

氏名	Briane Paul Veal Samson
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論文審査委員	主査 角 康之 副査 白石 陽 副査 角 薫 副査 葛岡 英明（東京大学・教授）

## 論文要旨

Modern navigation applications are now ubiquitous in the daily commutes of drivers to avoid congested roads in urban areas. This enthralls governments to use it as a potential tool that could promote sustainable routes and promote altruistic driving behaviors among its driving citizens. With a traffic management system that helps avoid traffic congestion, drivers who commute daily can be distributed and be recommended to follow alternative paths. But this "smart city" approach can face challenges in convincing daily commuters because they already have regular and familiarized routes.

In this dissertation, I posit that route information and navigation guidance provided by modern navigation applications can be redesigned to motivate drivers to choose unselfish routes. I focus on the HCI aspect of the traffic management problem and ask the question of how to encourage drivers to follow system optimal routes for their daily commutes. Motivated by the previous literature around navigation applications, HCI of recommender systems, traffic psychology and behavior, and factors that affect route choice, and my positionality as a non-driver, I begin with an observational study of drivers using modern navigation systems and applications in their daily commutes. It was found that while drivers choose a recommended route in urgent situations, many still preferred recommendations that are familiar to them. Additionally, they make deviations while following their original choice because of

unfamiliar roads, lack of local context, perceived driving unsuitability, and inconsistencies with realized navigation experiences.

Then, I rethink navigation applications as a form of civic technology by evaluating two separate techniques, each focused on a different step in the driving navigation task. With the goal of encouraging unselfish route choices while still respecting the agency and self-efficacy of a user or driver, the Self-Determination Theory was used to inform the designs. When a driver plans the trip before driving, the first is a GUI-based technique that provides motivative and familiarity information to route recommendations. By providing motivative information such as critical mass, travel time gains and overall positive benefits of choosing the unselfish route, along with the number and names of familiar roads, drivers were convinced to choose the unselfish route at least once. But it was most likely when driving from home to work and they are provided with information about the overall positive benefit of choosing the unselfish route along with a list of familiar roads. For drivers with moderate impersonal and controlled orientation based on SDT, information that emphasizes social comparison would be more effective. During a trip, traffic conditions along a chosen route might change. The second is a voice-based technique that uses two-party conversations between voice agents in giving alternative turns or routes. It was able to convince drivers to follow alternative routes as they are made available, especially when the alternative route is appropriate for the trip scenario. Hearing conversations between two voice agents gave drivers a point of comparison to reflect better on their realized and forgone choices, possibly affecting future choices. However, drivers can still experience increased workload especially during time-constrained navigational maneuvers and turns.

Refining and combining both techniques, I culminate this dissertation with Navigo, a holistic approach that uses personality-targeted design in providing motivative and familiarity information before a trip. While driving, it plays motivative messages when the driver chooses an unselfish route, and a two-party conversation when the driver chooses otherwise. Its evaluation showed supporting evidence that showing the list of familiar roads and positively framing the benefits of an unselfish route choice can encourage drivers to choose unselfish routes. And this unselfish choice can be sustained by providing them frequently in different trip scenarios. When a driver follows an optimal route, the two-party conversation was successful in encouraging them to switch into following an unselfish route especially when they have diverse experiences of

following different routes. When the drivers choose the unselfish route at the beginning, the provision of motivative messages along the trip was successful in encouraging drivers to stick to following unselfish routes. Here, I challenge the rigidity of existing navigation application designs and start a conversation of what navigation applications can and should be. In order to realize further its potential in shaping sustainable driving behavior, designers should include diverse stakeholders (e.g. government, communities) in the co-design of their applications and underlying algorithms.

### 審査結果の要旨

本博士論文は、交通渋滞緩和のために非利己的な経路選択を運転者に促すナビゲーションシステムを実現する技術の開発と評価に関するものである。本論文は8章で構成されており、序章、関連研究調査から始まる。本論の最初では（3章）、現状の一般的なナビゲーションシステムを利用する際の運転手の行動観察を行い、システムから提示された経路を運転手が選択するか否かは経路への慣れや運転状況に大きく依存することを確認した。その結果に基づいて、4章では運転者を非利己的な行動に導くためのシステム設計に向けて、本研究の根幹となる内発的動機づけ理論（Self-Determination Theory）を導入する。その上で、運転を始める前の複数経路提示と選択（5章）、運転中の音声による経路案内（6章）のそれぞれについて、非利己的な経路の選択を促す手法の提案を行い、ユーザが非利己的経路を選択する動機づけへの影響を評価した。5章では、非利己的経路を選ぶことによる渋滞緩和への貢献や慣れた道の割合の表示の仕方がどのように非利己的経路選択に影響するかを明らかにした。6章では、最適経路、慣れ親しんだ経路、混雑回避のための迂回経路の3種類の経路を推薦する3つの音声エージェントによる会話を提示するナビゲーションシステムを提案し、運転シミュレータ実験によりユーザ反応を分析した。7章ではこれらの知見を受け、前の2章のシステムを統合した運転シミュレーション実験によって非利己的な経路選択の動機づけの効果について評価し、ユーザの性格との関係も分析した。8章は結言である。

本論文が扱うのは何気ない人間の心理であり、運転中の状況や運転者の性格など様々なことに依存する。したがって、単純に複数手法を比較して明確な差が出るわかりやすい結果が得られるような内容ではなく、無意識の行動による定量的変化、行動変化のパターン分類、そしてその背景にある理由の聞き取りといった様々な角度での分析が重要である。本研究で確認された知見（慣れ親しんだ道は選ばれやすい、他者への貢献が読み取りやすい情報提示が効果的である、といったこと）そのものは結果的には単純な内容であるが、実際の自動車内の観察、オンライン実験、運転シミュレータによる実験といった複数の実験プラットフォームの実装、複数の被験者実験の統計的分析を通して、身近な市民科学的

トピックを対象とした研究手法を確立した貢献は大きい。これらの成果の一部は Human-Computer Interaction分野の重要国際会議ACM CHIの2019（フルペーパー，3章部分）と2000（ポスター発表，6章部分）で発表しており，専門分野からも一定の評価を受けている。

審査委員からは，タイトルの再考，概要や最終章のまとめ直し，動機付けの心理学や説得技術に関する関連研究調査を充実させるべきといった指摘があった。これらについてはその後修正がなされ，全体を通して，システム情報科学の博士論文としての学術的意義や社会的価値を的確に記述できていることを確認した。以上のことより，システム情報科学の博士論文として合格と判定する。