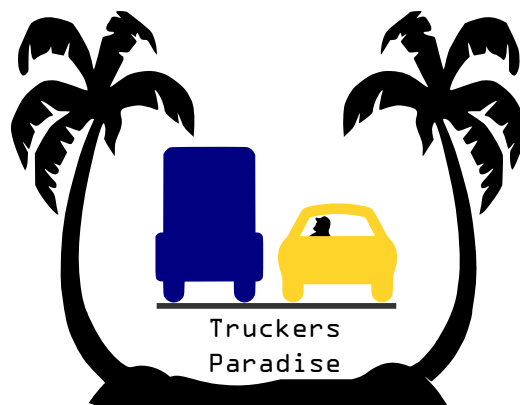


Test Protocol LiU Racetrack 2017

Version 1.0

Author: Truls Nyberg
Date: December 7, 2017



Status

Reviewed	Truls Nyberg	
Approved	Oskar Ljungqvist	

Course name: Automatic Control - Project Course
Project group: Truckers Paradise
Course code: TSRT10
Project: LiU Racetrack 2017

E-mail: axesk370@student.liu.se
Document responsible: Truls Nyberg
Author's E-mail: truny887@student.liu.se
Document name: test_protocol.v1.0.pdf

Document History

Version	Date	Changes made	Sign	Reviewer
0.1	2017-11-06	First draft.		OT
0.2	2017-12-04	Second draft.		AS
1.0	2017-12-07	Updates from orderer.		AS

Contents

1	Introduction	2
2	System Overview	2
3	Simulator	3
4	Motion Planner for the Car	5
5	Motion Planner for the Truck with Semi-trailer	6
6	Low-level Controller for Truck with Semi-trailer	8
7	Low-level Controller for the Truck with Dolly-steered Trailer	9
8	Code Quality	10

Project Identity

Group E-mail: axesk370@student.liu.se
Homepage: <http://www.isy.liu.se/edu/projekt/tsrt10/2017/racetrack/>
Orderer: Oskar Ljungqvist, Linköping University
Phone: +46 (0)70 577 18 68, **E-mail:** oskar.ljungqvist@liu.se
Customer: Daniel Axehill, Linköping University
Phone: +46 (0)13 28 40 42, **E-mail:** daniel@isy.liu.se
Course Responsible: Daniel Axehill, Linköping University
Phone: +46 (0)13 28 40 42, **E-mail:** daniel@isy.liu.se
Advisors: Olov Holmer, Linköping University
Phone:+46 (0)13 28 16 17, **E-mail:** olov.holmer@liu.se

Group Members

Name	Responsibility	Phone	E-mail (@student.liu.se)
Axel Skyttner	Project Manager	072-3410045	axesk370
Truls Nyberg	Documentation	073-0968687	truny887
Andreas Westerlund	Software	073-7421323	andve192
Oscar Törnroth	Testing	073-0640797	oscto799
Carl Rapp	Control systems	073-4065264	carra862
Gustav Sandvik	Design	073-0293777	gussa744
Martin Olsson	Motion planner, car	070-7187739	marol219
Joakim Säfdal	Motion planner, truck	070-7492814	joasa165

1 Introduction

This document includes instructions on how the requirements in the requirements specification [3] are to be verified. Each requirement is listed with a test description describing how to perform the test together with the requirements for a passed test. Each requirement has an associated test protocol where all trials are listed. Each trial include date, a note if the trial passed or failed and additional comments.

2 System Overview

1	Original	The system should be controlled by a single program that is executed from a version controlled executable file.	1
Test Description: Get the executable file from the git-repository. Start the program with the executable file.			
Pass Requirements: The executable file exist in the Git-repository. The program starts without any problems.			
Trial	Date	Comments	Pass/Fail
1	2017-12-01		Pass
2	Reneg. 17-12-04	The simulator should be controlled by a program that is executed from a version controlled executable file.	1
Test Description: Get the executable file from the git-repository. Start the simulator with the executable file.			
Pass Requirements: The executable file exist in the Git-repository. The simulator starts without any problems.			
Trial	Date	Comments	Pass/Fail
1	2017-12-05		Pass
3	Reneg 17-12-04	Choosing to use truck with semi-trailer or truck with dolly-steered trailer should be accessible through the programs Graphical User Interface (GUI).	1
Test Description: Briefly test all program features in the GUI.			
Pass Requirements: All implemented features are accessible in the GUI.			
Trial	Date	Comments	Pass/Fail
1	2017-12-01	Traveling direction of the truck cannot be altered.	Fail
2	2017-12-05		Pass
4	Original	With all requirements of priority 1 under sections 4, 5 and 6 fulfilled, the car and the truck with semi-trailer should be able to drive autonomously in the same direction on the track without any interruptions for 5 consecutive laps each.	1
Test Description: Make sure that the all requirements of priority 1 under sections 4, 5 and 6 are fulfilled. Start the car and the truck with semi-trailer in the same direction, truck reversing. Count the laps they travel without interruption.			
Pass Requirements: The car and the truck with semi-trailer can drive without interruption for 5 consecutive laps each.			
Trial	Date	Comments	Pass/Fail
1	2017-12-05	The truck with semi-trailer drove 5 consecutive laps and the car drove around 20 consecutive laps without interruption.	Pass

Course name: Automatic Control - Project Course
 Project group: Truckers Paradise
 Course code: TSRT10
 Project: LiU Racetrack 2017

E-mail: axesk370@student.liu.se
 Document responsible: Truls Nyberg
 Author's E-mail: truny887@student.liu.se
 Document name: test_protocol.v1.0.pdf



5	Original	With all requirements of priority 1 under sections 4, 5 and 6 fulfilled, the car and the truck with semi-trailer should be able to drive autonomously in different directions on the track without any interruptions for 5 consecutive laps each.	2
Test Description: Make sure that the all requirements of priority 1 under sections 4, 5 and 6 are fulfilled. Start the car and the truck with semi-trailer in different directions, truck with semi-trailer in forward drive. Count the laps they travel without interruption.			
Pass Requirements: The car and the truck with semi-trailer can drive without interruption for 5 consecutive laps each.			
Trial	Date	Comments	Pass/Fail
1	2017-xx-xx		Fail

6	Reneg. 17-12-04	The car should have a success rate of 80% for initiated overtaking procedures. When the planner draws a new trajectory in the GUI an overtake is considered to be initiated.	2
Test Description: Start the car with a static obstacle in the reference trajectory of the car, use the truck with semi-trailer as obstacle. Calculate the success rate from at least ten overtaking procedures. Repeat the above with a moving obstacle instead of a static one, use the truck with semi-trailer reversing as moving obstacle.			
Pass Requirements: Calculated success rates are at least 80%.			
Trial	Date	Comments	Pass/Fail
1	2017-12-01	Test with truck and trailer as static obstacles failed with a success rate of about 50% over several locations around the track.	Fail

3 Simulator

7	Original	The simulator should be able to execute without any external hardware.	1
Test Description: Compile and execute the simulator on a computer not connected to any external hardware used in the project.			
Pass Requirements: The simulator is executed without any errors.			
Trial	Date	Comments	Pass/Fail
1	2017-11-20		Pass

8	Original	To be able to evaluate the software used in the reality, the simulator should be able to operate using the same modules.	1
Test Description: Check that the simulator uses algorithms with the same source code as the racetrack project.			
Pass Requirements: Algorithms applied both in the simulator and in the racetrack project should have the same source code and be of the same version.			
Trial	Date	Comments	Pass/Fail
1	2017-11-20		Pass

9	Original	The simulator should have a GUI which imitates the real-world, i.e. the racetrack, cars and the truck.	1
Test Description: Start the simulator.			
Pass Requirements: The GUI imitates the real-world.			

Course name: Automatic Control - Project Course
 Project group: Truckers Paradise
 Course code: TSRT10
 Project: LiU Racetrack 2017

E-mail: axesk370@student.liu.se
 Document responsible: Truls Nyberg
 Author's E-mail: truny887@student.liu.se
 Document name: test_protocol.v1.0.pdf



Trial	Date	Comments	Pass/Fail
1	2017-11-20		Pass
10	Original	The simulator should visualize the generated trajectories from the planner in the GUI.	1
Test Description: Start a simulation in the simulator.			
Pass Requirements: The generated trajectories from the planner is drawn in the GUI.			
1	2017-11-20		Pass
11	Original	The simulator should be able to create static obstacles.	1
Test Description: Create a static obstacles and run the simulator.			
Pass Requirements: The static obstacle is shown in the GUI.			
1	2017-11-20	Passed by commenting out the motion of truck	Pass
12	Original	The simulator should be able to create dynamic obstacles.	1
Test Description: Create a dynamic obstacle, i.e a truck, and run the simulator.			
Pass Requirements: The moving obstacle is shown in the GUI.			
1	2017-11-20		Pass
13	Original	The simulator should include a motion model of the car.	2
Test Description: Check in the code if there exist a motion model for the car.			
Pass Requirements: The simulator operates using a motion model for the car.			
1	2017-xx-xx		Fail
14	Original	The simulator should be able to simulate the closed-loop system consisting of the controlled car and its low-level controller.	2
Test Description: Start the simulator and run a simulation. Validate that the low-level controller controls the car.			
Pass Requirements: The car is controlled.			
1	2017-xx-xx		Fail
15	Original	The simulator should include a motion model of the truck with semi-trailer.	2
Test Description: Check in the code if there exist a motion model for the truck with semi-trailer.			
Pass Requirements: The simulator operates using a motion model for the truck with semi-trailer.			
1	2017-xx-xx		Fail
16	Original	The simulator should be able to simulate the closed-loop system consisting of the controlled truck with semi-trailer and its low-level controller.	2



Test Description: Start the simulator and run a simulation. Validate that the low-level controller controls the truck with semi-trailer.			
Pass Requirements: The truck with semi-trailer is controlled.			
Trial	Date	Comments	Pass/Fail
1	2017-xx-xx		Fail

17	Original	The simulator should be able to replay logged data from real-world experiments.	2
Test Description: Start the simulator, import logged data and run a simulation.			
Pass Requirements: The logged data is replayed in the GUI.			
Trial	Date	Comments	Pass/Fail
1	2017-xx-xx		Fail

4 Motion Planner for the Car

All requirements in this section, except requirement 23, will be tested by running the system with a car and a reversing truck with a semi-trailer driving clockwise around the racetrack. Requirement 23 will be tested with a car and a forward driving truck with a semi-trailer where the truck will drive counter-clockwise around the track. The system should run continuously until all the requirements have been tested.

18	Original	Planning a new trajectory in multiple Werling steps should be possible in real time.	1
Test Description: Observe the car overtake the truck with semi-trailer.			
Pass Requirements: The whole trajectory for the overtake should be drawn on the racetrack.			
Trial	Date	Comments	Pass/Fail
1	2017-11-28		Pass

19	Original	If the reference trajectory is blocked by an obstacle moving in the same direction as the car, but with a lower speed, the Werling planner should then generate a reference trajectory which overtakes the obstacle within the resolution of the Werling grid.	1
Test Description: Observe the car overtake the truck with semi-trailer.			
Pass Requirements: A trajectory for the overtake should be drawn on the race-track.			
Trial	Date	Comments	Pass/Fail
1	2017-11-28		Pass

20	Original	A trajectory generated for overtaking should end back at the reference trajectory.	1
Test Description: Observe the car overtake the truck with semi-trailer.			
Pass Requirements: The whole trajectory for the overtake should be drawn on the racetrack.			
Trial	Date	Comments	Pass/Fail
1	2017-11-28		Pass

21	Original	An overtake should only be initiated if the entire overtake can be planned.	1
----	----------	---	---



Test Description: Observe the car overtake the truck with semi-trailer.			
Pass Requirements: The whole trajectory for the overtake should be drawn on the racetrack before the car initiates the overtake.			
Trial	Date	Comments	Pass/Fail
1	2017-11-28		Pass

22	Original	If the reference trajectory is blocked by an obstacle moving in the same direction as the car and no overtake is possible, the Werling planner should then generate a trajectory that follows the obstacle.	1
----	----------	---	---

Test Description: Observe the car when driving behind the truck with semi-trailer in a part of the track where an overtake is not possible.			
Pass Requirements: The car should drive with the same speed as the truck with semi-trailer, without tailgating or initiating overtakes.			
Trial	Date	Comments	Pass/Fail
1	2017-11-28		Pass

23	Original	The Werling planner should be able to use the trajectory of the truck with semi-trailer when planning an overtake.	2
----	----------	--	---

Test Description: Observe the car overtaking the truck with semi-trailer on the outside in a curve.			
Pass Requirements: A trajectory around the truck with semi-trailer should be drawn. It should be clear that the new trajectory would interfere with the truck with semi-trailer if the truck with semi-trailer were to continue straight forward and not follow the tracks curve.			
Trial	Date	Comments	Pass/Fail
1	2017-12-06		Pass

24	Original	The Werling planner should be able to plan a trajectory for overtaking a moving obstacle moving towards the car within the resolution of the Werling grid.	2
----	----------	--	---

Test Description: Observe the car driving towards the truck with semi-trailer.			
Pass Requirements: A trajectory for the overtake should be drawn on the race-track.			
Trial	Date	Comments	Pass/Fail
1	2017-xx-xx		Fail

5 Motion Planner for the Truck with Semi-trailer

All requirements in this section will be tested by running the system with a truck with a semi-trailer alone on the track. The truck will drive around the track clockwise in reverse and counter-clockwise when driving forward.

25	Original	The lattice planner should be able to plan trajectories in both forward and backward motion.	1
Test Description: Observe the truck with semi-trailer driving both forward and in reverse.			
Pass Requirements: A reference trajectory should be drawn on the track.			
Trial	Date	Comments	Pass/Fail

Course name: Automatic Control - Project Course
 Project group: Truckers Paradise
 Course code: TSRT10
 Project: LiU Racetrack 2017

E-mail: axesk370@student.liu.se
 Document responsible: Truls Nyberg
 Author's E-mail: truny887@student.liu.se
 Document name: test_protocol.v1.0.pdf



1	2017-11-28		Pass
26	Original	The truck should wait for the motion planner to generate the entire trajectory before driving.	1
Test Description: Observe the truck when starting the system.			
Pass Requirements: The truck should wait for the the entire trajectory to be drawn on the racetrack before driving.			
Trial	Date	Comments	Pass/Fail
1	2017-11-28		Pass
27	Original	The motion planner should be able to generate a reference trajectory within 5 seconds.	1
Test Description: Observe time elapsed from starting the system to drawing a reference trajectory.			
Pass Requirements: The elapsed time should not exceed 5 seconds.			
Trial	Date	Comments	Pass/Fail
1	2017-11-28	10 seconds	Fail
2	2017-12-01	1.6 seconds	Pass
28	Original	When the truck with semi-trailer is selected in the GUI, the motion planner should create a reference trajectory around the entire racetrack, if a feasible trajectory exists within the resolution of the planner.	1
Test Description: Observe the drawn reference trajectory when the system has been started.			
Pass Requirements: The reference trajectory should be complete around the track with no open ends.			
Trial	Date	Comments	Pass/Fail
1	2017-11-28		Pass
29	Reneg. 17-12-04	If no feasible trajectory exists when planning is initiated, a trajectory should be created which takes the truck with semi-trailer as far as possible on the racetrack.	2
Test Description: Place an obstacle in the center of one of the hairpin turns on the track before start-up. Observe the truck when starting the system.			
Pass Requirements: A trajectory should be drawn on the racetrack from the start to the obstacle. The truck with semi-trailer should follow the planned trajectory and stop at the end. Log data should verify that no feasible trajectory was found around the obstacle.			
Trial	Date	Comments	Pass/Fail
1	2017-xx-xx		Fail
30	Reneg. 17-12-04	If an obstacle appears on the racetrack and blocks the generated trajectory, the truck should stop immediately and the motion planner should generate a new, reference trajectory.	2
Test Description: Place an obstacle in the middle of the long straight part of the track after the truck has entered the first turn.			
Pass Requirements: The truck should stop and a new trajectory past the obstacle should be drawn which the truck should begin to follow.			
Trial	Date	Comments	Pass/Fail



1	2017-xx-xx		Fail
31	Reneg. 17-12-04	The motion planner should be able to plan a trajectory that ends with the truck parked at the side of the track.	2
Test Description: Select <i>Park Truck</i> in the GUI and observe the truck.			
Pass Requirements: The truck should stop, draw a new trajectory, follow it and park close to the side at the starting line.			
Trial	Date	Comments	Pass/Fail
1	2017-xx-xx		Fail

6 Low-level Controller for Truck with Semi-trailer

The low-level controller for the truck with semi-trailer will be tested by running the system and checking the tests described below.

32	Original	Use the existing model for the truck with semi-trailer described in [1] when designing the lateral low-level controller for forward driving.	1
Test Description: Verify in the low-level controller code that the same model is used.			
Pass Requirements: The existing model for the truck with semi-trailer is used.			
Trial	Date	Comments	Pass/Fail
1	2017-12-01		Pass

33	Original	When the truck with semi-trailer is alone on the track it should be able to drive either forward or backward five consecutive laps without interruption. The reference trajectory around the track should be generated by the motion planner for the truck with semi-trailer.	1
Test Description: Observe the truck with semi-trailer drive forward alone on the track for five consecutive laps. Observe the truck with semi-trailer drive backward alone on the track for five consecutive laps.			
Pass Requirements: The truck drives forward five consecutive laps without interruption. The truck drives backward five consecutive laps without interruption.			
Trial	Date	Comments	Pass/Fail
1	2017-12-01	Forward and Backward motion OK.	Pass

34	Reneg. 17-12-04	The lateral deviation of the truck with semi-trailer should stay within 4 cm of the reference trajectory for at least 80% of the time on each lap.	1
Test Description: Inspect the logged data from the lateral deviation.			
Pass Requirements: The lateral deviation is less than 4 cm for at least 80% of the time on each lap.			
Trial	Date	Comments	Pass/Fail
1	2017-12-01	Mostly under 6cm in forward motion.	Fail
2	2017-12-04		Pass



35	Reneg. 17-12-04	The heading deviation of the truck with semi-trailer should not be greater than 5 degrees for at least 80% of the time on the lap.	1
Test Description: Inspect the logged data from the heading deviation.			
Pass Requirements: The heading deviation of the truck with semi-trailer is not greater than 5 degrees for at least 80% of the time on each lap.			
Trial	Date	Comments	Pass/Fail
1	2017-12-01	Mostly under 5 degrees.	Fail
2	2017-12-04		Pass

36	Reneg. 17-12-04	The deviation in the relative angle between the semi-trailer and the truck should not be greater than 5 degrees for at least 80% of the time on the lap.	1
Test Description: Inspect the logged data from the relative angle between the semi-trailer and the truck.			
Pass Requirements: The deviation in the relative angle between the semi-trailer and the truck is not greater than 5 degrees for at least 80% of the time on each lap.			
Trial	Date	Comments	Pass/Fail
1	2017-12-04		Pass

37	Reneg. 17-12-04	The truck with semi-trailer should have a longitudinal cruise controller.	1
Test Description: Visually inspect the truck using longitudinal cruise control.			
Pass Requirements: The cruise controller seems to work.			
Trial	Date	Comments	Pass/Fail
1	2017-12-04		Pass

7 Low-level Controller for the Truck with Dolly-steered Trailer

The tests for the low-level controller for the truck with dolly-steered trailer is described below.

38	Original	The model for the truck with dolly-steered trailer should be based on [2].	1
Test Description: Verify in the low-level controller code that the model from [2] is used.			
Pass Requirements: See Test Description!			
Trial	Date	Comments	Pass/Fail
1	2017-11-28		Pass

39	Original	The low-level controller for the truck with dolly-steered trailer should be implemented with the same structure as the one implemented for the existing low-level controller for the truck with semi-trailer given in [1].	1
Test Description: Verify in the low-level controller code that the same control structure as in [1] is used.			
Pass Requirements: See Test Description!			



Trial	Date	Comments	Pass/Fail
1	2017-11-28		Pass

40	Original	The truck with dolly-steered trailer should be able to drive around the whole racetrack in forward motion.	1
----	----------	--	---

Test Description: Start the truck with dolly-steered trailer in forward motion at the starting line.

Pass Requirements: The truck with dolly-steered trailer is able to drive around the entire racetrack in forward motion.

Trial	Date	Comments	Pass/Fail
1	2017-12-05		Pass

41	Reneg. 17-12-04	The truck with dolly-steered trailer should be able to follow a straight reference trajectory without folding when reversing.	1
----	-----------------	---	---

Test Description: Start the truck with dolly-steered trailer at the starting line as close to the reference trajectory as possible. Observe the truck reversing.

Pass Requirements: The truck should not fold.

Trial	Date	Comments	Pass/Fail
1	2017-11-28	Able to reverse but with more than 2 cm error.	Pass

42	Original	The truck with dolly-steered trailer should be able to reverse through a 90-degree turn with a minimum turning radius of 25 cm.	2
----	----------	---	---

Test Description: Observe the truck reversing through a 90-degree turn.

Pass Requirements: The turning radius is 25 cm at minimum.

Trial	Date	Comments	Pass/Fail
1	2017-xx-xx		Fail

43	Original	The truck with dolly-steered trailer should be able to reverse through a 180-degree turn with a minimum turning radius of 25 cm.	2
----	----------	--	---

Test Description: Observe the truck reversing through a 180-degree turn.

Pass Requirements: The turning radius is 25 cm at minimum.

Trial	Date	Comments	Pass/Fail
1	2017-xx-xx		Fail

44	Original	The truck with dolly-steered trailer should be able to reverse around the whole racetrack.	3
----	----------	--	---

Test Description: Observe the truck with dolly-steered trailer reversing.

Pass Requirements: The truck with dolly-steered trailer can reverse through the entire track without interruptions.

Trial	Date	Comments	Pass/Fail
1	2017-xx-xx		Fail

8 Code Quality

To ensure this years code quality some code quality tests have been formulated. These tests are described below.

Course name:	Automatic Control - Project Course	E-mail:	axesk370@student.liu.se
Project group:	Truckers Paradise	Document responsible:	Truls Nyberg
Course code:	TSRT10	Author's E-mail:	truny887@student.liu.se
Project:	LiU Racetrack 2017	Document name:	test_protocol.v1.0.pdf



45	Original	No unused code files should be delivered in the finished Visual Studio solution.	1
Test Description: Check the source code and verify that all code files are needed for the system.			
Pass Requirements: No unused code files are found.			
Trial	Date	Comments	Pass/Fail
1	2017-12-07		Pass
46	Reneg. 17-12-04	All new code files should include a descriptive file comment at the top.	1
Test Description: Check all new code files.			
Pass Requirements: All new files starts with a comment.			
Trial	Date	Comments	Pass/Fail
1	2017-12-07	Will be fixed on delivery.	Fail
47	Reneg. 17-12-04	All new code files should comply with Google C++ Style Guide.	1
Test Description: Read new files and compare with Google C++ Style Guide.			
Pass Requirements: The code follows the style guide.			
Trial	Date	Comments	Pass/Fail
1	2017-12-07	Will be fixed on delivery.	Fail
48	Original	A structure for constructing new tests and unit test should be produced.	2
Test Description: Run a test on some source code.			
Pass Requirements: The test should run.			
Trial	Date	Comments	Pass/Fail
1	2017-12-07	Simple makefile and catch.hpp tests implemented.	Pass
49	Original	Automatic tests should find build errors.	2
Test Description: Try to merge or push code with build errors to the master branch of the GIT repository.			
Pass Requirements: The merge or push should be rejected.			
Trial	Date	Comments	Pass/Fail
1	2017-xx-xx		Fail
50	Original	New functionality should be delivered together with a unit test.	2
Test Description: Run delivered tests on all new source code.			
Pass Requirements: The tests should run and verify that the new functionality is implemented.			
Trial	Date	Comments	Pass/Fail
1	2017-xx-xx		Fail
51	Original	New code will be code reviewed.	2
Test Description: Study the merge requests in the git repository.			
Pass Requirements: A reviewer should be stated in every merge to the master branch.			
Trial	Date	Comments	Pass/Fail
1	2017-xx-xx		Fail



52	Original	A proposal for refactoring of the structure of the parallel processes and the data communication between these should be made.	2
Test Description: Study the proposal.			
Pass Requirements: A proposal has been made.			
Trial	Date	Comments	Pass/Fail
1	2017-xx-xx		Fail

53	Original	The proposed refactoring of the parallel processes should be implemented.	3
Test Description: Run the system.			
Pass Requirements: Check that the new structure of parallel processes are working.			
Trial	Date	Comments	Pass/Fail
1	2017-xx-xx		Fail

References

- [1] M. Almen. Technical documentation liu racetrack 2016, 2016.
- [2] O. Ljungqvist, N. Evestedt, M. Cirillo, D. Axehill, and O. Holmer. Lattice-based motion planning for a general 2-trailer system. In *2017 IEEE Intelligent Vehicles Symposium (IV)*, pages 819–824, June 2017.