Analyzing the Impact of e-Caducée, a Serious Game in Pharmacy on Students' Professional Skills over Multiple Years

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Abstract: In an academic program of our faculty of pharmacy, we tried to improve the training of future pharmacists aiming at their professionalization. We proposed a learning game called e-Caducée, which allows students to train during 3 semesters with about one hundred clinical cases. We investigated the consistency between skills worked in the game with those defined by the pedagogical team as well as the impact of the game and of the embedded dashboard on students' skills. We collected data from the game (activity traces), from the faculty (academic results) and from the students (opinion about the game). To answer our research questions, we used both multiple linear regressions as well as classical statistical inference. Results reveal that the score predictions based on the use of e-Caducée correspond with the definition of the teachers. We also found clues that the use of e-Caducée helped with learning some professional skills but the result was not confirmed with statistical analysis. Finally, we found a link between the use of the dashboard in the game and one particular professional skill's academic results (prescription). Our future work aims at developing an adaptive learning dashboard for the game and analyzing its possible impact.

1 INTRODUCTION

When training health professionals, a saying is often heard: "never practice the first time on a patient". To meet this need, simulation is a reliable solution to enable future health professionals to train without real consequences. Thus, learners can practice without exposing patients to risk, making mistake and learning serenely. Simulation associated with a learning game allows leveraging the benefits of game-based learning in training. Alvarez et al. (2012) define "a Serious Game (as) an artifact, digital or otherwise, for which the original intention is to combine with consistency, both serious aspects such as non-exhaustive and non-exclusive, teaching, learning, communication, or the information, with playful elements from the game". It is sometimes referred to as a learning game in the education context (George, 2019), and "[their] main benefit (...) is the user's motivation linked to the inherent goals of the game whose fulfillment is a source of satisfaction and rewards". Some studies have also shown a positive impact of learning games on academic results (Pacheco-Velazquez et al., 2019; Papadakis et al., 2020).

The impact of learning games on knowledge and skills acquisition is usually evaluated with a pre-test/post-test, but this method can be "expensive, time-consuming and provides limited information about the user in the learning process" (Alonso-Fernandez et al., 2017). Collecting traces of activities and their analysis can be a complementary way to evaluate the impact of a learning game, that may also help to understand the learning process in order to improve it (Alonso-Fernández et al., 2019). We developed a learning game called e-Caducée, to simulate professional life in a pharmacy, used by students over multiple years. Using various learning analytics methods, we have investigated the possible impacts on students' learning process and tried to answer the following research questions (RQ):

- **RQ1.** Are the professional skills worked in the game consistent with those defined by the peda-

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gogical team?

- **RQ2.** Does the learning game allow students to strengthen their professional skills?
- **RQ3.** Does the use of the embedded dashboard have a positive impact on learning?

The outline of this paper is as follows: section 2 reviews previous works about simulation and learning games, with a focus on the pharmacy profession, and introduces the concept of Learning Analytics Dashboards (LAD); section 3 describes the learning game e-Caducée, section 4 details materials and methods of this study, section 5 shows its main results, section 6 discusses these results and section 7 gives a conclusion and opens the first perspectives of our work.

2 PREVIOUS WORK

Simulation and learning game are common tools in health education and pharmacy curriculum. Cain and Piascik (2015) identify serious games as a real opportunity in pharmacy education: "Advantages of serious gaming in pharmacy education include authentic, situated learning without risk of patient consequences, collaborative learning, ability to challenge students of all performance levels, high student motivation with increased time on task, immediate feedback, ability to learn from mistakes without becoming discouraged, and potential for behavior and attitude change." A review of several educational games in pharmacy concludes on a lack of evidence that educational games foster learning in pharmacy schools, even if they may impact students' motivation (Aburahma and Mohamed, 2015). An imbalance between educational and entertainment components could be the cause. However when coupled with simulation, learning games seem to have a positive effect on the learning process as Berger et al. (2018) experimented with one clinical case, or as Abed et al. (2016) studied for vocational training in a professional context. This result is still uncertain and could be context-dependent, as some recent studies (Blanié et al., 2020) cast doubts over the positive impact of learning with simulation compared with health traditional teaching method based on clinical cases and debriefing. It is therefore critical to keep on investigating this issue in multiple contexts. Moreover, a potential limit to the aforementioned works is that they tend to focus on simulation used over a relatively short period of time (from a few hours for Blanié et al. (2020) to several weeks at home for Pacheco-Velazquez et al. (2019) or Berger et al. (2018)). We hypothesize that these various time of use could be one of the reasons explaining the discrepancy in the results observed so far. To the best of our knowledge, we did not find study about the learning impact of a learning game used over several years by the same cohort of students.

In a learning game, a Learning Analytics Dashboard (LAD) is a helpful tool which supports online learning. A LAD can be defined as "a single display that aggregates different indicators about learner(s), learning process(es) and/or learning context(s) into one or multiple visualizations" (Schwendimann et al., 2017). Thus, the user can use all this information to make a decision. By summarizing learning data for the student with an appropriate visualization, LAD supports awareness of learning process (Jivet et al., 2017) and self-assessment. Its functions mirror those of the dashboards in video games, that show to the player which goals are achieved and that guide them to the next level. Today, LADs in learning games are increasingly being studied (Scheneider and Lemos, 2020) and are evolving from a static to an interactive form. Alonso-Fernandez et al. (2017) explained that "not all classical gamification metrics are suitable or useful for learning and training", by example, peer comparison can discourage students or speed constraint can have negative effects. We can suppose that data defined for a LAD of a serious game by Alonso-Fernandez et al. (2017) (proportion of correct answers, final score) are adapted to LAD in a learning game with simulation in the specific context of health.

3 LEARNING GAME E-CADUCÉE

3.1 Overview of the Game

The learning game e-Caducée scenario introduces the player to a little town with several key places (cf. figure 1), where students start a pharmacy internship. Their main objective is to handle patients (cf. figure 2), by dispensing medications and/or providing medical advice. Each visit of a patient corresponds to a clinical case, built with the following general frame: context definition with a 3D video (cf. figure 2), questions relative to the pathophysiology of the disease, therapeutic strategies, pharmacology of medication, treatment optimization, and education and counseling of the patient. By following this framework, the clinical cases written for the game allow students to work on the different skills planned by the teaching team: prescription, prescription dispensing and advice. Two endings are possible, positive or mildly negative (patients never die), depending on the student's score. Clinical cases have been written by experts from different universities in France and validated by an ed-

itorial committee. They have formative evaluation purposes and contain multiple explanations of the answers to the exercises and links to official references (i.e. immediate feedback is provided after a case to explain why the selected answer was correct or incorrect).

In e-Caducée, as in a real pharmacy, patients arrive randomly and the player never knows which topic will be next. Some clinical cases are related to each other, with a previously seen patient that may randomly come back to the pharmacy with questions about the evolution and the treatment of their pathology. If students are successful (more than 60% of good answers in several clinical cases), they receive some in-game rewards from the internship supervisor which can be extradiegetic (e.g. badges) or intradiegetic (e.g. the virtual character is invited to restaurant). After a fixed number of successful clinical cases, students can be promoted as assistant, and then as pharmacist associate, the level of the clinical cases increasing with the status of the student in the game. Although a scenario leads the student through the game, he or she can at any time review previously seen clinical cases and make the choice to deal with lower level untreated cases. This allows them to revisit previous topics if needed. When the player becomes assistant, he can also visit different places of the town, such as the faculty which allows him or her to review courses or to train about a specific pathology. Finally, the trophy room provides the student with a static dashboard (cf. figure 3) which gives the obtained scores, the opinion of the internship supervisor, the corresponding rewards and the rewards to be earned. The game ends with the most complicated case as the final challenge. The learning game was developed with open source software Scenari Opale to write clinical cases, and Scenari Topaze to develop the game engine. This choice allows teachers to update clinical cases easily by themselves. 2d illustrations and 3d videos have been made by external companies.

Figure 1: Illustration of the fictitious town Berdeghem and its virtual pharmacy.

Figure 2: A patient in the pharmacy to introduce each clinical case, in this example a pregnant woman coming with a prescription.

3.2 Game Implementation

e-Caducée has been used in several public universities in France, with different modalities (distributed over a single semester as an option or spread over 3 years with a validation requirement) and different game configurations (clinical cases by theme or by level of difficulty). In the current study context, the game has been an optional part of a mandatory teaching unit PROFFIteROLE (PRatiques OFFIcinales et jeux de ROLEs), for the last three semesters of the academic program of the Faculty of Pharmacy of Lille (France) intended to future dispensary pharmacists. In this teaching unit, students alternate practicing online with the game e-Caducée and in physical classrooms. Students begin with a physical classroom where teachers introduce the teaching unit by presenting its global organization, learning objectives, evaluation methods, as well as the e-Caducée game. During this course, students can discover the game and ask questions. Then, they are free to play online, as many times as they want, in group or alone, or even to not play at all. Meanwhile, during each semester, 3 sessions of face-to-face simulations are organized with 3 clinical cases to be treated. Students are given the topics in advance and asked to prepare them, possibly with the serious game. Sessions are then organized in three sequences: a prebriefing introduces the aim and the contents of the session; the simulation time gives students the opportunity to alternate playing as a pharmacist, a patient or an observer; a debriefing summarizes the skills that have been used properly and those that need to improve. Although the main focus in on training the pharmacist skills, taking on the role of patient helps to develop empathy for patients, and playing as an observer helps in developing a critical and objective look while filling a criterion-based evaluation grid of the pharmacist.

Each semester, the content of the teaching unit evolves, students deal with 9 new clinical cases in ad-

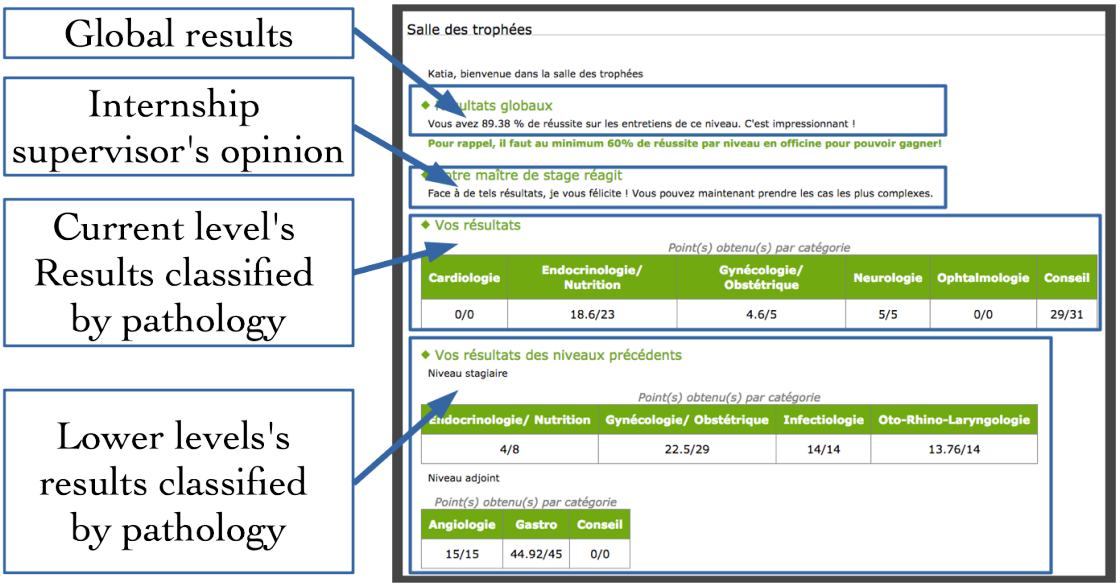

Figure 3: Dashboard of the game.

dition to the game in face-to-face simulation and can work on about 30 new clinical cases in the game online. This progressive releasing of new cases encourage students to go back to the learning game for a sustained use over multiple semesters. Clinical cases included in the game change and became more complex with cases involving multiple pathologies. Face-to-face simulations aim at developing other skills which cannot be directly targeted in the learning game, such as communication between health professionals by including medical and dental students to simulate the direct exchanges between health professionals needed to solve complex clinical cases. Student assessment is also adapted to the pedagogical goals of each semester and takes several forms: students have to solve 2 clinical cases from the serious game in the first semester, to write in group a new clinical case in the second semester, and to manage a face-to-face simulation with a teacher for the last semester.

4 MATERIALS AND METHODS

4.1 Materials

In order to answer to the aforementioned three research questions, we collected data from several sources:

- From the game, for each of the 3 semesters: number of game attempts, overall average grade, number of clinical cases completed for each of the 3 levels of difficulty, access to the online training space and access to the trophy room. All these data are exported in csv format from the Learning Management System (Moodle) in which e-Caducée is embedded.
- From the faculty: overall average grade, whether the year was repeated or not, grade in this teaching unit, grade obtained in the mandatory internship each student has to do after the last semester (with detailed assessments for 6 different skills: posology [POS], good preparation practices [GPP], prescription [PRE], work in public health [WPH], prescription dispensing [PDI] and advice [ADV]). All these data are exported in csv format from the university management software (Apogée).
- From a questionnaire to the students: whether they worked in a pharmacy during their studies for each semester (independently from the final mandatory internship), their opinion about the game and its current dashboard (trophy room) and their expectations to improve them. These data are exported in csv format from an optional online questionnaire (Lime Survey) sent to students during the third semester.

We worked with data coming from two cohorts of students of a faculty of pharmacy, with n=94 for 2017-2018 and n=100 for 2018-2019.

4.2 Methods

Prior to data collection, we worked with our data protection officer to ensure compliance with the General Data Protection Regulation (GDPR), the Euro-

pean Union's data protection law. Thus, teachers have informed students about our research and why we collect data. Then, students could choose to access a version of the game with or without data collecting.

Initially, we considered comparing the results of students who played and did not play the game by dividing the cohort in two groups, one with the game and one with just clinical cases. But this method cannot be used with the actual game design. As explained in 3.1, to simulate a real pharmacy, patients arrive randomly and students do not have to do all clinical cases to succeed in the game. We used this method to evaluate the game design and to help us improve it when the game was created, and we observed that each student of each group took a different path (different clinical cases studied and different number of attempts). We therefore considered other methods to assess the impact of the game on learning: machine learning-based one and classical statistical inference summarized in figure 4.

To examine the first and second research questions, our approach consisted in training multiple linear regression models in order to predict the grade associated to each of the 6 skills evaluated in the internship (as well as the overall internship grade), using features coming from the game data. The idea is that if the game trains a particular skill, features representing how much the students use the game should help in predicting the grade they obtained on the skill during the internship. On the opposite, if a skill is not particularly trained in the game, the correlation between the game usage and the grade on that skill should be low and therefore the regression model should perform poorly for it. This analysis was conducted using RapidMiner (version 9.8) with 10-fold cross-validation to estimate the correlation (Pearson r) and mean absolute error (MAE).

To explore the second and third research questions, our approach used continuous variables expressed as mean $\pm$ SD or median [25th – 75th percentile], as appropriate. Categorical variables are presented as absolute numbers and percentages. Linear regression analysis was used to study the relationship between academic results and the use of the learning game. Models were adjusted on potential confounding factors. The linearity assumption for continuous covariates was assessed by testing the addition of a quadratic component in the model. Multivariate models were built by first including all predictors and then using a manual backward selection to reduce the model. Regression underlying assumptions were visually inspected with residual plots. Longitudinal data of academic results for the three semesters were analyzed using repeated-measures analysis of covariance (PROC MIXED) with a REPEATED statement for within student correlation over the three semesters. The main covariate was the number of visits of the LAD, and potential confounding variables were included in the analyses. Models were built as described above for the linear regression models. The two-sided type I error was set at 5%. Analyses were conducted using SAS software (SAS version 9.3, SAS Institute Inc., Cary, NC, USA).

5 RESULTS

To answer our first and second questions, the table 1 presents our results to predict the grade associated to each of the 6 skills evaluated in the internship (posology [POS], good preparation practices [GPP], prescription [PRE], work in public health [WPH], prescription dispensing [PDI] and advice [ADV]). According to the teaching team, e-Caducée allows to work mainly on prescription (PRE), prescription dispensing (PDI) and advice (ADV) skills.

Table 1: Performance of the linear regression models trained on each skill and on the overall internship grade.

Skill	Correl. (r)		MAE		Best
	M	SD	M	SD	model
POS	.200	.314	1.871	1.123	Lin. reg.
GPP	.337	.439	2.900	1.369	GLM
PRE	.425	.374	2.575	1.087	Lin. reg.
WPH	.330	.398	1.763	0.993	Lin. reg.
PDI	.306	.363	2.306	0.971	GLM
ADV	.156	.307	2.830	1.093	Lin. reg.
Total	.271	.369	1.816	0.861	GLM

To answer our second question, our analyses have identified links between the learning game and academic results. A link between the use of the game and the teaching unit score ($p = 0.02$) is highlighted. Playing 3 times on e-Caducée increases the teaching unit score by an average of 1.29 points (IC95% [0.40; 2.18]). But we did not identify any link between the use of the game and the internship results. The students who responded to the game evaluation survey ($n = 102$ for both cohorts) felt that: the game was satisfying at 99%, the distribution of clinical cases by level were appropriate at 86%, the number of cases to be treated was adapted at 92%, the gaming was adapted at 92%, the game allowed a synthesis of knowledge at 85%, the game allowed to learn new knowledge at 86%, the game helped to improve one's professional practice at 83%.

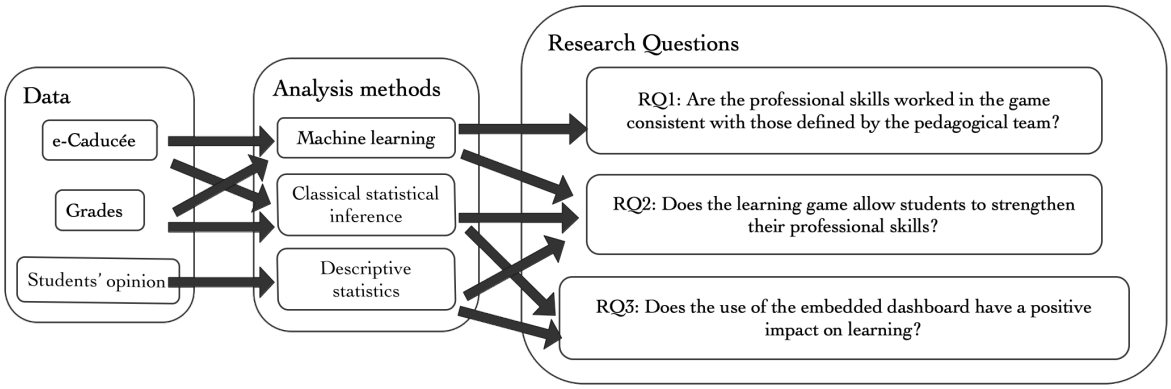

Figure 4: Data and analyses used to investigate the three research questions.

And last but not least, we did a focus on players only, to observe if the use of the LAD had consequences on their results. We analyzed the use of the game by each student for each of the 3 semesters ($n = 431$) and we identified a link between the number of visits and the results in the game ($p = 0.003$). Visiting voluntarily the trophy room at least twice increased the results in the game EC by an average of 6.41 points (IC95% [2.82; 10.]). Then, we tried to search a link between the use of the LAD and the internship results, with adjustment factors on gender, overall average, teaching units results and game results of each semester. We could demonstrate a link between the use of the LAD during the last semester and prescription skill evaluation ($p = 0.04$). Visiting the trophy room once increased the average prescription score by 2.12 points (IC95% [0.41; 3.82]). A link between the number of visits to the trophy room during the second semester and the prescription dispensing skill score ($p = 0.02$) was found. Visiting the trophy room once increases the average prescription dispensing score by 1.82 points (95% IC [0.08; 3.56]).

To complete this study, we asked the students' opinions from the cohort 2017-2018 about the LAD. For students who responded ($n = 47$), 85% of the players remembered visiting the trophy room. Some elements are considered useful by the majority, such as overall results and results by pathology. Other elements do not meet unanimous approval, such as the opinion of the internship supervisor. The 15% who did not remember having visited the trophy room explained this for 3 reasons: not being aware of it, finding it useless or not taking the time. Some students' comments are encouraging, as for example "Thanks to these results, I could see the areas in which I had already achieved good results, but also and above all, I could see the gaps that I had not necessarily noticed when I had completed the questionnaires. When other clinical cases dealing with subjects in which I did not have a lot of points, I took more time to answer and possibly do further research on the internet or on my courses." The students then expressed some expectations for improving the LAD in the future, with different opinions on the types of data and visualizations desired.

6 DISCUSSION

The main goal of the game is to prepare students before real professional practice. Teachers have defined more precisely the skills concerned within the game, which are prescription, prescription dispensing and advice. The results of the score predictions correspond partially to the teachers' opinions. We can answer to the first question, some professional skills worked in the game are consistent with those defined by the teaching team, as prescription and prescription dispensing, but not the advice skill. To understand, it would be necessary to work with the pedagogical team to identify how this skill is evaluated. We can conclude the pedagogical alignment between the game, the assessment and the skills of prescription to be acquired is correct.

In response to our second question, which supposes that the learning game allows to reinforce professional skills, the first analysis with a machine learning type of approach suggests links between the game and some professional skills. But with the classical statistical inference method, we establish a link between using the game and academics results in the teaching unit, but not with the professional skills evaluated during the internship. We compared students who played a little, a lot and those who did not. But the definition of non-player may be inaccurate, as we simply defined non-players as students with no trace in the game. We can assume that these data can be refined, considering that some students have chosen

to use a game with no record, but they were counted as non-players. Then, as the game is optional, they could play in groups, and in this case, we have no data about it. Informal interaction with students suggest that this type of behavior does exist, but we have not evaluated their prevalence to know if it is high enough to potentially significantly affect our observations. We should identify students who played with no data record to have some more accurate results. According to the students' opinions, the majority believes that the game e-Caducée improves their professional practice (83%). It might contribute to build up the self-confidence in their professional practice that is necessary for caring for real patients.

Some results on the impact of the dashboard on learning allow us to answer partially our last question, suggesting that its use can improve learning. We have observed that the use of the LAD improves the result in the game. We can assume that the proposed data are relevant for some players. The use of the LAD also shows an increase in the scores of the internship evaluation. If we look at the semestrial results more precisely, it appears that its use in the second semester has a stronger impact on the prescription note. Most of the clinical cases of that semester involve a prescription, which could explain this result.

Debriefing has an important place in learning games as Crookall (2010) explains "Some learning often occurs while a game is being played, but deeper lessons are drawn and drawn out in a debriefing session". He says that with "the use of computers, we have a powerful tool indeed for debriefing. ... The data can then be processed to provide material for feedback during play, as in-game debriefing". This tool has some similarity with the definition of a LAD. Thus, a LAD may have a positive impact on learning games because it can take the role of the in-game debriefing. LAD's elements defined as useful by some students, e.g. the results by categories, seem to provide useful feedback for this in-game debriefing, and thus enable awareness of acquired and underdeveloped skills. Finally, we may wonder why some players have not used LAD. We can assume that this very simple LAD was not adapted to their needs as demonstrated by the work of Roberts et al. (2017) and Teasley (2017). Indeed, adaptive LADs seem to better meet the expectations of all users (Dabbebi et al., 2017), which is supported by the expectations expressed by our students, and this is one of the directions we intend to work on in the future.

The positive results of our study are certainly in line with several existing works on the acquisition of professional skills. But replicating in different contexts is important to confirm a result, as some studies shew different results in health domain (Blanié et al., 2020). Then, our research is based on an moderate sample size, but with the use of a game spanning over multiple years, which is a modality little studied according to our investigations. Finally, our approach presents an original analysis using machine learning methods in addition to traditional analysis methods.

7 CONCLUSIONS AND NEXT STEPS

e-Caducée offers students in pharmacy the opportunity to work on their professional skills by treating almost a hundred of clinical cases. In our context, we first identified that the professional skills worked in the game were consistent with those defined by the teaching team, e-Caducée seemed to be adapted to the pedagogical objectives. According to the students' opinion, the learning game may reinforce professional skills, but with a partial confirmation of a link between the game and internship results using several analysis methods as learning machine and classical statistical inference. Finally, we observed that the use of the student's dashboard in the game enhanced learning, with a link between the use of the dashboard and prescription skills results. To conclude, our work deals with a widely addressed issue but with an original context with a multi-year game and several analysis methods. Although we do not demonstrate it here and further studies would be needed, the fact we find a positive impact of the game is in line with our initial hypothesis that it may be important to consider long-term use of learning game simulations to measure positive impact.

Our future work will focus on the LAD by exploring adaptive approaches. First, we will improve the LAD design using co-design methods such as PADDLE (Oliver-Quelennec, 2020) adapted from Dabbebi et al. (2019), and then observe possible impacts of these adapted and adaptive LAD.

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