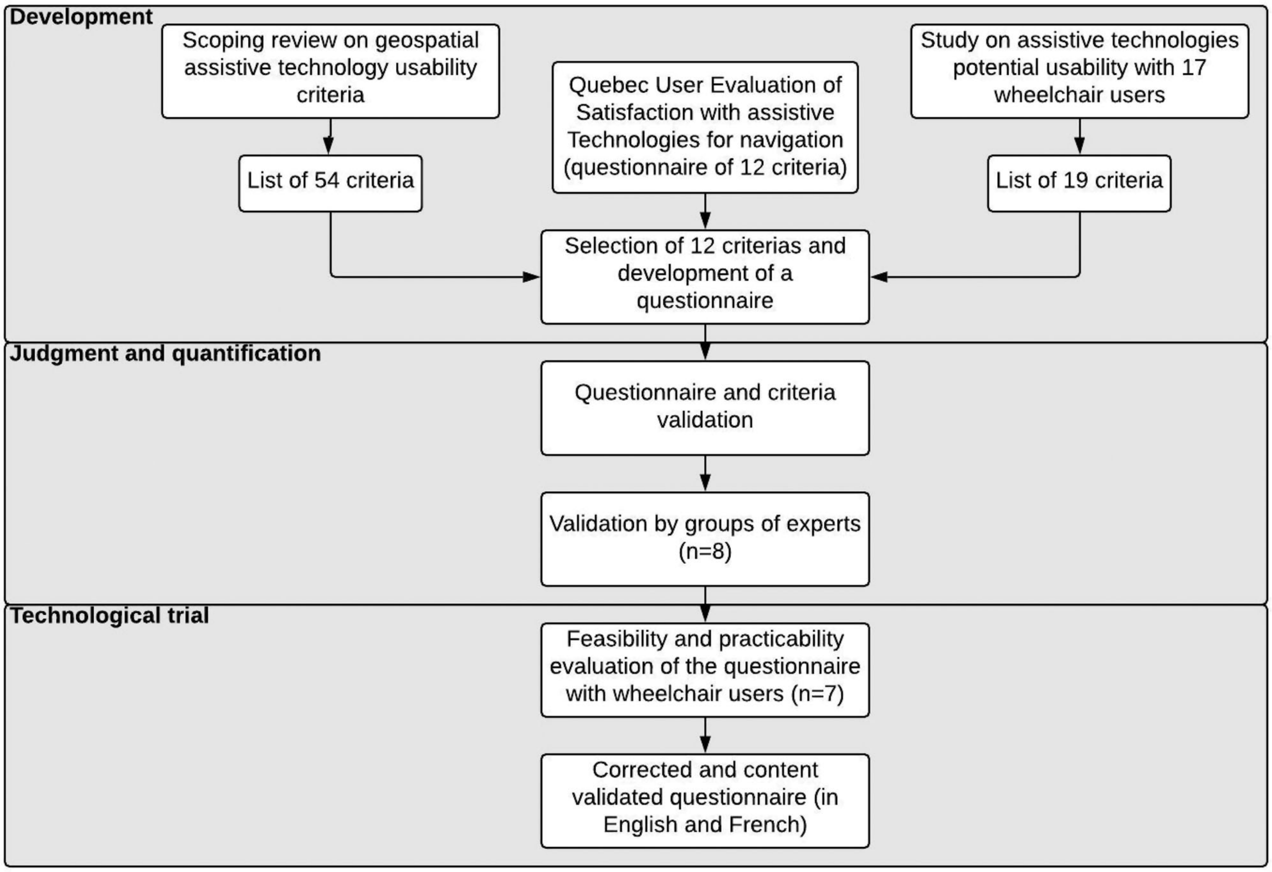

Figure 1. Methodologic steps to develop the questionnaires and to assess its feasibility and practicability.

both groups, to reach "data saturation", participants had to reach consensus with the structure of the questionnaires, the items, their definitions and the scoring. Five participants were approached because they were working at the research centre and three others had provided consent to be approached for other projects, after having participated in a previous wheelchair mobility study. This diversity and number of experts were suggested in Almanasreh, Moles and Chen [14]. Both focus groups followed the same process:

- Step 1 – After the research project and its specific objectives were introduced, participants filled in a consent form as well as a sociodemographic form (10 min).
- Step 2 – A 5-min video was shown presenting the use of a GAT. It exhibited the research coordinator planning a short itinerary in a dense urban area, using the pedestrian function of Google Maps. The itinerary was done in the Saint-Roch neighbourhood (Quebec City, Canada) and involved navigating between two locations using a manual wheelchair and a smartphone in voice-guided navigation mode. The cellphone was installed on the wheelchair's armrest and held in place by Velcro tape. The itinerary had a predicted duration of 6 min, but in fact took 10 min by navigating in a manual wheelchair. The participant's navigation was slowed by an inadequate direction advice and by the device's positioning, requiring him to immobilise his wheelchair every time he needed information in order to look down towards the mobile phone.
- Step 3 – Each participant was provided with the following documentation: the first draft of our new questionnaire in English and French, the QUEST 2.0 and both lists of criteria from the articles by Prémont et al. [4,12]. Retained criteria of the lists and from the QUEST 2.0 were highlighted in yellow while items included as examples were highlighted in blue on the documents (10 min).
- Step 4 – While relying on the expert validation process [14], four rounds of the question were conducted by the animator (RG). For the first round, it was asked: "*about technical navigational assistance, how satisfied are you with item 1, 2, 3, and later on 4, 5, 6*", as shown on the PowerPoint; for the second round: "*… with items 7, 8, 9, and later on 10, 11, 12 …*". The co-animator (CV) oversaw audiotaping of the discussions and the transcription of all proposed corrections. The animator read three items at a time and asked participants to make sure every single criterion and its wording was relevant, understandable and clear. To this end, all criteria and their sub-criteria were discussed and adjusted, where necessary. Any changes made needed to be approved by every involved expert. For the third round, the participants were invited to make suggestions related to any missing aspects or criteria in the questionnaire presented, basing their choices on all three provided lists of usability criteria. The questions were "*Do you think other criteria should be added? What for?*". On round 4, participants had to adjudicate on the questionnaire's preliminary items. The questions were: "*After the criteria are added, do you want to withdraw or reject a criterion? Do you agree with the wording that has been enhanced? Do you agree with the criteria that have been added to the questionnaire*?". Finally, co-animator read every criterion aloud, integrating changes

made and asked for every expert's last suggestions and final approval.

- Step 5 – The co-animator (CV) had corrected the questionnaires in English and French in compliance with the preceding discussion before going with a second focus group on the following day. These reviewed versions were presented to the second group and used as a baseline for the discussion. The focus group discussion proceeded as for the first group. The adjusted questionnaire, resulting from both focus group discussions, was finally conceived. The rating scale was preserved, but a "user experience" section was added to the preliminary questions. The audio recordings were replayed after the focus groups and were helpful for the content analysis, to ensure that all the requested changes had been fully integrated, as suggested by participants.

Trial in field (stage 3)

An in-field trial was set up with eight new participants. The same recruitment process as for the focus groups was used. A convenience sample was planned with permanent and temporary wheelchair users (clinicians or students having some experience with manual wheelchair mobility). Five were French speaking but fluent in English and the three others had English as their first language. Each participant was met individually for a total period of approximately 1 h 45 min.

- Step 1 – At the research centre and a community organization, the meeting began with the presentation of the GAT example video (see stage 2). It was followed by the presentation of the research specific objectives; then the consent form and the sociodemographic form were completed (15 min).
- Step 2 – Participants were asked: (1) to plan an itinerary of approximately 5–10 min between two locations in Quebec City (Canada), using the pedestrian option of Google Maps with their own mobile device (nothing else could be selected to customize the route according to users' capabilities). This planning procedure was videotaped. It was decided to plan a route of only 10 min because obstacles were unknown, the route could take twice the time to complete. In addition, participants were required to go back to the starting point, and then complete the questionnaire at home. In fact, the experiment lasted one hour and participants' fatigue had to be taken into account. (2) to go to the starting location of the itinerary. A wheelchair was loaned by the research centre to temporary wheelchair users. (3) to set up the smartphone on their support of choice, to turn on the Google Maps application, to make sure the voice was audible, and to start to navigate to the planned destination. The navigation process was videotaped as well. (4) to come back to their starting location and to fill in the questionnaire in both English and French, starting with the one written in their mother tongue. (5) To circle the terms and wordings they thought were not clear or relevant on both questionnaires. Filling the questionnaires and the fifth step was timed.
- Step 3 – Video files of the field trials were examined by the research coordinator, who had not participated in Steps 1 and 2. He filled a scoring grid evaluating the usability of the GAT for every participant, filmed during the planning and navigation steps. He analyzed the efficacy of the planning and navigation tasks and the efficiency of reaching the optimal destination. To this end, a four-level rating scale was retained: "completed, completed with errors, partially completed (help needed) and unable to perform", and all incidents and environmental obstacles were identified and counted. This scale was based on a standardized instrument, developed by Dumont et al. [15], that assesses computer task performance with different assistive devices.

A database using an Excel file was created to incorporate sociodemographic data, results and comments of the ESGAT questionnaires and results from the video evaluation grids. A third and last draft of the questionnaire was developed accordingly in English and French, by analyzing comments and misunderstandings written or expressed by participants throughout the whole experimentation process. Descriptive statistics (mean, sums, frequency, total score) were performed for quantitative data. Most representative commentaries were retained and presented for each of the variables of the ESGAT, based on the in-field trial.

Results

Participants' profile

Table 1 shows the profile of the bilingual participants for the focus groups ($n = 8$) and the field trial ($n = 8$). The mean age was 38.1-years-old in the focus groups and 29.8-years-old in the field trial. For the focus groups, 8 had French as their first language, and for the in-field trial, 3 had English as their first language. Participants were permanent wheelchair users ($n = 5$), researchers ($n = 5$) and clinicians ($n = 9$); some of them had more than one role. Eleven participants had occasional wheelchair experience from their clinical training or work experience. Table 1 shows variations in the level of education, employment, diagnosis and wheelchair accidents as well as the type of support for their smartphone during the field trials.

Questionnaires developed and validation of their content

The scoping review consulted [4] included 54 usability criteria extracted from15 selected articles examining usability measures and criteria coming from12 usability questionnaires evaluating all kinds of technologies, either involving the geospatial aspect or not. None of them were specific for users with disabilities, except for the *Quebec User Evaluation of Satisfaction with assistive Technology* (QUEST 2.0) [13]. The qualitative study [12] also presented a list of 19 specific potential usability criteria for wheelchair users, containing 7 criteria similar to those identified by the scoping review [4]. QUEST 2.0 was tested with several users (adults with multiple sclerosis, wheelchair users, individuals with spinal cord injuries and older adults in nursing homes) [16–18] in Canada, the United States and the Netherlands [19] and also translated and validated in Dutch, Chinese, Taiwanese, Korean, Portuguese and Greek [20–25]. This questionnaire was validated with many assistive technologies (seating and mobility aids, transfer aids, augmentative communication devices, lower limb prostheses and environment control devices) [19,26,27] but not with GATs.

The research coordinator (FD) kept four usability criteria from the QUEST 2.0 in the new instrument (security, ease of use, comfort and effectiveness), six from the scoping review [4] and two from the study regarding potential usability criteria for manual wheelchair users [12]. Also, some criteria were linked to the same concept and were merged. They were added in parentheses as examples in the first version of the developed instrument. This first draft was developed in English and French. The decisions about which item to be included as main criteria or as an

Table 1. Sociodemographic profile of focus groups and field trial participants.

Personal characteristics	Focus groups ($n = 8$)	Field trial ($n = 8$)
Age (mean ± standard deviation in years)	38.1 ± 12	29.8 ± 13
Gender (Male:Female)	4:4	2:6
First language (French:English)	8:0	5:3
Wheelchair experience (Occasional:Permanent use)	5:3	6:2
Clinical experience/internship in occupational therapy, physiotherapy or kinesiology[a]	4	5
Research experience[a]	4	1
Education level		
High school (completed)	1	0
Postsecondary or ongoing first university level	1	3
First university level completed	2	4
Second or third university level	4	1
Employment status		
Employed (part-time:full-time)	1:4	3:3
Unemployed, not looking for employment	1	0
Volunteer (part-time:full time)	1:1	0:1
Student (part-time:full time)	1:1	0:3
Diagnosis for wheelchair permanent users[b]		
Spina bifida	2	1
Paraplegia	1	0
Hydrocephaly	1	0
Osteogenesis imperfecta	0	1
Number of accidents for permanent users ($n = 2$) (mean ± standard deviation)	1.3 ± 1	1 ± 1.4
Accidents needing medical consult (mean ± standard deviation)	0	0.5 ± 0.7
Experience with assistive technology tested		
Application tested (Google Maps Pedestrian)		8
Computer device used (smartphone)		8
Installation accessory		
Thighband		3
Adjustable smartphone/tablet stand		5
Type of wheelchair used		
Quickie		7
Orthofab		1
Experience with application tested		
More than 5 years		4
Less than 5 years		3
None		1

[a]Some participants had more than one type of experience.
[b]One participant had two diagnosis.

example were made based on the literature and the experience of the research coordinator and principal investigator (CV).

Appendix 1 presents the final English and French versions of the questionnaires, entitled ESGAT and the *Évaluation de la Satisfaction envers une Technologie Géospatiale d'Assistance (ÉSTGA)*. Page 1 includes space to acquire information on the user's profile and their experience with the technology and also provides instructions on how to fill the questionnaire. Pages 2 and 3 show satisfaction items 1 up to 12 (ease of access, learnability, hands-free function, ease of use, transportability/appearance, content, geographic information, effectiveness, efficiency, navigation assistance and security) with a satisfaction scale of 1 to 5. There is space for comments if the given score is less than 3. At the end of page 3, the user should encircle the three most important items according to his opinion and indicate a global appreciation of the GAT. Page 4 is a scoring sheet meant to compile the results.

Following the first version of the questionnaire, it was modified following the focus groups, and following the trial in the urban area. Table 2 shows the changes made in the questionnaire's 12 criteria from the first draft (first column), following the two focus groups (second column) and after the in-field trial (third column). After the two focus groups, only criterion 3 (hands-free function) remained exactly the same. Criteria 2, 4, 5, 8, 9, 10, 12 (learnability, ease of use, geographic information, effectiveness, efficiency and security) were precise and/or modified. Criteria 1, 6, 7, 11 underwent major changes. More specifically, ease of access to the planification and navigation service became "1-ease of access to the application". The cost aspect, which was judged essential by most experts, was added as a sub-criterion. The term maintenance was also added as an example of this criterion. The transportability criterion was modified for "6-transportability and the appearance" as most experts expressed that the appearance aspect was missing from the questionnaire. Consequently, dimensions and colour were added as sub-criteria. The details of the "7-content" criterion were completely changed and made broader by mentioning the clarity, quality and quantity of information, instead of specifying information on accessible locations and vocabulary used. The guidance criterion was changed to "11-navigation assistance" for understandability. For that criterion, the example correctness of the geographic position was reformulated to orientation accuracy, while indications about obstacles were added as another example.

After the experience with the GAT in an urban area, 7 minor changes were done in the criteria, with respect to wordings in the English version and 4 in the French version. Every change is indicated in italics in the third column of Table 2.

Feasibility and practicability of the questionnaires

Both questionnaires were rated as feasible (rf the possibility that can be made, done, or achieved, or is reasonable) and practicable (rf put into practice or usable for a specified purpose) to complete. Completing both questionnaires took approximately 10 to 15 min which is considered reasonable, including circling incorrect words. The variance in completing time of the questionnaires for the users is due to the number of written comments given by

Table 2. Content validation of the questionnaire's criteria through judgement and quantification, and field trials.

	List of criteria from the 1st draft of the questionnaire (before focus gr.)	List of criteria from the 2nd draft of the questionnaire (after 2 focus gr.)	List of criteria from the final questionnaire (after trial in field)[a]
1.	The ease of access to the planification and navigation service (installation of the application, registration process, user profile, mobile data performance, maintenance)?	The ease of access to the application (cost, installation, registration process, creation of user profile, Internet connection and network, maintenance, updates)?	The ease of access to the application (cost, installation, registration process, creation of user profile, Internet connection and network, maintenance, updates)?
2.	The learnability of the service (intuitive, familiarity and coherence with other applications)?	The learnability of the application (intuitive learning, intuitive use, similarity with other applications)?	The learnability of the application (intuitive learning, intuitive use, similarity with other applications)?
3.	The hands-free function (audibility, verbal commands, sound effects, vibratory mode, verbal instructions clarity, Bluetooth connections)?	The hands-free function (audibility, verbal commands, sound effects, vibratory mode, verbal instructions clarity, Bluetooth connections)?	The hands-free function (audibility, verbal commands, sound effects, vibratory mode, verbal instructions clarity, Bluetooth connections)?
4.	The ease of use during planification (manipulation, readability, letters and icons format)?	The ease of use during planification (manipulation, keys, readability, screen layout, icons, customization)?	The ease of use during *planning* (manipulation, keys, readability, screen layout, icons, customization)?
5.	The ease of use during navigation (manipulation, visibility, audibility, concentration, attention, memory)?	The ease of use during navigation (manipulation, visibility, audibility, required level of attention and memory, synchronisation with the environment)?	The ease of use during navigation (manipulation, visibility, audibility, required level of attention and memory, synchronisation with the environment)?
6.	The transportability of the device (portable, positioning support, solidity, handling, comfort)?	The transportability and the appearance (type of computing device and/or its support, solidity, stability, grip, comfort, dimensions, colour)?	The transportability and the appearance (type of computing device and/or its *installation accessory*, *robustness*, stability, grip, comfort, dimensions, colour)?
7.	The content presented (useful information on accessible locations, vocabulary used)?	The content presented (clarity, quality and quantity of information)?	The content presented (clarity, quality and quantity of information)?
8.	The nature of the proposed geographic information. (maps, routes and graphic directions, indications)?	The nature of the proposed geographic information (maps, routes, visual aspect of the itinerary)?	*The characteristics* of the proposed geographic information. (maps, routes, visual aspect of the itinerary)?
9.	The effectiveness for obtaining an accessible and safe route (goal achievement, routes recalculations, adaptation to unexpected changes)?	The effectiveness for obtaining an itinerary and reaching the destination (many routes possibilities, route recalculations, adaptation to unexpected changes)?	The effectiveness for obtaining an itinerary and reaching the destination (many routes possibilities, route recalculations, adaptation to unexpected changes)?
10.	The efficiency for obtaining a direct, accessible and safe route (fast and precise path, without unnecessary detour)?	The efficiency for obtaining an itinerary and reaching the destination (fast, without unnecessary detour, accessible and safe)?	The efficiency of the itinerary for reaching the destination *in an optimal way* (fast, without unnecessary detour, accessible and safe)?
11.	The guidance provided during the navigation (correctness of the geographic position, real-time location accuracy)?	The navigation assistance provided (indications about obstacles, real-time location accuracy, orientation accuracy)?	The navigation assistance provided (indications about obstacles, real-time location accuracy, orientation accuracy)?
12.	The security aspect of the application (feeling of trust while navigating, risky situations avoidance)?	The security aspect (reliability, absence of risk on the route)?	The security aspect (reliability, absence of *risky situations* on the route)?

[a]All words written in italics in the third column mean that the term or the wording changed from the second draft of the questionnaire (second column).

some of the participants; no comment was required when completing in the second language. Regarding the practical aspect of completing the questionnaire, the participants easily completed each of the three pages. On page 1, they quickly entered some words to clarify their profile. On pages 2 and 3, they circled without hesitation the 13 satisfaction scores out of 5, add comments when the rating was less than 3/5 and circled the 3 most important items. The vocabulary used in the questionnaires was relevant to the use of Google Maps in an urban area (no word was circled for the misunderstanding).

Usability of Google Maps Pedestrian

Google Maps Pedestrian was considered moderately usable by manual wheelchair users taking into account the three concepts evaluated. First, satisfaction is shown in Tables 3 and 4. The global appreciation of the GAT is 4.1 and 4 (quite satisfied), and the mean total scores for the ESGAT and ÉSTGA were 3.9 and 3.8 out of 5, respectively. They were scored equally by participants in the field trials for items 1, 5, 6, 8 and 12, but not for the other ones, where a small mean difference of 0.1 to 0.4 was observed. The three satisfaction criteria with the worst scores were navigation assistance (2.8/5 and 2.9/5), hands-free function (3.4/5 and 3/5) and security (3.5/5). Comments in Table 4 indicate the main issue with the navigation assistance was the lack of accuracy with the localization and orientation, provided by the application. The hands-free function received a poor ranking since the volume of the device could not be loud enough and some vocal indications had a long delay with actual experience. In terms of security, participants pointed out that Google Maps does not provide information regarding risks for wheelchair users and that it is difficult to see where to navigate while looking at the device, which can be dangerous. Finally, the three most important criteria chosen by the participants are navigation assistance ($n = 4$), effectiveness ($n = 3$) and ease of use during planning ($n = 3$).

Second, effectiveness observations are shown in Table 5 for the planning and navigation tasks with a GAT during the field trials ($n = 8$). In the context of testing a GAT with different routes, efficacy (defined as the performance of an intervention under ideal and controlled circumstances) could not be done, but the effectiveness (refers to its performance under "real-world" conditions) [28]. The planning task with the GAT was rated as "effective" (75% of the participants had fully completed it, 12.5% had completed it with errors and 12.5% partially completed it) as well as the navigation task (37.5% had fully completed the itinerary, 50% had completed it with errors and 12.5% needed help to complete their trip).

Third, efficiency is shown only for the navigation task in Table 5. Efficiency consists of the good use of time and energy in a way that does not waste any [29]. However, the navigating task was

Table 3. Scores for ESGAT and ÉSTGA questionnaires.

	ESGAT ($n = 8$)	ÉSTGA ($n = 8$)	Most important items
Related to the navigation aid application, how satisfied are you with the	Score on 5	Score on 5	
1. Ease of access (to the service)[a]	4.8	4.6	0
2. Learnability*	4.5	4.5	2
3. Hands-free function	3.4	3	2
4. Ease of use during planning	4.1	4.3	3
5. Ease of use during navigation*	3.1	3.1	2
6. Transportability and appearance*	4.1	4.1	1
7. Content	4.1	4.3	1
8. Geographic information*	4.3	4.3	2
9. Effectiveness	4.1	4	3
10. Efficiency	3.9	3.5	2
11. Navigation assistance	2.8	2.9	4
12. Security*	3.5	3.5	2
Mean score – service[a]	4.8	4.6	
Mean score – technology	3.8	3.8	
Mean score – total	3.9	3.8	
Mean score – global appreciation of the assistive technology	4.1	4	

ESGAT: Evaluation of Satisfaction with Geospatial Assistive Technology. *ÉSTGA*: *Évaluation de la Satisfaction envers une Technologie Géospatiale d'Assistance.*
[a]Equivalent of the mean score service (only one item).
*Item marked identically in English and French.

Table 4. Comments collected with ESGAT after the field trial.

Related to the navigation aid application, how satisfied are you with the	Typical comments after the field trial ($n = 8$)
1. Ease of access (to the service)	"Requires an Internet access, so not always accessible"
2. Learnability	"Sometimes difficult to change parameters"
3. Hands-free function	"The volume is not loud enough. The indications have a delay with reality"
5. Ease of use during navigation	"I had to plan ahead for crossing the street because it was not indicated" "Orientation of the arrow that shows the direction is not accurate"
6. Transportability and appearance	"Screen is hard to see with sun reflection"
7. Content	"Lack of choice of itinerary and does not provide the easiest"
8. Geographic information	"Its good for walking, but in a MWC its hard to know where the curbs are, what barriers exist on the route"
9. Effectiveness	"Lack of itinerary possibilities, no adaptation to unexpected changes, but we reach the destination"
10. Efficiency	"Does not indicate obstacles and accessibility for wheelchair"
11, Navigation assistance	"The app had a hard time with my location and orientation"
12. Security	"Should find a safer way to place the device in order to look at the screen and see where we are going at the same time" "Doesn't measure risks for wheelchair users"

ESGAT: Evaluation of Satisfaction with Geospatial Assistive Technology.

rated as "inefficient", since efficiency observations did not suggest routes easily completed by wheelchair participants; only one participant (12.5%) had fully completed the navigation task without loss of time and energy, 50% of participants completed the trip with errors of time and energy and 37.5% would not have completed it without human aid.

Table 6 presents the challenges met by participants while navigating with the geospatial assistive technology. It took approximately 78% more time to complete the trip in a wheelchair compared to what was estimated by the "pedestrian" option. The GAT does not seem to work well with a lower speed, such as that of a manual wheelchair user, as the direction arrow was oscillating a lot for half of the participants and the vocal indications (of turns, etc.) arrived too early in most cases (57%). Also, participants would have benefitted from receiving earlier vocal indication about the side of the street they must go as they could then have planned if they needed to cross the street (50%). Finally, 75% of participants faced damaged or congested sidewalks. Furthermore, sidewalk curb angle and sidewalk tilt (side slopes) were impossible to navigate for 25% of participants.

Discussion

In this study, both aims were achieved. A bilingual (English/French) questionnaire addressing the satisfaction with an assistive mobile application was developed in order to navigate in an urban area for wheelchair users and content validation of this questionnaire was completed. Following a trial in the field with manual wheelchair users, the feasibility and practicability of this questionnaire proved to be conclusive and usability of Google Maps Pedestrian was tested.

This is the first study that evaluated the satisfaction with a geospatial assistive technology for manual wheelchair users. Moreover, the tool developed is the first questionnaire having GATs as a topic. It can be compared to the QUEST regarding the number of criteria and the rating scale. By contrast, all 12 usability questionnaires identified by *Prémont* et al. [4,12,13] did not explore the aspect of disability, which is a central matter in this study.

This study also addressed the usability issue [10]. It considered satisfaction, effectiveness and efficiency of the planning and navigation tasks by individuals participating in a field trial and also by making observations using video footage post trials. Low-efficiency results corroborated the participants' dissatisfaction with the security, navigation assistance and hands-free function, as many challenges were met by participants on their path. Shultz et al. [30] and Nielson [31] recommended using more than one data collection method to assess the usability of technologies *already on market*, especially with elderly and fragile populations. In this study, data collection was twofold (self-administered questionnaire and video analysis of field trials). Table 3 clearly indicates an issue with the navigation assistance aspect of Google Maps, as this is ranked as the tool's worst function as well as the most important aspect in geospatial assistive technology for wheelchair users.

Table 5. Observations of the planning and navigation tasks with a GAT.

Field trial participants ($n = 8$)		
Planning	%	Comments
Selected user profile		
Pedestrian	100	
Others (bicycle, car, bus, etc.)[a]	0	
Effectiveness		
Completed	75	The app does not know the exit you want to take when in a big building
Completed with errors	12.5	The automatic suggestions might lead one to the wrong place if not careful
Partially completed (help needed)	12.5	Help needed to plan an itinerary
Unable to perform (without help)	0	
Navigation		
Installation accessory		
Leg strap holder	63	
Wheelchair cellphone holder	37	
Others (armband, velcro, etc.)	0	
Interface used		
Visual mode	100	
Hearing mode	87.5	
Touch mode	100	
Other (voice, sound and vibration)	0	
Interface changes	12.5	Due to a wrong vocal indication the participant decided to look only at the map for indications
Effectiveness		
Completed	37.5	
Completed with errors	50	Difficulty to orient themselves especially at the beginning, which led to some errors in direction
Partially completed (help needed)	12.5	Difficult route for wheelchair
Unable to perform (without help)	0.0	
Efficiency		
Completed	12.5	To surpass normal urban obstacles, one must have excellent wheelchair skills
Completed with errors	50	Tiring route with difficult obstacles proposed by the app but could be overcome
Partially completed (help needed)	37.5	Obstacles encountered that could not be overcome and needed human aid
Unable to perform	0	

GAT: geospatial assistive technology.
[a]Option of wheelchair was not available in Quebec City.

Strengths and limitations

All through this study's process, special attention was taken in order to recruit a diverse group of participants. Both for the focus groups and for the field trial, there was a contribution by permanent and temporary wheelchair users, French speaking, English speaking or bilingual individuals as well as researchers, clinicians and students. This consideration for the diversity of the population enhanced the reliability of the questionnaire's content validation and its feasibility assessment. This is definitely a strength of the content study. The content validation process was improved in setting up two distinct focus groups taking place one after the other while making corrections and adjustments between both groups. The feasibility and practicability of the measuring instrument were maximized, in repeating the same steps (described in the method above) for each trial participant. The only variable aspects were the itinerary, the type of manual wheelchair and the installation accessory used. Another strength of this study was apparent after analyzing the different results. In fact, the scores and comments received by participants after evaluating the assistive technology (Tables 3 and 4) were consistent with the observations made by a research professional (FD) while analyzing video footage of each trial (Tables 5 and 6). Both analyses highlighted issues with the technology's hands-free function, navigation assistance and security.

One of the study's limitations is that no test of bilingual aptitudes was requested for the 16 participants. They were considered functionally bilingual since they had followed English and French courses in high school, as it is the educational practice in Canada. In that sense, this can explain why the mean scores for ESGAT and ÉSTGA were slightly different (between 0.1 and 0.4) for seven items. Besides having to fill the second version of the questionnaire without having the first version they filled as a reference, some criterion not written in their first language could have been misinterpreted. Other work will be undertaken to determine if the difference is due to a translation that is not quite exact, a poor understanding by the participants, or a sample that is too small. Another limitation for practicability purposes was that only one assistive technology had been tested, namely the Google Maps application using a smartphone. Other applications (Plan, Yelp, etc.) or devices (tablet, tactile watch, augmented reality glasses, etc.) were not included in this study. Also, due to a lack of existing and available resources, the GAT tested (Google Maps) was not specifically meant for manual wheelchair users.

Future research

Future research is needed with the purpose of testing different GATs for manual wheelchair users, other applications than Google Maps. Furthermore, GATs should be tested with populations moving with diverse assistive devices (e.g., electric wheelchair users, pedestrians with a walker) in different cities. It also should be tested with electronic devices other than a smartphone. Finally, future research is needed to ensure the ESGAT's psychometric properties with a larger sample of permanent wheelchair users, such as test-retest reliability with manual wheelchair users. This will also ensure the external validity of the questionnaire.

Conclusions

In this article, a questionnaire of satisfaction with GATs for manual wheelchair users was developed in English and French. The 12 criteria proposed were considered to be the most important, based on multiple literature searches and on this study's focus groups. This instrument was proven validated in content, feasible

Table 6. Challenges encountered during the navigation task with the GAT.

Itinerary time		
Estimated time in minutes, mean (SD)	8.3 (1.3)	
Real time, in minutes, mean (SD)	14.8 (3.6)	
Percentage of difference	78	
Problems encountered	%	
Screen visibility	37.5	The sun makes it difficult to see
Volume	12.5	Traffic noises were problematic
Touch screen	00	
Voice activation	NA	
Sidewalk crossing ramp	25	Impassable for two participants but three others had difficulties
Sidewalk (damaged, congested)	75	Posts or garbage can on the sidewalk
Sidewalk tilt (side slopes)	25	Too steep or damage
Thresholds or borders at destination	38	Destination not accessible in wheelchair
Verbal indication too soon or too late	57	Indications arrived early
Incorrect indication	38	
The arrow does not indicate the right direction	50	Oscillating in various directions, which might lead to wrong vocal indications
Readjustment of the route needed	50	Especially to exit the parking at the beginning
A lack of indication where to cross	50	No indication in advance indicating you which the side of the street is your destination
Human intervention needed	38	To overcome steep ramps

GAT: geospatial assistive technology.

(10–15 min to fill) and practicable (vocabulary applicable and related to GAT). The field trials and observation videos also showed that low-efficiency results in navigating corroborated the participants' dissatisfaction with the security, navigation assistance and the hands-free function, as many challenges were met by participants on their route. This ESGAT questionnaire is the first instrument taking the disability aspect into account. The results suggest that further research is needed in order to test this measuring tool in different contexts. It is also possible to conclude that the questionnaire can be used with manual wheelchair users, but should be tested with individuals having other types of disabilities. More research is need with a bigger sample of permanent manual wheelchairs users to ensure the external validity of the questionnaire.

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Appendix 1.

Evaluation of Satisfaction with Geospatial Assistive Technology (ESGAT)

Name: ______________________________ Date: _____________________

Geospatial assistive technology tested (ex. app “X”): ____________________

Electronic device used: ❑ smartphone ❑ tablet ❑ tactile watch ❑ augmented reality glasses ❑ augmented reality headset ❑ other: _____________________
Electronic device’s brand: ____

Installation accessory: ❑ tablet/smartphone adjustable support ❑ armband ❑ thigh band ❑ other: _____________________________________

Wheelchair used (brand and type): __________________________________

User experience with technology tested:
❑ None
❑ I already use this technology since ________________ (number of years); frequency per month: ___________________
❑ I use another technology called ___________________since __________ (number of years); frequency per month: ___________________

The purpose of this questionnaire is to evaluate your satisfaction following the trial of a navigation aid application. The questionnaire consists of 12 satisfaction items.

- For each item, we are asking you to rate your satisfaction level by using the following scale of 1 to 5

1	2	3	4	5
not satisfied at all	not very satisfied	more or less satisfied	quite satisfied	very satisfied

- Please **circle** the one number that best describes your level of satisfaction with each of the 12 items.
- Please, answer all questions.
- If you are not very satisfied or not satisfied at all by some items, write a comment in the space provided. Thank you

1	2	3	4	5
not satisfied at all	not very satisfied	more or less satisfied	quite satisfied	very satisfied

Related to the navigation aid application, how satisfied are you with:	
1. The **ease of access** (cost, installation, registration process, creation of user profile, Internet connection and network, maintenance, updates)? *Comments*:	1 2 3 4 5
2. The **learnability** (intuitive learning, intuitive use, similarity with other applications)? In other words, how quickly did you become familiar with the navigation aid? *Comments*:	1 2 3 4 5
3. The **hands-free function** (audibility, verbal commands, sound effects, vibratory mode, verbal instructions clarity, Bluetooth connections)? *Comments*:	1 2 3 4 5
4. The **ease of use** during **<u>planning</u>** (manipulation, keys, readability, screen layout, icons, customization)? *Comments*:	1 2 3 4 5
5. The **ease of use** during **<u>navigation</u>** (manipulation, visibility, audibility, required level of attention and memory, synchronization with the environment)? *Comments*:	1 2 3 4 5
6. The **transportability and the appearance** (type of computer device and/or its installation accessory, robustness, stability, grip, comfort, dimensions, color)? *Comments*:	1 2 3 4 5
7. The **content** presented (clarity, quality and quantity of information)? *Comments*:	1 2 3 4 5

1	**2**	**3**	**4**	**5**
not satisfied at all	not very satisfied	more or less satisfied	quite satisfied	very satisfied

8. The characteristics of the proposed geographic information (maps, routes, visual aspect of the itinerary)? Comments:	1 2 3 4 5
9. The **effectiveness** for obtaining an itinerary and reaching the destination (many routes possibilities, route recalculations, adaptation to unexpected changes)? Comments:	1 2 3 4 5
10. The **efficiency** for reaching your destination in an optimal way (fast, without unnecessary detour, accessible and safe)? *Comments*:	1 2 3 4 5
11. The **navigation assistance** provided (indications about obstacles, real-time location accuracy, orientation accuracy)? *Comments*:	1 2 3 4 5
12. The **security** aspect (reliability, absence of risky situations on the route)? *Comments*:	1 2 3 4 5

Below is the list of the same 12 satisfaction items. PLEASE SELECT THE THREE ITEMS that you consider to be the most important to you. Please put an X in the **three boxes** of your choice.

- ❑ 1. Ease of access
- ❑ 2. Learnability
- ❑ 3. Hands-free function
- ❑ 4. Ease of use- planning
- ❑ 5. Ease of use- navigation
- ❑ 6. Transportability and Appearance
- ❑ 7. Content
- ❑ 8. Geographic information
- ❑ 9. Effectiveness
- ❑ 10. Efficiency
- ❑ 11. Navigation assistance
- ❑ 12. Security

What is your global appreciation of the geospatial assistive technology tested?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

*Comments:*____
____

ESGAT

(Scoring sheet)

This page is for scoring the answers to your questions. DO NOT WRITE ON THIS PAGE.

• Number of non-valid responses: __________

• **Technology** subscale score:__________
For items 2 to 11, add the ratings of the valid responses and divide this sum by the number of valid items in this scale.

• **Services** subscale score:__________
For item 1 (possibility of 5 points)

• **Total** ESGAT-Navigation score:__________
For items 1 to 12, add the ratings of the valid responses and divide this sum by the number of valid items.

• The 3 most important satisfaction items:
____
____
____

• Global appreciation score (out of 5):__________

Évaluation de la Satisfaction envers une Technologie Géospatiale d'Assistance (ÉSTGA)

Nom de l'utilisateur ______________________________ Date : ______________

Technologie d'assistance testée (ex. application « X »): _____________________

Appareil informatique utilisé : ❑ téléphone ❑ tablette ❑ montre tactile ❑ lunettes de réalité augmentée ❑ casque de réalité augmentée ❑ autre : _______________
Marque de l'appareil informatique utilisé : ________________________________

Accessoire d'installation : ❑ support ajustable pour tablette/smartphone ❑ brassard ❑ cuissard □ autre: __________________________

Fauteuil roulant utilisé (compagnie et modèle): ____________________________

Expérience utilisateur avec la technologie d'assistance testée :
❑ Aucune
❑ J'utilise déjà cette technologie depuis : ______________ (nombre d'années); fréquence d'utilisation par mois : ________________
❑ J'utilise une autre technologie appelée : _________________, depuis : ______ (nombre d'années); fréquence d'utilisation par mois : _________________

Ce questionnaire a pour but d'évaluer votre satisfaction à la suite de l'essai d'une application d'aide à la navigation. Le questionnaire comprend 12 énoncés de satisfaction.

- Pour chacun d'eux, nous vous demandons d'indiquer votre degré de satisfaction sur une échelle de 1 à 5.

1	2	3	4	5
pas satisfait(e) du tout	peu satisfait(e)	plus ou moins satisfait(e)	assez satisfait(e)	très satisfait(e)

- **Encerclez** le chiffre qui décrit le mieux votre degré de satisfaction pour chacune des 12 énoncés.
- S'il-vous-plaît, répondez à toutes les questions.
- Si vous êtes peu ou pas satisfait(e) de certains énoncés, inscrivez un commentaire dans l'espace prévu. Merci.

1	2	3	4	5
pas satisfait(e) du tout	peu satisfait(e)	plus ou moins satisfait(e)	assez satisfait(e)	très satisfait(e)

En lien avec la technologie géospatiale d'assistance, dans quelle mesure êtes-vous satisfait(e),	
1. De la **facilité d'accès** à la technologie (coût, installation, processus d'inscription, création du profil d'utilisateur, connexion et réseau internet, entretien, mises à jour)? *Commentaires :*	1 2 3 4 5
2. De l'**apprenabilité** de la technologie (apprentissage intuitif, l'utilisation intuitive, similitude avec d'autres applications)? En d'autres termes, la familiarisation avec l'aide à la navigation était-elle rapide? *Commentaires* :	1 2 3 4 5
3. De la fonction **main-libre** (audibilité, commandes vocales, effets sonores, mode vibratoire, clarté des indications verbales, connexions Bluetooth)? *Commentaires*:	1 2 3 4 5
4. De la **facilité d'utilisation** pendant la **planification** (manipulation, touches, lisibilité, affichage, icones, personnalisation)? *Commentaires*:	1 2 3 4 5
5. De la **facilité d'utilisation** pendant la **navigation** (manipulation, visibilité, audibilité, niveau requis d'attention et de mémoire, synchronisation avec l'environnement)? *Commentaires*:	1 2 3 4 5
6. De la **transportabilité et de l'apparence** (type d'appareil informatique et/ou de son, accessoire d'installation, solidité, stabilité, préhension, confort, dimensions, couleur)? *Commentaires:*	1 2 3 4 5
7. Du **contenu** présenté (clarté, qualité et quantité d'information)? *Commentaires:*	1 2 3 4 5

1	2	3	4	5
pas satisfait(e) du tout	peu satisfait(e)	plus ou moins satisfait(e)	assez satisfait(e)	très satisfait(e)

8. De la nature des **informations géographiques** (cartes, trajets, aspect visuel de l'itinéraire)? Commentaires:	1 2 3 4 5
9. De l'**efficacité** pour obtenir un trajet et atteindre la destination (plusieurs possibilités d'itinéraires, recalculs d'itinéraires, adaptation aux imprévus)? *Commentaires*:	1 2 3 4 5
10. De l'**efficience** du trajet pour se rendre à destination de manière optimale (rapide, sans détour inutile, accessible et sécuritaire)? *Commentaires*:	1 2 3 4 5
11. De l'**assistance à la navigation** (indications concernant les obstacles, exactitude de la position géographique, exactitude de l'orientation)? *Commentaires*:	1 2 3 4 5
12. De l'**aspect sécuritaire** (fiabilité, absence de situations risquées pendant le trajet)? *Commentaires*:	1 2 3 4 5

Vous avez ci-dessous la liste des 12 énoncés de satisfaction précédents. CHOISISSEZ LES TROIS ÉNONCÉS qui sont les plus importants pour vous. Inscrivez un X dans les **trois cases** qui correspondent à votre choix.

- ❑ 1. Facilité d'accès
- ❑ 2. Apprenabilité
- ❑ 3. Fonctions mains libres
- ❑ 4. Facilité d'utilisation - planification
- ❑ 5. Facilité d'utilisation - navigation
- ❑ 6. Transportabilité et Apparence
- ❑ 7. Contenu
- ❑ 8. Informations géographiques
- ❑ 9. Efficacité
- ❑ 10. Efficience
- ❑ 11. Assistance à la navigation
- ❑ 12. Sécurité

Quelle est votre appréciation globale de la technologie géospatiale d'assistance que vous avez testée? ❑ 1 ❑ 2 ❑ 3 ❑ 4 ❑ 5.

*Commentaires :*____

ÉSTGA

Feuille de cotation

Cette page est réservée pour calculer le pointage de vos réponses.
NE PAS ÉCRIRE SUR CETTE PAGE.

- Nombre de réponses non valides : __________

- Total de la sous-échelle **Technologie** : __________
  Additionnez les points des énoncés 2 à 11 et divisez cette somme par le nombre d'énoncés valides.

- Total de la sous-échelle **Services** : __________
  Énoncé 1 (sur 5 points)

- Pointage ÉSTGA **total** : __________
  Additionnez les points des énoncés 1 à 12 et divisez cette somme par le nombre d'énoncés valides.

- Les trois plus importants énoncés de satisfaction sont:

  ____
  ____
  ____

- Cote de l'appréciation globale (sur 5) : __________

Annexe 2

Article 2 (soumis) ; voir l'ESGAT-ESTGA **1.0** p. 54

Usability of a navigation application for safe travel with wheeled mobility device and, further validation of the Evaluation of satisfaction with geospatial assistive technology

Abstract

Purpose: Knowledge of route accessibility is indispensable for 'wheeled mobility device' users to travel safely and efficiently; however, current navigation technologies barely provide adapted information for this population. Aims of the study were to collect data on the usability of a navigation application and to propose a version 1.0 of the Evaluation of satisfaction with geospatial assistive technology, i.e., the ESGAT/ÉSTGA questionnaires in English and French, by addressing the criterion, construct and cross-cultural validities.

Method: A filmed field trial and a methodological study were conducted in parallel. Thirty wheeled mobility device users were filmed planning and making a 10-minute journey using HERE WeGo. The ESGAT/ÉSTGA and the *Computer System Usability Questionnaire* were administered and, a video observation grid for the effectiveness and efficiency of HERE WeGo. Descriptive, correlation and multiple match analyses were performed.

Results: Fourteen men and 16 women (mean age of 45.9 years) tried out HERE WeGo; 14 were powered wheelchair users. Usability of the app was moderate (good effectiveness, moderate efficiency and quite satisfied). The criterion validity of the ESGAT was good ($r=0.598$; $p<0.001$). The construct validity was average considering the results for factor 1 ($\alpha=0.789$, acceptable), factor 2 ($\alpha=0,586$, low) and factor 3 ($\alpha=0.409$, unacceptable). The cross-cultural validity (French vs English) was moderate ($r=0.861$; $p<0.001$).

Conclusion. ESGAT-ÉSTGA 1.0 questionnaires are now available in English and French with a total mean score (11 items), an informatics subscore (mean of 5 items) and a geomatic subscore (mean of 6 items). Their validation should be pursued with new navigation applications.

Key words:

Mobile device; geospatial assistive technology; usability engineering; wheelchair user; scooter, wheeled mobility, mobility impairment; urban accessibility; user interface

Usability of a navigation application for safe travel with wheeled mobility device and further validation of the Evaluation of satisfaction with geospatial assistive technology

Introduction

Knowledge of route accessibility is indispensable for 'wheeled mobility device' users to travel safely and efficiently; however, current navigation technologies barely provide adapted information for this population [1]. Wheeled mobility devices (WMD) include scooters, powered and manual wheelchairs. WMD users would like to avoid physical barriers such as high ramps and curbs, blocked curbs, steep ramps, etc., as such obstacles can prevent them from reaching a desired destination [2]. Avoiding such obstacles would, therefore, increase their social participation and reduce disability situations. This is because, disability occurs when individuals living with impairments find their participation limited by the presence of barriers in their environment [3]. Some applications such as Google Maps [4] and Wheelmaps [5] use crowdsourcing to provide information about the accessibility of public places, such as the presence of accessible entrances and accessible restrooms [6,7]. However, Wheelmaps does not provide WMD users with adapted and accessible itineraries to reach the public places in question, [7] whereas Google Maps features accessible public transport routes in London, New York, Tokyo, Mexico City, Boston, and Sydney [8], but no pedestrian routes adapted to WMD users' needs proposed. Some route planning aids for WMD users are currently available such as OpenRouteService's Maps Client [9] and Classic Maps [10], developed by Heidelberg Institute for Geoinformation Technology using data from OpenStreetMap, which feature wheelchair accessible routes. However, wheelchair accessible itineraries are only available in Europe for the moment and no real-time route planning application for mobile devices is available yet; although geospatial assistive technology can be used on a mobile device if accessed with a web browser [11]. The navigating tool providing wheelchair users with the most accessibility information is, to our knowledge, Route4U, a navigation application [13] that features personalised routes for users of WMD. This app will select the best possible route, considering user-set preferences on features such as maximum curb height, maximum slope inclination and minimum width. The application then informs the user about possible routes, including accessibility level. Although Route4U features crucial information and to facilitate route planning for users of mobility devices, only portions of five cities (Dublin, Portsmouth, Angers, Budapest Swords and Székesfehérvár) have been mapped at this point. To summarize, while some navigation applications for WMD users have been developed, there is still a lack in the quantity and quality of the information they provide.

To overcome the lack of data regarding the usability of geospatial assistive technologies (GATs) for wheelchair users, *Prémont et al.* [14] conducted a scoping review in 2018 with the purpose of assembling a list of GATs usability criteria for wheelchair users as such a list was then non-existent. As a result, 54 criteria were identified by extracting and selecting criteria from 15 articles selected through an exhaustive literature review. In the course of the study, 12 usability questionnaires were examined and none of them had been validated as applicable for wheelchair users, which attests to the lack of data regarding the usability of navigation aids of wheelchair users.

A face-to-face cross-sectional study published in 2019 in which *Prémont et al.* [15] proposed 15 potential usability criteria identified from 17 community-dwelling manual wheelchair users (aged 18–45 years) who used a mobile device. A semi-structured interview was conducted with them, using four video clips presenting technologies related to GATs (applications on a smartphone or smart watch, augmented reality glasses, virtual reality helmet); they were questioned about the perceived advantages and disadvantages of route planning prior to travel and navigation while receiving guidance in urban areas with these GATs; and they were asked to rank fifteen defined usability criteria by importance.

Based on these studies [14,15] and to make up for the lack of tools to assess GATs usability for wheelchair users, *Vincent et al.* (2020) developed a tool measuring wheelchair users' satisfaction when using GATs: the *Evaluation of satisfaction with geospatial assistive technology* (ESGAT) and its French version the *Évaluation de la satisfaction envers une technologie géospatiale d'assistance* (ÉSTGA) [16]. The content of the questionnaire (English and French) was validated through two focus groups, and its feasibility and practicability were validated by the means of a field trial, with 8 wheelchair users, five of them being temporary users. The field trial also served the purpose of evaluating the usability of Google Maps Pedestrian for manual wheelchair users, which was done using the ESGAT/ÉSTGA to evaluate the users' satisfaction and an observation grid to evaluate the effectiveness and efficiency of the GAT used. The participants were the most dissatisfied with the navigation assistance, the hands-free function and the security criteria, which scored 2.8/5 and 2.9/5, 3.4/5 and 3/5, and 3.5/5 respectively.

It is important to know the metrological properties of the instrument and to have it in two official languages of Canada. The instrument was not translated, it was really created initially in both languages in parallel [16]. It is also important to evaluate the usability of a GAT, to be able to look at usability (user satisfaction with the effectiveness and efficiency) of a GAT in a pedestrian journey.

The general purpose of the present study was to collect data on the usability of a navigation application and to propose a version 1.0 of the ESGAT/ÉSTGA questionnaires by continuing their validation. The specific research objectives were: (1) To assess the usability of a navigation application (mobility app) when used by WMD users within their neighbourhood, and (2) To evaluate the criterion validity, the construct validity and the cross-cultural validity of the English and French versions of the ESGAT/ÉSTGA.

Given the inaccessibility of a GAT customized for WMD (example, we can't use Route4U), we formulated this research hypothesis. H1: GAT costumed for pedestrians will be moderately effective, poorly efficient and WMD users will be moderately satisfied with it. Given the need to measure the metrological properties, we have formulated the following research hypotheses. H2: half of the ESGAT/ÉSTGA items, which are specific to WMD users, will predict the same outcome as a tool measuring informatics usability. H3: ESGAT/ÉSTGA measures two dimensions: the mobile computer assistive technology and the geographical localisation aspects. H4: ratings given by bilingual participants will be similar in both versions of the questionnaire.

Method

Research designs

A filmed field trial and a methodological study were conducted in parallel. For "usability" in the field trial, we will refer to the concepts of effectiveness, efficiency and satisfaction, defined according to ISO 9241-11:2018 [17]. Therefore, for the purpose of this study, effectiveness is defined as the "accuracy and completeness with which users achieve specified goals", efficiency is defined as the "resources used in relation to the results achieved" and satisfaction is defined as the "extent to which the user's physical, cognitive and emotional responses that result from the use of a system, product or service meet the user's needs and expectations" [17]. For the methodological study, according to the American Psychological Association's Dictionary of Psychology, the criterion validity or criterion-related validity is defined as "an index of how well a test correlates with an established standard of comparison (i.e., a criterion)" [18]. The construct validity can be defined as "the degree to which a test or instrument is capable of measuring a concept, or other theoretical entity" [19]. *Porta* (2016) defines cross-cultural validity as "the degree to which the performance of the items on a translated or culturally adapted health related-patient reported outcomes (HR-PRO) instrument are an adequate reflection of the performance of the items of the original version of the HR-PRO instrument" [20]. The present study was approved by ethics committee [redacted]

Sample and recruitment

Based on a subject to item ratio (2.5), a sample of 30 WMD users is sufficient to pursue the validation of the questionnaire (which includes 12 items). The participants were recruited through community-based partners and within a list of former participants who had agreed to be contacted for other research projects (Inclusion criteria for the sample were the following: 1- Being at least 18 years old; 2- being able to propel themselves autonomously with a manual, powered or scooter type wheelchair, i.e., without human, for a minimum of thirty minutes; 3- being familiar with using a smartphone or a computer tablet; 4 - Being able to communicate in English or French and 5 - Living within the perimeter of Quebec City or its surroundings.

Intervention

The HERE WeGo [21] mobility app is a navigation application that suggests itineraries for the user to reach a destination by foot, car or public transport. It provides the user with the time required to reach their destination, and with vocal and visual indications during navigation. The application features two different maps, default and satellite, and provides information about traffic.

Dependent variables

An observation grid was produced to assess the usability of google map pedestrian in Vincent et al [16]. This grid evaluates the effectiveness and efficiency of a GAT used during navigation, as well as the level of success achieved in planning the itinerary and the level of success of the mobile device's support used. The grid is composed of two sections: Planning and Navigation. The Planning section includes the "user profile", where the evaluator selects the travel mode used by the GAT user (car, pedestrian, bus, bicycle, airplane, wheelchair). It also includes the "route request", where the starting and ending points of the itinerary are indicated; whether the vocal mode was used to dictate the itinerary; the display parameters used (map, satellite, itinerary, other); the preference options used; and the estimated travel time. The success level of the route request was evaluated on a four-level scale: 4-completed, 3-completed with error, 2-partially completed with human assistance and 1-unable to perform. The Navigation section of the observation grid consists of four subsections. In the "functionality of the smartphone/tablet holder" subsection, the evaluator indicates the type of support used (thigh band, arm band, mobile device holder attached to the wheelchair or scooter, direct fixation with Velcro band, or other). In the "interface used for aided navigation" subsection, the evaluator indicates which navigation modes were used (visual, auditory, tactile, vocal, sound, and/or vibration mode). In the "effectiveness" subsection, the evaluator indicates the actual travel time and rates the navigation application's effectiveness, defined as a safe mobilization from point A to point B without human assistance. The effectiveness was rated on a four-level scale: 4-completed, 3-completed with error, 2-partially completed with human assistance and 1-unable to perform. In the "efficiency" subsection (defined as the capacity of reaching the destination optimally), the efficiency was graded on a four-level scale according to the number and types of obstacles faced during navigation. The evaluator also indicated the type of obstacles and the frequency with which they were encountered within a list of 22 potential obstacles (see table 3). The observation grid [16] was updated for the present study. It was determined that not all obstacles had the same degree of impact on efficiency; therefore, each obstacle was given a weight between 0.25 and 1 point. For example, participants reported that when verbal indications arrived too early it was not hindering very much (i.e. 0.25) but when they were too late, that could lead to bigger problems (i.e. 1.00) Thus, the efficiency scores were weighted according to obstacles encountered. A four-level scale was then used to qualify the completion of the walking route including the type of obstacles encountered.: 4-"completed" if between 0 and 0.99 point, 3-"completed with error" if 1 to 2.99, 2-"partially completed" if 3 to 4.99, and 1-"unable to perform" if 5 or more.

The ESGAT/ÉSTGA is composed of sociodemographic questions (age, diagnostic, mobile device used, type of mobile device support used, type of WMD used, geospatial assistive technology used and experience with geospatial assistive technologies). Items are formulated in 12 questions for the following criteria: Ease of access, Learnability, Hands-free function, Ease of use/planning, Ease of use/navigation, Transportability and Appearance, Content, Geographic information, Effectiveness, Efficiency, Navigation assistance, and Security. Each of question is formulated with contextual examples. GAT user indicates their satisfaction on a 1 to 5 scale (1 meaning "not satisfied at all" and 5 being "very satisfied") for each item. Scoring 3 or less, the participant is invited to explain why, in the space comment. The GAT user also indicates which three out of the twelve criteria are the most important to them along with their global appreciation of the GAT tested on a 1 to 5 scale.

The Computer System Usability Questionnaire (CSUQ), developed by Lewis (1995) [22], is a questionnaire assessing the satisfaction of users regarding the usability of a computer system.

It is composed of 19 questions and answers are given on a seven-point scale according to the level of agreement of the computer system user with each of the 19 statements (1 meaning “I strongly disagree” and 7 meaning “I strongly agree). The statements are based on multiple usability criteria such as the simplicity and ease of use; the learnability; the clarity, organisation and understandability of the information provided; the “functions and capabilities” provided; the ability to complete a task “efficiently”, “quickly” and “effectively”; the satisfaction regarding mistakes and problem solving; the satisfaction regarding the system’s interface; and global satisfaction. The computer system user is also asked to list three positive and negative aspects regarding the system used.

Procedure

An undergraduate occupational therapy student as a research intern met each of the participants individually at the participants’ residence, each meeting lasting from 60 to 80 minutes. Consent forms were filled by the participants. The experimental procedure included five steps: 1) The participants were asked to install the HERE WeGo application (from version 2.0.14156 to 4.1.390) on their mobile device and research intern helped the participants to configure the right audio settings; 2) The participants were asked to plan a ten-minute long itinerary using the HERE WeGo application. The mobile device was then fixated according to the participant’s preference. The research intern offered some Velcro band and Velcro tape to make a thigh band or to fixate the device on the wheelchair’s armrest if needed. The planning of the itinerary was video recorded (10-20 minutes); 3) The participants were then asked to activate the navigation mode of the application and to follow the indications to get to their destination. The participants had to propel themselves autonomously, but the research intern made sure that the participant traveled safely towards their destination and provided help if needed. The navigation towards the destination was video recorded.; and 4) The participants were asked to answer the three following questionnaires in order: ÉSTGA, CSUQ and ESGAT. The latter was only answered if the participant was bilingual (20 minutes). 5) Following the meetings, the planning and navigation videos were reviewed and evaluated by the research coordinator and the research intern, with the use of the observation grid. The answers to the three questionnaires as well as the data from the observation grid were compiled in an Excel file.

Data analysis

Descriptive statistics were done for all questionnaires and the evaluation grid, to assess the usability of the HERE WeGo application (total mean score, item mean scores, median, standard deviation, frequencies and percentages). To assess the criterion validity, a Spearman's correlation analysis was done between the mean scores of the four computer related items of the ESGAT/ÉSTGA (1-6) and the total mean scores for the CSUQ, as both are measuring the same construct. It was hypothesized that a strong positive correlation would result between the ESGAT/ÉSTGA items and the CSUQ score ($r = 0.7$-0.9 [23]). To determine construct validity, a multivariate statistical technique was used to test if ESGAT/ÉSTGA items were grouped according to the two constructs they were based on, i.e., the mobile computer assistive technology factor (items #1-6) and the geographic navigation factor (items# 7-12). A multiple correspondence analysis (MCA) was performed between ESGAT/ÉSTGA items. Each item was dichotomized based on the 50% lower answers and 50% higher answers. The Cronbach's alpha served to judge the internal consistency of items of each factor (> 0.7 being acceptable [22]). To evaluate the cross-cultural validity of the English and French versions, a Spearman's correlation analysis was done between the ratings of ESGAT and ÉSTGA given by bilingual participants.

Results

Thirty participants (14 men and 16 women) tried out the HERE WeGo mobility app. Most of them were powered wheelchair users (n=14). The mean age was 45.9+/-11.3 years and the most frequent diagnosis was paraplegia (n=7) followed by tetraplegia (n=4). None were familiar with the HERE WeGo application, but 19 of them were accustomed to the use of another navigation application such as Google maps, while 11 did not have previous experience with a navigation application. Seventeen participants used an Android phone and thirteen, an IOS phone. Table 1 presents the sociodemographic profile of the field trial participants.

[Insert table 1 here]

Usability

The usability of the navigation aid was ranked as moderate, given the result of the three measurements (satisfaction, effectiveness, efficiency).

The **satisfaction** was measured by the French version of the ESGAT/ÉSTGA (n=30), with a total mean score of 4.15 out of 5 (SD = 0.53). The average global appreciation score given by the participants was 3.90 (SD = 1.01), indicating that the participants were quite satisfied with the HERE WeGo application (see Table 2). Notably, the items that were the most unsatisfying according to the participants were the ease of use during navigation (3.77 SD = 1.01), the effectiveness (3.93 SD = 1.11), the navigation assistance (3.77 SD = 1.07)) and the security aspect (3.87 SD = 1.11. For the English version of the ESGAT/ÉSTGA (n=16) the average total mean score was 4.05 (SD = 0.5) and the average global appreciation score given by the participants was 3.53 (SD = 1.19). In both versions of the questionnaire, the ease of access was most often judged as the most important satisfaction criterion, followed by the hands-free function, the ease of use during planning and the geographic information criteria. Our research hypothesis (that WMD users will be moderately satisfied with the navigation application) was not confirmed because they were more satisfied than expected (a score of 4 out of 5 is **quite satisfied**).

[Insert table 2 here]

The **effectiveness** of the application was measured by the observation grid, with a mean score of 3.47 (min 1.00 – max 4.00). Most participants (23) succeeded in planning their itinerary whereas three succeeded with errors, one needed help to succeed and three were unable to perform the planning. For the effectiveness of the navigation aspect, most participants (20) successfully reached their destination whereas six participants succeeded in reaching their destination but made mistakes, two participants needed help to reach their destination safely and two participants did not reach their destination. Our hypothesis (which suggested that the GAT would be moderately effective) was not confirmed, since the effectiveness was higher than expected. It is considered to have a **high** effectiveness.

The **efficiency** of the application was also measured by the observation grid, with a mean score of 2.67 (min 1.00 – max 4.00). In contrast, four participants successfully completed the navigation, fifteen participants completed it with errors, two participants partially completed their itinerary, while three participants were unable to reach their destination. The obstacles that were most frequently met were the following: verbal indications given too soon or too late or absence of verbal indications (50.0%), traveling on the street for a long portion of the trip and not on the sidewalk (46.7%) and incorrect indications (33.3%). Table 3 presents the scores given for the effectiveness during planning and navigation, and table 4 the detailed efficiency scores and obstacles met during navigation. Our hypothesis (that said GAT will be poorly efficient) was not confirmed, since efficiency was above poorly efficient (>2 out of 4). Thus, the efficiency is **moderate** but the high rate of unexpected obstacles and the longer travel time (+25.2%; see table 3) must also be considered.

[Insert table 3 here]

[Insert table 4 here]

Criterion validity

Table 5 presents the results of the 19 items of the CSUQ. The criterion validity was calculated by the Spearman's correlation between the total mean CSUQ score (5,8/7 SD 0,9) and mean ESGAT/ÉSTGA score of items #1-6 related to mobile computer assistive technology (4.2/5 SD 0.5). There was a positive and significant correlation between the two scores ($r=0.598$; $p<0.001$). Our hypothesis (that half items of the ESGAT predict the same outcome of a tool measuring informatics usability but for WMD users) was confirmed. Figure 1 shows that most participants had a similar relation (slope) between questionnaires. The criterion validity is considered to be good.

[Insert table 5 here]

[Insert figure 1 here]

Construct validity

Multivariate correlation analyses showed that the construct of this questionnaire version was better explained by a model composed of three dimensions (Table 6). Together, they explained 61.4% of the total inertia (variance) observed; factor 1 explicates 30.1% of the variance ($\alpha=0.789$, acceptable), factor 2 explains 18.0% ($\alpha=0.586$, low) and factor 3 explains 13.3% ($\alpha=0.409$, unacceptable). It is to be noted that 6 out of 12 items are associated with their predicted dimension and that 5 others contribute significantly (more than half of the higher score) to their predicted dimension (see figure 2). Factor 1 includes items from 1 to 6, apart from item 3 (Hands-free function) and 5 (Ease of use- navigation). Besides, items 7 to 12 all contribute, at least partially, to the factor 2 except for the item 8 (Geographic information) and 11 (Navigation assistance). Questioning on why items 8, 10-12 contributed more to the first factor, resulted in the items' revision as presented in the next section. Our hypothesis (that the ESGAT/ÉSTGA measures two dimensions: mobile computer assistive technology and geographical localisation aspects) was partially confirmed, since 11 out of 12 items fell under the two dimensions. The construct validity was average considering that factor 1 was acceptable, factor 2 was low and factor 3 was unacceptable.

[Insert table 6 here]

[Insert figure 2 here]

Cross-cultural validity

Sixteen participants completed the English version of the ESGAT/ÉSTGA. Spearman' correlations indicated a very strong positive association between the French and English versions for the total mean scores ($r=0.861$; $p<0.001$) and the geographic navigation factors ($r=0.849$; $p<0.001$). For their part, the French and English mobile computer assistive technology factors were strongly correlated ($r=0.793$; $p<0.001$). Most individual items were significantly correlated (r ranged from 0.897 to 0.529) apart from items 5, 6, 7, 8 and 11 (r ranged from 0.494 to 0.003) (see table 2). Our hypothesis (that the ratings given by bilingual participants are similar in both versions of the questionnaire) was partially confirmed. The cross-validity is considered moderate for the initial questionnaire.

Considering the results of the cross-cultural validity analysis, the items below were reworded and reviewed by two bilingual external researchers (specialized in mobility) that their first language is the English (see acknowledgement). **Item 3** (hands-free function) is the main component of factor 3. It can be described as a sensory dimension (auditory, vocal, vibratory computer interface) which makes it somewhat apart. However, it remains in the informatics theoretical dimension, because it is indeed a criterion for the usability of computer aids. Both **items 4 and 5** were evaluating the ease of use, one for the planning and the other for the navigation. The ease of use during navigation was classified in the second factor in the construct analysis rather than the first one as it was hypothesized. Possibly, the word "navigation" associated it with geomatics aspect. Both items were merged to address the possible confusion between them. Also, the examples were also reworked to reflect this broader concept, "manipulation, keypad, readability, visibility, audibility, screen layout, icons, customizability". To better capture the essence of **item 6** (transportability and the appearance, now item 5) and its comprehension in both languages, it was decided to change the examples from "type of computer device and/or its accessory of positioning, robustness, stability, grip, comfort, dimensions, color" to "accessory for positioning the computer device, robustness, stability, grip, comfort, dimensions, color". The answers to **item 7** (content presented, now item 6) were not consistent between the French and the English version. It was reworked for more clarity by two new bilingual researchers into: The presentation of content (clarity, quality and quantity of information during planning and navigation, including street names, distances, etc.)? For **item 8** (characteristics of the proposed geographic information, now item 7), it would be better to use "map, directions, route, indication of slopes, pavement/sidewalk quality, traffic, curb cut, etc." as it would be more detailed and precise. For **item 11** (now item 10), the concept of navigation assistance was not well understood by several participants. Based on participants' feedback, it would be beneficial to precise that this measure is about the "real-time" navigation assistance and to change examples to "correction of the route, warning of obstacles, location accuracy, orientation accuracy, required level of attention and memory". **Item 12**, the aspect of security (now item 11), was also revised for more clearness and to better represent real-life situations including between parentheses occurrence of risky situations, respecting road safety code, clear directions.

ESGAT/ÉSTGA 1.0

Tests and changes presented in this article have resulted in the first official versions of these questionnaires. Each version now consists of 11 items, contains 2 theoretical sub-scores and a main score that are reported on a 5 points scale. English and French versions are available in Appendix.

Discussion

In this study, we collected data to evaluate the usability of a navigation application when used by WMD users. To do so, we tested and then refined an observation grid to assess its effectiveness and efficiency and we assessed the validity of the French and English version of the ESGAT/ÉSTGA questionnaire to measure participants' satisfaction regarding this app. Our four research objectives were met, but only one hypothesis was confirmed, otherwise two were partially confirmed and one was not confirmed.

Our 1st hypothesis was not confirmed. We predicted that efficiency of HERE WeGo would be lower than the two other usability factors but they were all higher than expected (good effectiveness, moderate efficiency and quite satisfied with the mobile app). It had an effectiveness of 3.47/4 (86.8%), an efficiency of 2.67/4 (66.8%) and a satisfaction of 4.15/5 (83.0%), for a mean of 78.8%. We conclude that HERE WeGo was moderately usable for a population using a MWD. The efficiency has shown that it takes a longer time for them to complete their travel (+25%) and that many obstacles that were not announced by the mobile app were encountered. The higher efficiency might be explained by the weighting of each obstacle in the observation because the weighting was not in place when this hypothesis was formulated. Furthermore, leaving from home and using a known path might have played a role in the higher effectiveness and satisfaction. It is worth noting that the efficiency was the least frequent item to be selected by participants as their most important aspect of the ESGAT/ÉSTGA (see table 2). It was the first time they used the application, so the ease of access, hands-free function and ease of use for planning were far more important. Also, the efficiency matters a lot less considering that they did not need to go to their destination to fulfil a need and they were not in a hurry. It was done for a research purpose, so they possibly gave less importance to the efficiency of the GAT.

Due to the correlation analysis, we consider that our 2nd hypothesis was confirmed (that half items of the ESGAT-ÉSTGA, which are specific to WMD users, predicts the same outcome of a tool measuring informatics usability). As we can see in figure 1, the vast majority of participants keep their rank between questionnaires (e.g. someone with a high score in the CSUQ also had a high score in the ESGAT/ÉSTGA)

Our 3rd and 4th hypothesis are partially confirmed (that the ESGAT/ÉSTGA measures two dimensions: mobile computer assistive technology and geographical localisation aspects; that the ratings given by bilingual participants are similar in both versions of the questionnaire). Even though the cross-cultural validity was high as a whole, a large proportion of items were not significantly correlated between versions (items 5, 6, 7, 8 and 11). It is possible that the lower number of participants in this analysis (n=16) made it more susceptible to outliers. Nevertheless, when we consider that many of the same items also “escaped” their theoretical dimension in the construct validity analysis, there are incentives to revisit the items to improve their translation. Furthermore, the internal consistency (Cronbach's Alpha) of the second and third dimensions were low, and redefinition of some items is needed to strengthen them and to possibly reduce to two dimensions. We are confident that the new proposed version (ESGAT/ÉSTGA 1.0) will improve the cross-cultural validity and internal consistency, but it is to be tested.

Strengths and Limitations of the study

This study has good internal validity, as the concepts measured, the dependent and independent variables are detailed, as is the entire data collection process. The statistical analyses used were consistent for the methodological specifications. The use of two English-speaking mobility researchers to ensure the adequacy between the items of the two versions is an asset for this study. Regarding the WMD participant's profile, it was well balanced between power and manual mobility. This study led to the development of better assessment tools, such as the improvement of the observation grid (weighting and detailed barriers or obstacles), the revision of the wording of some ESGAT/ÉSTGA items and taking into account the three concepts of usability.

The external validity was limited for many reasons. For the trial, WMD users had left from their home and they knew the path that was planned and executed. At times, it is fortunate that the participants knew where they were going because they would have reportedly been more stressed; the navigation aid was not adapted for wheeled mobility device, and we were in COVID-19 times. The trial has been realised only in optimal conditions in terms of weather (no rain, no ice, no snow). Half of the participants were not bilingual, so the sample for the cross-cultural validation iwa limited. A selection bias was also possible when answering the questionnaires, as mentioned in the discussion.

Future research

Future research is needed to continue the validation of the ESGAT/ÉSTGA 1.0 with new applications, new populations, with unknown routes. It is also important to document the effectiveness and efficiency of new navigation applications, like Route4U Hive, that is offered in only few cities for wheelchair mobility at this time. Our future hypothesis is that the usability of a GAT like Route4U Hive would be excellent, since it would consider features personalised routes for manual ("active") wheelchair users, "powered" wheelchair users, "hand bike" users, "pram" users and pedestrians. That WMD users can adjust the following accessibility settings to meet their needs: Maximum curb height up, maximum curb height down, maximum slope up, maximum slope down, and minimum width [13]. That the WMD users will be informed about the roughness, the curb height and the inclination of the sidewalks as well as about the accessibility level of sidewalks and public places and it is also possible for users to report obstacles. That this accessibility in real time will be the same as the color code on the GAT: green for "accessible", yellow for "uncomfortable", orange for "with assistance", red for "not accessible" and grey for "no accessibility data". Route4U also developed a sidewalk information system called Route4U Hive [12], which is currently only available as a demo. Route4U Hive features "accessibility indices" ("walkability, rollability and inclusion index"), "sidewalk properties" ("roughness, curb heights, incline, width, paving materials and reported obstacles") and suggests routes for pedestrians and wheelchair users.

Conclusion

This study presented results from a filmed field trial, with 14 individuals using a power wheelchair, 8 a manual wheelchair and 8 a scooter. They all tested a navigation app for the first time, on a journey from their home to a location of their choice, lasting approximately 10 minutes. This study also shows results of the metrological qualities of the *Evaluation of satisfaction with geospatial assistive technology*, and the ESGAT/ÉSTGA 1.0 questionnaires. Essentially, it can be concluded that the usability of the HERE Wego, an application customized for pedestrians, was moderate (good effectiveness, moderate efficiency and quite satisfied), considering that WMD users took 25% longer to get to their destination than indicated at the time of planning and that the app did not indicate the many obstacles on the way. For the ESGAT/ÉSTGA, the criterion validity was good, since six items that measure satisfaction for mobile computer assistive technology are strongly correlated with the 19 items of the Computer System Usability Questionnaire (CSUQ). The cross-cultural validity was moderate, adjustments had to be made for five items in both languages (English and French version). Finally, the construct validity is average; modifications were made and the ESGAT/ÉSTGA now presents a sub-score for 5 items concerning the mobile computer assistive technology aspect, and a sub-score for 6 items regarding the geolocation for navigation. ESGAT/ÉSTGA 1.0 questionnaires are now available to pursue its validation with new navigation applications, new populations and unknown routes, in combination of documenting their effectiveness and efficiency.

APPENDIX.

Evaluation of Satisfaction with Geospatial Assistive Technology (ESGAT 1.0)

Name: ________________________________ Date: ______________________

Geospatial assistive technology tested (ex. app “X”): ______________________

Electronic device used: □ smartphone □ tablet □ tactile watch □ augmented reality glasses
□ augmented reality headset □ other: ______________________________________
Electronic device’s brand: ____

Electronic device’s positioning accessory: □ tablet/smartphone adjustable support
□ armband □ thigh band □ other: ____
Wheeled mobility device used (brand and type): ___________________________
Principal diagnosis: ____

Age: ____________

User experience with technology tested:
□ None
□ I already use this technology since _________________ (number of years); frequency per month: ____________________
□ I use another technology called ____________________since ___________ (number of years); frequency per month: ____________________

The purpose of this questionnaire is to evaluate your satisfaction following the trial of a navigation aid application. The questionnaire consists of 11 satisfaction items.

- For each item, we are asking you to rate your satisfaction level by using the following scale of 1 to 5

1	**2**	**3**	**4**	**5**
not satisfied at all	not very satisfied	more or less satisfied	quite satisfied	very satisfied

- Please **circle** the one number that best describes your level of satisfaction with each of the 11 items.
- Please, answer all questions.
- If you are not very satisfied or not satisfied at all by some items, write a comment in the space provided.

Thank you.

1	2	3	4	5
not satisfied at all	not very satisfied	more or less satisfied	quite satisfied	very satisfied

Informatics

How satisfied are you with:

1. The **ease of access** (cost, installation, registration process, creation of user profile, internet connection and network, maintenance, updates)? *Comments*:	1 2 3 4 5
2. The **learnability** (intuitive learning, intuitive use, similarity with other applications)? *Comments*:	1 2 3 4 5
3. The **hands-free function** (audibility, verbal commands, sound effects, vibratory mode, verbal instructions clarity, Bluetooth connections)? *Comments*:	1 2 3 4 5
4. The **ease of use** (manipulation, keypad, readability, visibility, audibility, screen layout, icons, customizability) *Comments*:	1 2 3 4 5
5. The **transportability and the appearance** (accessories for positioning the computer device, robustness, stability, grip, comfort, dimensions, color)? *Comments*:	1 2 3 4 5

1	2	3	4	5
not satisfied at all	not very satisfied	more or less satisfied	quite satisfied	very satisfied

Geomatics

How satisfied are you with:

6. The presentation of **content** (clarity, quality and quantity of information during planning and navigation, including street names, distances, etc.)? Comments:	1 2 3 4 5
7. The characteristics of the proposed **geographic information** (map, directions, route, indication of slopes, pavement/sidewalk quality, traffic, curb cut, etc.)? Comments:	1 2 3 4 5
8. The **effectiveness** for obtaining an itinerary and reaching the destination (many routes possibilities, route recalculations, adaptation to unexpected changes)? Comments:	1 2 3 4 5
9. The **efficiency** for reaching your destination in an optimal way (fast, without unnecessary detour, accessible and safe)? *Comments*:	1 2 3 4 5
10. The **real-time navigation assistance** provided (correction of route, warning of obstacles, location accuracy, orientation accuracy, required level of attention and memory)? *Comments*:	1 2 3 4 5
11. The **aspect of security** (occurrence of risky situations, respecting road safety code, clear directions)? *Comments*:	1 2 3 4 5

Below is the list of the same 11 satisfaction items. PLEASE SELECT THE THREE ITEMS that you consider to be the most important to you. Please put an X in the **three boxes** of your choice.

- ❑ 1. Ease of access
- ❑ 2. Learnability
- ❑ 3. Hands-free function
- ❑ 4. Ease of use
- ❑ 5. Transportability and Appearance
- ❑ 6. Content
- ❑ 7. Geographic information
- ❑ 8. Effectiveness
- ❑ 9. Efficiency
- ❑ 10. real-time navigation assistance
- ❑ 11. Aspect of security

What is your global appreciation of the geospatial assistive technology tested?

□ 1 □ 2 □ 3 □ 4 □ 5

*Comments:*____

ESGAT 1.0

(Scoring sheet)

This page is for scoring the answers to your questions. DO NOT WRITE ON THIS PAGE.

• Number of non-valid responses: _______

• **Informatics** subscale score: _______
add the ratings of the valid responses (items **1 to 5**) and divide this sum by the number of valid items.

• **Geomatics** subscale score: _______
add the ratings of the valid responses (items **6 to 11**) and divide this sum by the number of valid items.

• **Total** ESGAT-Navigation score: _______
For items 1 to 11, add the ratings of the valid responses and divide this sum by the number of valid items.

• The 3 most important satisfaction items:
____
____
____

- Global appreciation score (out of 5):__________

Évaluation de la Satisfaction envers une Technologie Géospatiale d'Assistance (ÉSTGA 1.0)

Nom de l'utilisateur ______________________________ Date : ______________
Technologie d'assistance testée (ex. application « X »): ______________________

Appareil informatique utilisé : □ téléphone □ tablette □ montre tactile □ lunettes de réalité augmentée □ casque de réalité augmentée □ autre : _________________________
Marque de l'appareil informatique utilisé : ________________________________

Accessoire de positionnement de l'appareil informatique : □ support ajustable pour tablette/smartphone □ brassard □ cuissard □ autre: __________________________

Aide à la mobilité roulante utilisée (compagnie et modèle): _________________

Diagnostic principal : ____

Age : ______________________

Expérience utilisateur avec la technologie d'assistance testée :
□ Aucune
□ J'utilise déjà cette technologie depuis : ______________ (nombre d'années); fréquence d'utilisation par mois : ________________
□ J'utilise une autre technologie appelée : _________________, depuis : ______ (nombre d'années); fréquence d'utilisation par mois : _________________

Ce questionnaire a pour but d'évaluer votre satisfaction à la suite de l'essai d'une application d'aide à la navigation. Le questionnaire comprend 11 énoncés de satisfaction.

- Pour chacun d'eux, nous vous demandons d'indiquer votre degré de satisfaction sur une échelle de 1 à 5.

1	**2**	**3**	**4**	**5**
pas satisfait(e) du tout	peu satisfait(e)	plus ou moins satisfait(e)	assez satisfait(e)	très satisfait(e)

- **Encerclez** le chiffre qui décrit le mieux votre degré de satisfaction pour chacune des 11 énoncés.
- S'il-vous-plaît, répondez à toutes les questions.
- Si vous êtes peu ou pas satisfait(e) de certains énoncés, inscrivez un commentaire dans l'espace prévu.

Merci.

1	2	3	4	5
pas satisfait(e) du tout	peu satisfait(e)	plus ou moins satisfait(e)	assez satisfait(e)	très satisfait(e)

Informatique

Dans quelle mesure êtes-vous satisfait(e),

1. De la **facilité d'accès** à la technologie (coût, installation, processus d'inscription, création du profil d'utilisateur, connexion et réseau internet, entretien, mises à jour)? *Commentaires :*	1 2 3 4 5
2. De l'**apprenabilité** de la technologie (apprentissage intuitif, l'utilisation intuitive, similitude avec d'autres applications)? *Commentaires* :	1 2 3 4 5
3. De la fonction **main-libre** (audibilité, commandes vocales, effets sonores, mode vibratoire, clarté des indications verbales, connexions Bluetooth)? *Commentaires*:	1 2 3 4 5
4. De la **facilité d'utilisation** (manipulation, touches, lisibilité, visibilité, affichage, icones, audibilité, personnalisation)? *Commentaires*:	1 2 3 4 5
5. De la **transportabilité et de l'apparence** (accessoires de positionnement de l'appareil informatique, solidité, stabilité, préhension, confort, dimensions, couleur)? *Commentaires:*	1 2 3 4 5

1	2	3	4	5
pas satisfait(e) du tout	peu satisfait(e)	plus ou moins satisfait(e)	assez satisfait(e)	très satisfait(e)

Géomatique

Dans quelle mesure êtes-vous satisfait(e),

6. Du **contenu** présenté (clarté, qualité et quantité d'information lors de la planification et de la navigation incluant le nom des rues, les distances, etc.)? Commentaires :	1 2 3 4 5
7. Des **informations géographiques** présentées (carte, itinéraires, trajet, indication des pentes, de la qualité de la chaussée, de la circulation, descente de trottoir, etc.)? Commentaires :	1 2 3 4 5
8. De l'**efficacité** pour obtenir un trajet et atteindre la destination (plusieurs possibilités d'itinéraires, recalcules d'itinéraires, adaptation aux imprévus)? *Commentaires* :	1 2 3 4 5
9. De l'**efficience** du trajet pour se rendre à destination de manière optimale (rapide, sans détour inutile, accessible et sécuritaire)? *Commentaires*:	1 2 3 4 5
10. De l'**assistance à la navigation en temps réel** (correction de l'itinéraire, indications concernant les obstacles, exactitude de la position géographique, exactitude de l'orientation, niveau requis d'attention et de mémoire)? *Commentaires*:	1 2 3 4 5
11. De l'**aspect sécuritaire** (avertissement de situations risquées, respect du code de sécurité routière, absence de confusion dans les indications)? *Commentaires*:	1 2 3 4 5

Vous avez ci-dessous la liste des 11 énoncés de satisfaction précédents. CHOISISSEZ LES TROIS ÉNONCÉS qui sont les plus importants pour vous. Inscrivez un X dans les **trois cases** qui correspondent à votre choix.

- ❑ 1. Facilité d'accès
- ❑ 2. Apprenabilité
- ❑ 3. Fonctions mains libres
- ❑ 4. Facilité d'utilisation
- ❑ 5. Transportabilité et Apparence
- ❑ 6. Contenu
- ❑ 7. Informations géographiques
- ❑ 8. Efficacité
- ❑ 9. Efficience
- ❑ 10. Assistance à la navigation
- ❑ 11. Aspect sécuritaire

Quelle est votre appréciation **globale** de la technologie géospatiale d'assistance que vous avez testée? □ 1 □ 2 □ 3 □ 4 □

*Commentaires :*____

____

ÉSTGA 1.0
Feuille de cotation

Cette page est réservée pour calculer le pointage de vos réponses.
NE PAS ÉCRIRE SUR CETTE PAGE.

- Nombre de réponses non valides : __________
- Total de la sous-échelle **informatique** : __________
  Additionnez les points des énoncés 1 à 5 et divisez cette somme par le nombre d'énoncés valides
- Total de la sous-échelle **géomatique** : __________
  Additionnez les points des énoncés 6 à 11 et divisez cette somme par le nombre d'énoncés valides
- Pointage ÉSTGA **total** : __________
  Additionnez les points des énoncés 1 à 11 et divisez cette somme par le nombre d'énoncés valides.
- Les trois plus importants énoncés de satisfaction sont:
  ____
  ____
  ____
- Cote de l'appréciation globale (sur 5) : ________

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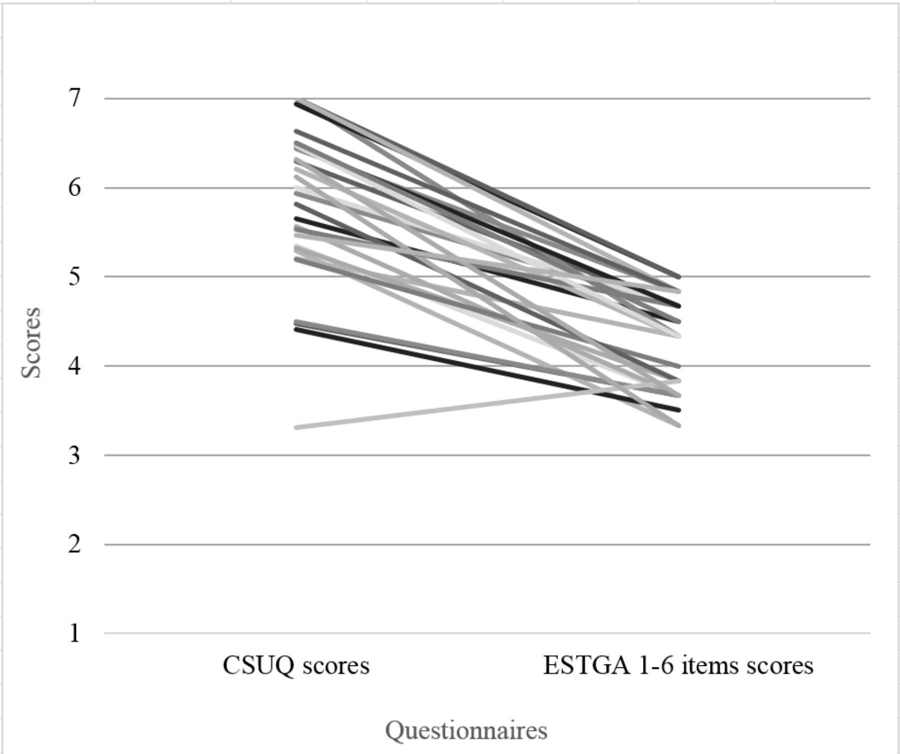

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Figure 1 Caption: Relations between the CSUQ scores and the ESGAT/ÉSTGA 1-6 items scores of all participants (n=30). The higher the similarity between slopes is the better will be the correlation. Legend: The vertical axis is 1 to 7, since the CSUQ score varies between 1 and 7, and the ÉSTGA score varies between 1 and 5.

Figure 1 Alt Text: There is a graphic representation of 30 participants who rated 6 computer-related items in the ESGAT/ÉSTGA, on a scale of 1 to 5, and a representation of CSUQ respondents, on a scale of 1 to 7. The higher the similarity between slopes is the better will be the correlation. We can see that all high scores on the ESGAT/ÉSTGA also have high scores on the CSUQ, as well as the few moderate scores.

Figure 1 Long Description: There is a graphic representation of 30 participants who rated 6 computer-related items in the "Evaluation of satisfaction with geospatial assistive technology", on a scale of 1 to 5, and a representation of "Computer system usability questionnaire" respondents, on a scale of 1 to 7. The higher the similarity between slopes is the better will be the correlation. We can see that almost all high scores on the "Evaluation of satisfaction with geospatial assistive technology" also have high scores on the "Computer system usability questionnaire", as well as the few moderate scores.

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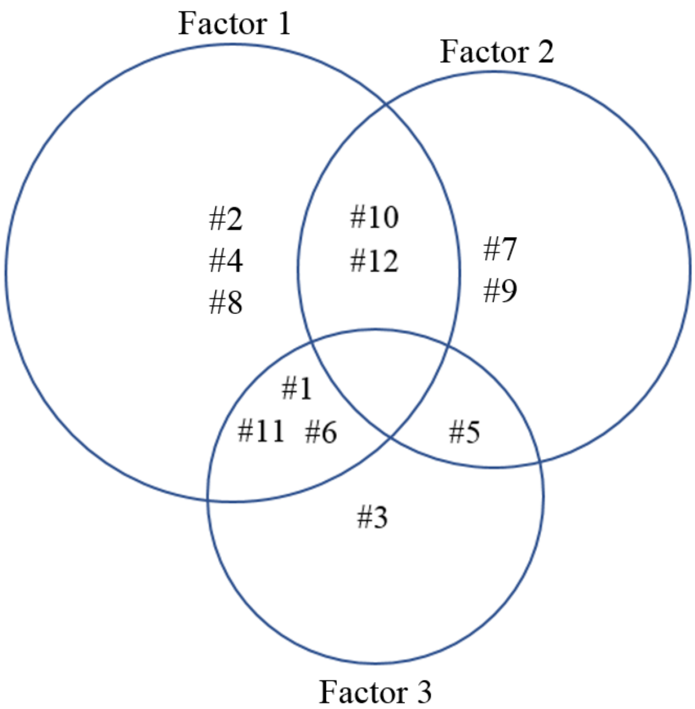

Figure 2 Caption: Distribution of items between factors. To be contested by two factors, an item must have at least, for the second factor, half of the contribution of the higher one. Legend. #1: Ease of access, #2: Learnability, #3: Hands-free function, #4: Ease of use- planning, #5: Ease of use- navigation, #6: Transportability and Appearance, #7: Content, #8: Geographic information, #9: Effectiveness, #10: Efficiency, #11: Navigation assistance, #12: Security.

Figure 2 Alt text: There are three circles each representing a theoretical factor including the 12 items evaluated in the ESGAT questionnaire. The third circle contains one item by itself and shares 4 items with the other two circles. The other two circles contain 3 and 2 items respectively: the first circle shares 5 items with the other two circles, while the second circle shares 3. Two items are only shared by the first and second circle. To be contested by two factors, an item must have at least, for the second factor, half of the contribution of the higher one.

Figure 1 Long Description: There are three circles each representing a theoretical factor including the 12 items evaluated in the ESGAT questionnaire. The third circle contains one item by itself (Hands-free function) and shares 4 items with the other two circles (Ease of access; Navigation assistance; Transportability and Appearance; Ease of use- navigation). The other two circles contain 3 items (Learnability; Ease of use- planning; Geographic information) and 2 items (Content; Effectiveness) respectively by themselves: the first circle shares 5 items with the other two circles, while the second circle shares 3. Two items are only shared by the first and second circle (Efficiency; Security). Visually speaking, we can therefore conclude that the first two factors best explain the questionnaire's construct, but that a third theoretical factor could possibly be considered.

Table 1. Sociodemographic profile

Personal characteristics	n	%
Sex		
Men	14	46.7
Women	16	53.3
Age		
18-30	3	10.0
31-40	8	26.7
41-50	9	30.0
51-60	4	13.3
61-75	6	20.0
Mean (SD): 45.9 (11.3)		
Wheeled mobility devices (WMD)		
Powered wheelchair	14	46.7
Manual wheelchair	8	26.7
Scooter	8	26.7
Diagnosis		
Paraplegia	7	23.3
Tetraplegia	4	13.3
Arthrogryposis	2	6.7
Amputation	2	6.7
Multiple sclerosis	2	6.7
Spina Bifida	2	6.7
Spinal amyotrophy	2	6.7
Becker Muscular Distrophy	1	3.3
Cerebral palsy	1	3.3
Poliomyelitis	1	3.3
Pseudothalidomide syndrome	1	3.3
Not disclosed	5	16.7
Past experience with GAT		
Yes	19	63.3
No	11	36.6

Table 2. Detailed satisfaction scores of the French version of ESGAT/ÉSTGA and correlation with the English version

Items	Mean Score ÉSTGA n=30	SD	Median	Mean Score ESGAT n=16	SD	Spearman's correlation for cross-cultural validity (r)
1. Ease of access	4.53	0.82	5.00	4.75	0.45	0.832
2. Learnability	4.40	0.67	4.50	4.56	0.63	0.897
3. Hands-free function	4.00	1.11	4.00	3.88	1.45	0.983
4. Ease of use- planning	4.33	0.76	4.50	4.44	0.63	0.636
5. Ease of use- navigation	3.77	1.01	4.00	4.00	1.15	0.494 NS
6. Transportability and App earance	4.43	0.73	5.00	4.38	0.62	0.294 NS
7. Content	4.30	0.84	5.00	4.13	1.02	0.003 NS
8. Geographic information	4.43	0.73	5.00	3.81	1.11	0.399 NS
9. Effectiveness	3.93	1.11	4.00	3.81	1.05	0.529
10. Efficiency	4.07	1.08	4.00	3.75	1.00	0.867
11. Navigation assistance	3.77	1.07	4.00	3.63	1.09	0.113 NS
12. Security	3.87	1.11	4.00	3.56	1.31	0.841
Total mean score	**4.15**	**0.53**	**4.17**	**4.05**	**0.52**	
Global appreciation score	3.90	1.01	4.00	3.53	1.19	
Most important criterion	n	%				
1. Ease of access	14	46.67				
3. Hands-free function	13	43.33				
4. Ease of use - planning	12	40.00				
8. Geographic information	11	36.67				
5. Ease of use - navigation	8	26.67				
9. Effectiveness	8	26.67				
11. Navigation assistance	7	23.33				
12. Security	6	20.00				
2. Learnability	4	13.33				
6. Transportability and Appearance	3	10.00				
7. Content	2	6.67				
10. Efficiency	1	3.33				

NS: Spearman's correlation non-significant, i.e. $p > 0.05$

Table 3. Details of planning and navigation, including effectiveness and efficiency scores from the observation grid (n=30)

Items	n	%	mean [SD]
Planning (min 1.00 – max 4.00)			3.53 [0.97]
4pts-Completed	23	76.7	
3pts-Completed with errors	3	10.0	
2pts-Partially completed (help needed)	1	3.3	
1pt-Unable to perform (without help)	3	10.0	
Navigation			
Installation accessory used			
Velcro leg strap	10	33.3	
Held in hand	10	33.3	
Direct fixation on wheelchair with Velcro	8	26.7	
Device holder fixated on wheelchair	2	6.7	
Velcro arm band	0	0.0	
Level of success (min 1.00 – max 4.00)			3.40 [0.89]
4pts-Completed	20	66.7	
3pts-Completed with errors	2	6.7	
2pts-Partially completed (help needed)	8	26.7	
1pt-Unable to perform (without help)	0	0.00	
Effectiveness (min 1.00 – max 4.00)			3.47 [0.90]
4pts-Completed	20	66.7	
3pts-Completed with errors	6	20.0	
2pts-Partially completed (help needed)	2	6.7	
1pt-Unable to perform (without help)	2	6.7	
Efficiency (min 1.00 – max 4.00)			2.67 [0.84]
4pts-Completed (0-0.99 obstacles)	4	13.3	
3pts -Completed with errors (1-2.99 obstacles)	15	50.0	
2pts-Partially completed (3-4.99 obstacles)	8	26.7	
1pt-Unable to perform (5+ obstacles)	3	10.0	
Time planned (min)	30		11.5 [2.9]
Real time (min)	30		14.4 [5.9]
Percentage of difference			+25.2 [43.4]

Table 4. Details of problems encountered during navigation (n=30)

Problems	Weight	Occurrence (n)	%
Verbal indication too soon or too late or absence of verbal indications		15	50.0
Too soon	0.25	4	13.3
Too late	1.00	11	36.7
Traveling on the street for a long portion of the trip and not on the sidewalk		14	46.7
Considered safe	0.50	12	40.0
Considered risky	1.00	2	6.67
Incorrect indications	0.50	10	33.3
Sidewalk (damaged or congested)	0.75	9	30.0
Unannounced road work	1.00	7	23.3
Human intervention necessary	1.00	5	16.7
Inaccessible sidewalk tilts (side slopes)	1.00	3	10.0
Readjustment of the route needed	0.75	3	10.0
A lack of indication where to cross	0.75	3	10.0
Sound or volume	0.50	2	6.7
Problems fixing or positioning the phone	0.50	2	6.7
The arrow does not indicate the right direction	0.50	2	6.7
Destination not present on arrival (automatic fail)	-	2	6.7
Screen visibility	0.25	1	3.3
Touch screen	0.25	1	3.3
Inaccessible thresholds or borders at destination	1.00	1	3.3
Inaccessible sidewalk crossing ramp	1.00	0	0.0
Voice activation	0.25	0	0.0
Change in the choice of interface	0.25	0	0.0
Other	Observer's judgement	5	16.7

Table 5 Criterion validity – Computer System Usability Questionnaire (CSUQ) data, mobile computer assistive technology dimension (ESGAT-ÉSTGA items 1-6) and their correlation.

Items (1-19) of CSUQ What best describes your experience (1-7)		n	Mean	SD	Median
1	Overall, I am satisfied with how easy it is to use this system.	29	6.2	1.1	6.0
2	It is simple to use this system.	30	6.2	0.9	6.0
3	I can effectively complete my work using this system.	29	6.0	1.5	7.0
4	I am able to complete my work quickly using this system	29	6.0	1.6	6.0
5	I am able to efficiently complete my work using this system.	29	5.9	1.6	7.0
6	I feel comfortable using this system	29	5.9	1.2	6.0
7	It was easy to learn to use this system.	29	6.0	1.2	6.0
8	I believe I became productive quickly using this system.	28	5.8	1.4	6.0
9	The system gives error messages that clearly tell me how to fix problems	9	4.7	2.1	5.0
10	Whenever I make a mistake using the system, I recover easily and quickly.	14	5,6	1.6	6.0
11	The information (such as on-line help, on-screen messages and other documentation) provided with this system is clear.	13	5.5	0.9	5.0
12	It is easy to find the information I need.	27	5.8	1.7	6.0
13	The information provided with the system is easy to understand.	29	6.2	0.9	7.0
14	The information is effective in helping me complete my work.	27	5.7	1.4	6.0
15	The organization of information on the system screens is clear.	28	6.1	1.1	6.0
16	The interface of this system is pleasant.	28	5.9	1.3	6.0
17	I like using the interface of this system	28	5.8	1.4	6.0
18	This system has all the functions and capabilities I expect it to have.	29	5.3	1.7	5.0
19	Overall, I am satisfied with this system.	28	5.5	1.6	6.0
CSUQ total [1]		30	5.8	0.9	6.0
ÉSTGA –mobile computer assistive technology dimension[1, 2]		30	4.2	0.5	4.3

Note 1. Spearman's correlation is r=0,598, *p*-value <0.001.
Note 2. ESGAT-ÉSTGA item (1 to 6) scores are presented in table 2.

Table 6 – Multiple correspondence analysis results of ESGAT-ÉSTGA

	Factors		
	1	2	3
1. Ease of access	0,313	0,027	0,191
2. Learnability	0,678	0,058	0,006
3. Hands-free function	0,079	0,089	0,514
4. Ease of use- planning	0,455	0,169	0,005
5. Ease of use- navigation	0,012	0,228	0,424
6. Transportability and Appearance	0,285	0,078	0,245
7. Content	0,147	0,416	0,001
8. Geographic information	0,424	0,116	0,009
9. Effectiveness	0,058	0,351	0,035
10. Efficiency	0,402	0,291	0,030
11. Navigation assistance	0,372	0,0010	0,139
12. Security	0,388	0,336	0,001
% of Variance	30,106	18,000	13,339
Cronbach's Alpha[1] (α)	0,789	0,586	0,409

Note 1. The value α is less than or equal to 1, being generally considered "acceptable" from 0.7. α coefficients that are less than 0.5 are usually unacceptable.