Human Factors in Transportation, Vol. 95, 2023, 182–193
https://doi.org/10.54941/ahfe1003804

Exploring Proactivity in Human-Vehicle Interaction: Insights for Proactive Interaction Design

Jinglu Li and Xiaohua Sun

College of design and innovation, Tongji University, Shanghai, China

ABSTRACT

Artificial Intelligence (AI) is rapidly evolving, and systems are becoming more proficient in collaborating with humans. These systems not only respond to users' requests but can also anticipate their potential needs and meet them. However, the understanding of proactivity in the context of human-vehicle interaction is limited, and existing research is based on common sense rather than a clear concept of proactivity. In this study, we explore the theme and concept of proactivity in human-vehicle interaction through a literature review and case study. We also provide insights about the content that needs to be designed for proactive interaction. The study's findings will help researchers and designers better comprehend proactive interaction in the new relationships between humans and vehicles and support interaction design in this field.

Keywords: Proactivity, Proactive interaction, Autonomous vehicle, Design contents

INTRODUCTION

The aim of this paper is to explore the concept of proactive interaction from existing literature and illustrate its application in proactive interaction design. By doing so, we aim to enhance the comprehension of proactive interaction design. Furthermore, we intend to identify the content of human vehicle proactive interaction, which can be leveraged to create effective and efficient proactive interaction designs.

THE RELATED WORKS OF PROACTIVITY

To explore the means of proactivity in human-vehicle interaction, we follow the prior study in many different disciplines, including human-computer interaction(HCI), human-robot interaction(HRI), human-vehicle interaction, and occupational psychology. It's worth understanding one term from different views in different contexts. We choose 20 critical papers from hundred related papers for inductive analysis.

We summarize information from a set of research papers, and categories them including author, year, context, description, discipline, and keywords in Table 1. The context is the proactivity-related context in the paper. The description is the proactivity-related description in the paper. Keywords are

Table 1. The description of proactivity in different disciplines.

No.Authorsyear	Context	Description	Key words
HCI			
1(Tennenhouse, 2000)	Describe a new paradigm for computer systems and proposal three loci for proactive computing.	"Will be intimately connected to the world around them by using sensors and actuators, respond to external stimuli at faster-than-human speeds, and move from human-centered to human-supervised (or even unsupervised) computing."	Respond to external stimuli, humans are above the loop, human supervised, Understanding user behavior and the world.
2(Xiao, Catrambone and Stasko, 2003)	This work examined the effects of interface assistants as compared to traditional documentation in helping people use an unfamiliar text-editing tool. The proactive suggestion of the assistant did not improve performance but was viewed as helpful.	"By proactive, we mean that the assistant, in addition to answering queries, will make unsolicited suggestions."	Unsolicited suggestions, understandable and appropriate are the important features in proactive assistant
3(Salovaara and Oulasvirta, 2004)	This work clarify the concept of proactivity and suggest a typology that distinguishes between 6 modes of proactive resource management.	"Proactive behaviors are intended to cause changes, rather than just to react to changes. Two critical features of proactive system: behalf of user, taking initiative autonomously, without user's explicit command."	Context-sensitive, behalf of user, initiatinon autonomously, cause changes rather than react
4(Isbell and Pierce, 2005)	Presents an interface-proactivity (IP) continuum that expresses potential balances of proactivity between the user and the system. They also consider the associated metrics.	This work frame proactivity by using responsibility for taking action.	Agent solely responsible for acting, metrics, system making suggestion and decision
5(Nothdurft, Ultes and Minker, 2015)	Present the challenges of proactiveness in dialogue systems and how these influence the effectiveness of turn-taking.	"Proactivity in technical systems is an autonomous, anticipatory system-initiated behaviour, with the purpose to act in advance of a future situation, rather than only reacting to it."	Action in advance, anticipatory action, system-initiated behaviour; future situation
6(Kraus *et al.*, 2020)	Present an empirical study on the effects of proactive dialogue strategies on user acceptance and UX.	Explicit, and implicit proactive assistance are extended the described basic functionalities by collecting user preferences and suggesting appropriate meals to users.	User preferences, give suggestion

Continued

Table 1. Continued.

No.Authorsyear	Context	Description	Key words
HRI			
7(Mok *et al.*, 2015)	This work examines how proactivity and expression effect user perception. The result shows that having a robot perform expressive movements greatly affects how interaction is perceived by the user.	"A proactive robot anticipated a user's impending needs and initiated an action to complete a task."	Anticipate, initiated by robot, user's impending needs
8(Cesta *et al.*, 2007)	This work evaluate elderly people's perception of assistive robots and domotic environments. The proactive interaction in more useful in emergency and healthcare situation than on-demand interactions and proactive suggestion situation.	"Proactive interaction in which the intelligent environment commences interaction guided by its internal reasoning."	Internal reasonin(robot), intelligent environment commences
9(Sirithunge, Jayasekara and Chandima, 2019)	This work assesses intelligent systems which were capable of evaluating the emotional state of humans prior to an interaction, and identifies the cues and evaluation techniques that were utilized by such intelligent agents to simulate and evaluate the suitability of a proactive interaction.	"Proactive robots: Robots which identify the requirement of a certain situation and acts instantly without any instructions from outside."	Situation clue, identify requirement of situation, acts instantly
10(Peng *et al.*, 2019)	Evaluate the effects of DMS robot's proactivity in 3levels on user perceptions and interaction behaviors.	"Defined the proactivity as the anticipatory action that robots initiate to impact themselves and/or others. "	Anticipation, autonomy dimensions, robots initiate, impact
11(Tan *et al.*, 2020)	This work explore the relationship between proactivity in social robot behavior and a user's perception of anthropomorphic attributes. The result indicated that all anthropomorphic attributes of different proactivity levels have a significant difference.	"They developed proactivity in 5 levels based on the robot's automatic levels, the amount of information sent by the robot through proactive behavior and the user's attention resources are used to implement the social interaction."	Automatic levels, information levels, user attention, user's attention resources

Continued

Table 1. Continued.

No.Authorsyear	Context	Description	Key words
Human-vehicle interaction			
12(Bader, Woerndl and Prinz, 2010)	Proposal a new model for situation awareness tailored to proactive recommendations in automotive scenarios.	"Proactive systems works on tasks and is supervised by the user, instead of the system answering user queries interactively."	supervised by the user, the right information at the right time to the right user, recommendations
13(Woerndl *et al.*, 2011)	This work introduce a model for proactivity in mobile recommender systems, which relies on domain-dependent context modeling in several categories.	"Proactivity means that the system pushes recommendations to the user when the current situation seems appropriate."	Relies on contest, user not to submit any request, current situation
14(Bader, 2013)	Thesis development of a conceptual framework for proactive recommender systems that can leverage contextual information such as the driver's location, traffic conditions, weather, and time of day to provide personalized recommendations.	"Proactive recommendations are delivered without explicit user request. Adding explanations is a promising method to improve the comprehensibility of a recommendation."	Delivered without explicit user request; explanations ; proactive recommendations; comprehensibility
15(Smirnov, Shilov and Gusikhin, 2015)	Regarding proactive interaction is the development of a proactive driver support approach that involves continuous monitoring, analysis, intervention, and adaptation to improve driver safety and performance.	"The next step in the development of proactive systems is appearance of systems based on prediction of the user behavior, his/her future locations or actions, as well as situation recognition."	Context, drivers' needs, preferences and intentions
16(Kabtoul, Spalanzani and Martinet, 2020)	Establish a pedestrian-vehicle behavioral model,which is capable of describing and predicting agents' behaviors when interacting with a vehicle in both lateral and frontal crossing scenarios.	"Proactive navigation is a major challenge on the way to integrating the autonomous vehicle in the shared space as an influential agent, taking an active role in the scene and not merely reacting to it."	Active role in the scene, influential agent, Proactive navigation

Continued

Table 1. Continued.

No.Authorsyear	Context	Description	Key words
Occupational psychology			
17(Bateman and Crant, 1993)	This study investigated a personal disposition toward proactive behavior. To enhance our understanding and predicting of behaviors, we need to declare proactive construct.	"Proactive behavior is behavior that directly to alters environment."	Directly and intentionally change the enviornment
18(Crant, 2000)	This work describe four constructs related to proactive behavior: proactive personality, personal initiative, role breadth self-efficacy, and taking charge.	"Proactive behavior as taking initiative in improving current circumstances or creating new ones; it involves challenging the status rather than passively adapting to present conditions."	Not passively adapting to conditions, personal initiative
19(Parker and Collins, 2010)	This work develop a framework designed to generalize across specific manifestations of proactivity, describing the nature, dimensions, situational antecedents, psychological mechanisms, dispositional moderators, and consequences of proactive behavior.	"Define proactive behavior as anticipatory action that employees take to impact themselves and/or their environments. Two characteristics of proactive behavior is acting in advance and intended impact."	Proactive behavior, anticipatory action, take to impact themselves and/or their environments
20(Parker and Collins, 2010)	This work clarify the similarities, differences, and interrelationships among multiple types of proactive behavior.	"In most definitions of proactive behavior have 3 elements:acting in anticipation, taking control and self-initiation."	Acting in anticipation, taking control, self-initiation.

refined from the proactivity-related descriptions, it's also an original label of the proactivity concept inductive analysis.

DEVELOPING CONCEPT OF PROACTIVE INTERACTION

The Theme of Proactivity

We follow the coding process in inductive analysis (Thomas, 2003). The specific segments are the proactivity-related description from the papers. Then, label the segments to create categories, which is the keywords in Table 2. Reduce overlap and redundancy among those categories to 18 categories, including context, human supervised, autonomy action, explanatory, take autonomous action, relevance, user agent, different from react, function list, understandable, anticipation, initiate by system(robot), impact, user's needs, user preferences, action in advance, anticipatory action, metrics. Last, create a model incorporating most important categories to create five summary categories, which is consider and manage context, anticipation and predictive ability, autonomy and action, understandability and transparency, proactive functions.

01 Consider and manage context: the system takes into account the user's context, including their environment, device, activity, and task, to perception and comprehension of context, to support and inform its actions.

02 Autonomy and action: the system's ability to use predictive analytics to anticipate user needs and preferences and initiate actions to impact others.

03 Anticipation and predictive ability: the system is designed to anticipate the user's needs and preferences and take anticipatory actions, using predictive analytics and other technologies to improve its accuracy.

04 Understandability and transparency: in collaboration between the user and the system, the system should make its actions transparent and understandable to the user, including providing feedback and explanations in plain language. In order to build trust and promote efficient collaboration, the system must provide transparent feedback and explanations that help the user understand what actions are being taken and why.

The 02 and 03 both concepts involve the system's ability to use predictive analytics to anticipate user needs and preferences and take proactive actions. Autonomy and action emphasize the initiation action part; Anticipation and

Table 2. First categories and summary categories for inductive analysis.

First categories	Summary categories
Context, relevance, impact	Consider and manage context
Different from react, action in advance, anticipation, anticipatory action	Anticipation and predictive ability
Human supervised, take autonomous action, autonomy action, user agent, initiate by system(robot)	Autonomy and action
Explanatory, understandable, metrics, user's needs, user preferences	Understandability and transparency
Function list	Proactive functions

predictive ability emphasis understanding the reasons behind the initiation of the action and the contents and ways of the specific action that should be taken to meet the user's needs and preferences.

The functions of proactivity are an important part of proactive interaction research, not belong to the theme of the proactivity concept.

Concept of Proactive Interaction in Autonomous Vehicles

Following the theme of proactivity, we propose the concept of proactivity, which refers to the ability of a system to take initiative and act without prior prompting, based on an understanding of the user's goals and the context in which they are operating. This can involve the system offering advice or taking control in a situation where it is deemed necessary to enhance safety, efficiency, or convenience.

To achieve this, the system must anticipate the user's needs and preferences based on their previous behavior and the current situation. This allows the system to provide personalized recommendations or assistance that are tailored to the user's goals and preferences.

Furthermore, the system should communicate its knowledge of the user's goals and the environmental context in a transparent and understandable way, which can help to build trust and enhance the user's engagement with the system. This is particularly important in the case of autonomous vehicles, where safety and trust are critical factors in user acceptance and adoption.

THE CASES OF PROACTIVE INTERACTION DESIGN IN VEHICLE MARKET

Many brands now offer a range of features designed to improve safety and convenience. Tesla's Autopilot system, Ford, Volkswagen Front Assist system, General Motors' Super Cruise system, and Toyota's Safety Sense system offers a range of proactive features, such as automatic braking to avoid collisions, pedestrian detection, proactive lane-keeping, automatic lane changing and speed control, automatic cruise control, smart parking that find available parking spaces and guide the driver to them. These features can improve safety and convenience by alerting drivers to potential hazards and taking action to prevent accidents.

Although proactive features have been shown to offer several benefits, it is important to conduct further research to determine how these features impact user experiences. Given the highly complex nature of the driving context, particularly with higher levels of autonomy, there may be greater scope for the design of proactive features that extend service-related content, such as actions based on users' preferences and state, rerouting based on users' goals and events, and other similar functions.

In some of its models, the BMW Vision iNEXT is equipped with a digital assistant that can help passengers with a variety of tasks, such as booking restaurant reservations, ordering groceries, and finding parking spots. MBUX (Mercedes-Benz User Experience) system learns user behavior based

on sensor data and event and location information. The car will recommend these activities to the user at the appropriate time. HANA (Honda Automated Network Assistant) determines the driver's current emotional state by analyzing body language, physical readings, and current actions. HANA can measure the driver's emotions and provide music recommendations or suggestions, as well as other media and entertainment options based on their mood. "Xiaodu Car OS Intelligent Scene Engine" developed by Baidu can recognize the current scene and suggest services based on that scene, such as recommending playlists, providing automatic appointment reminders for upcoming maintenance times, and implementing facial recognition automatic payment in payment scenarios.

Those many cases in the market take the form of a wide range of functions and services, the emphasis on the initiation of action is predictions of user's needs in context is an important shifting and orientation.

THE CONTENTS OF PROACTIVE INTERACTION DESIGN IN AUTONOMOUS VEHICLE

According to the concept and the functions and services related features, the design contents can be constructed. There are 3 parts involved. Anticipation of goal and need based on scenario, proactive behavior based on proactivity functions, and context-aware communication based on collaboration

Anticipation of Goal and Need Based on Scenario

The driving scenario is the space where human-vehicle interaction occurs. Bringing the proactive interaction behavior of AVs into specific scenarios for analysis is a precondition for design and research. A typical scenario is one that is representative and has a high probability of occurrence in driving context.

The study recruited volunteers who were licensed drivers with at least two years driving and who drove frequently, with more than 50% of their weekly trips being by car. The volunteers were asked to use a GoPro camera to film a 15–30 minute driving video based on their daily activities. The driving videos we collected were primarily filmed in Shanghai, China, and San Francisco, California, the US. totaling 2 hours and 30 minutes in duration.

The collected video materials were then analyzed to classify the driving scenarios into purpose-driven scenarios, which have clear goals and involve activities such as commuting, traveling, and running errands, and function-driven events, which are fragmented and include tasks such as finding parking spaces, refueling, or answering phone calls. By analyzing the scenarios, the researchers identified the users' goals and need in various driving scenarios, which helped establish a design target in proactive interaction design. The user goals of each scenario can be summarized in Table 3. These goals encompass eight types: information acquisition, problem-solving, making plans, executing plans, routine activities, status monitoring, security assistance, and information entertainment. Designers can refer to these effectively locate the user's needs and align user goals at design time.

Table 3. The goals of (1) purpose-driven scenarios and (2) function-driven events.

(1) Purpose-driven scenarios	User goals
Commuting	Get to work on time and relax on the way home.
Business trips	Arrive at the destination and avoid emergencies.
Going to grocery	Arrive at the destination and find an available parking lot.
Traveling	Arrive at the destination and enjoy the scenery along the way.
Going to the hospital	Arrive before the appointment time and find a parking space.
Visiting friends	Arrive at a friend's house at the appointed time.
(2) Function-driven events	**User goals**
Traffic jam	Relieve anxiety, get traffic information factually
Play music	Quickly find the target music and choose music according to the context
Find a parking space	Quickly find an available parking space that suits the situation (free/ close to an exit/…)
Find a restaurant	Find a favorite one/ the most time-saving one/…
Get gas	Plan your trip reasonably and find the right gas station
Pedestrians across	Drive safely, avoid danger
Schedule change	Update the schedule, don't delay the original plan
Route change	Plan a better route without delaying the itinerary
Cart approaching	Drive safely and keep a safe distance
Vehicle wear/maintenance information	Keep your vehicle in good condition before something goes wrong
Extreme weather	Drive safely, avoid danger

Proactive Behavior Based on Proactivity Functions

The autonomy of proactive interaction refers to the ability of a system to independently take actions. The degree of autonomy in proactive interaction can be manifested in the strength of the system's ability to act independently during the execution of tasks. This can be implemented in design through the integration of proactive functions.

In human-vehicle cooperation, the proactive autonomy functions of interaction can be classified into seven types based on the different behaviors exhibited by intelligent vehicles. These types include push, remind, recommend, suggest, inquire, request, and execute (report or silent). Each type comprises several application contents, as outlined in Table 4. These contents can be developed into design cases to improve design efficiency.

Context-Aware Communication Based on Collaboration

The degree of situational awareness conveyed to users is a critical dimension of communication between users and systems, serving as an indicator of the system's ability and as a basis for establishing trust. When the system supports or violates their goals and attracts users' attention, it will positively or negatively affect their acceptance, user experience, and trust. In contrast to literature that focuses on macro-technical planning(Omeiza

Table 4. Autonomy function type and application contents in AVs.

Autonomy function type	Application contents
Information push	News information, service information, managed information
Recommended	Points of interest(POI), infotainment content, system applications
Reminder	Danger prediction, event prediction, information service
Ask	Abnormal state ask, event ask, plan ask
Requests	Functional requests, permission requests
Suggestions	Locations suggest, user behavior suggest, plan suggest, security operations suggest
Execution (reporting/silence)	Emergency decision-making, safety decision-making, safety supervision, service on the road decision-making, in-vehicle environment adjustment, functional autonomous execution

et al., 2021)(Atakishiyev *et al.*, 2021), this study pays more attention to the relationship between system behavior and user experience.

The proactive interactions in context-aware communication involve informative and explanatory information. Informative information presents the vehicle system's situational awareness results and proactive behaviors, while explanatory information provides content-based, reason-based, and interactive presentations regarding the proactive behavior and its contents. Informative information comprises changes in user status, environmental status, and task status.

CONCLUSION

The concept of human-vehicle proactive interaction has gained significant attention in recent years due to its potential to improve road safety and enhance the driving experience. This approach enables vehicles to anticipate the driver's intentions and respond in advance, using advanced sensors, algorithms, and communication systems. In this work, we sum up the theme of proactive interaction by inductive analysis of literature and define the concept of proactive interaction in AVs. The function-based and service-based cases are the directions we can follow. As a result, the content of proactive interaction design in AVs is the early guideline to support proactive interaction design in the process.

REFERENCES

Atakishiyev, S. *et al.* (2021) 'Explainable Artificial Intelligence for Autonomous Driving: A Comprehensive Overview and Field Guide for Future Research Directions', *arXiv preprint arXiv:2112.11561* [Preprint].

Bader, R. (no date) 'Proactive Recommender Systems in Automotive Scenarios', p. 348.

Bader, R., Woerndl, W. and Prinz, V. (2010) 'Situation Awareness for Proactive In-Car Recommendations of Points-Of-Interest (POI)', p. 10.

Bateman, T. S. and Crant, J. M. (1993) 'The proactive component of organizational behavior: A measure and correlates', *Journal of organizational behavior*, 14(2), pp. 103–118.

Cesta, A. *et al.* (2007) 'Proactive Assistive Technology: An Empirical Study', in C. Baranauskas et al. (eds) *Human-Computer Interaction – INTERACT 2007*. Berlin, Heidelberg: Springer (Lecture Notes in Computer Science), pp. 255–268. Available at: https://doi.org/10.1007/978-3-540-74796-3_25.

Crant, J. M. (2000) 'Proactive behavior in organizations', *Journal of Management*, 26(3), pp. 435–462. Available at: https://doi.org/10.1016/S0149-2063(00)00044-1.

Isbell, C. L. and Pierce, J. S. (2005) 'An IP Continuum for Adaptive Interface Design', p. 10.

Kabtoul, M., Spalanzani, A. and Martinet, P. (2020) 'Towards Proactive Navigation: A Pedestrian-Vehicle Cooperation Based Behavioral Model', in *ICRA 2020 - IEEE International Conference on Robotics and Automation*. Paris, France (IEEE International Conference on Robotics and Automation Proceedings), pp. 6958–6964. Available at: https://hal.archives-ouvertes.fr/hal-02509637 (Accessed: 4 May 2022).

Kraus, M. *et al.* (2020) 'A Comparison of Explicit and Implicit Proactive Dialogue Strategies for Conversational Recommendation', in *Proceedings of The 12th Language Resources and Evaluation Conference. LREC 2020*, Marseille, France: European Language Resources Association, pp. 429–435. Available at: https://www.aclweb.org/anthology/2020.lrec-1.54 (Accessed: 20 August 2020).

Mok, B. K.-J. *et al.* (2015) 'A place for every tool and every tool in its place: Performing collaborative tasks with interactive robotic drawers', in *2015 24th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN)*. IEEE, pp. 700–706.

Nothdurft, F., Ultes, S. and Minker, W. (no date) 'Finding Appropriate Interaction Strategies for Proactive Dialogue Systems—An Open Quest', p. 8.

Omeiza, D. *et al.* (2021) 'Explanations in autonomous driving: A survey', *IEEE Transactions on Intelligent Transportation Systems* [Preprint].

Parker, S. K. and Collins, C. G. (2010) 'Taking stock: Integrating and differentiating multiple proactive behaviors', *Journal of management*, 36(3), pp. 633–662.

Peng, Z. *et al.* (2019) 'Design and Evaluation of Service Robot's Proactivity in Decision-Making Support Process', in *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems - CHI'19. the 2019 CHI Conference*, Glasgow, Scotland Uk: ACM Press, pp. 1–13. Available at: https://doi.org/10.1145/3290605.3300328.

Salovaara, A. and Oulasvirta, A. (2004) 'Six Modes of Proactive Resource Management: A User-Centric Typology for Proactive Behaviors', p. 4.

Sirithunge, C., Jayasekara, A. G. B. P. and Chandima, D. P. (2019) 'Proactive Robots With the Perception of Nonverbal Human Behavior: A Review', *IEEE Access*, 7, pp. 77308–77327. Available at: https://doi.org/10.1109/ACCESS.2019.2921986.

Smirnov, A., Shilov, N. and Gusikhin, O. (2015) 'Socio-cyberphysical system for proactive driver support approach and case study', in *2015 12th International Conference on Informatics in Control, Automation and Robotics (ICINCO). 2015 12th International Conference on Informatics in Control, Automation and Robotics (ICINCO)*, pp. 289–295.

Tan, H. *et al.* (2020) 'Relationship between social robot proactive behavior and the human perception of anthropomorphic attributes', *Advanced Robotics*, 34(20), pp. 1324–1336. Available at: https://doi.org/10.1080/01691864.2020.1831699.

Tennenhouse, D. (2000) 'Proactive computing', *Communications of the ACM*, 43(5), pp. 43–50. Available at: https://doi.org/10.1145/332833.332837.

Thomas, D. R. (2003) 'A general inductive approach for qualitative data analysis'.

Woerndl, W. *et al*. (2011) 'A model for proactivity in mobile, context-aware recommender systems', in *Proceedings of the fifth ACM conference on Recommender systems*. New York, NY, USA: Association for Computing Machinery (RecSys' 11), pp. 273–276. Available at: https://doi.org/10.1145/2043932.2043981.

Xiao, J., Catrambone, R. and Stasko, J. (2003) 'Be Quiet? Evaluating Proactive and Reactive User Interface Assistants', p. 10.