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Experimental assessment of SST evaluation as handling quality indicator

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Abstract

The growth of urban bicycles, including cargo and foldable designs, has driven the evolution of bicycle design. In order to support this evolution, design rules that ensure good handling quality - the ease and precision with which a bike can be controlled - could be beneficial. However, despite extensive research in recent years, theoretical approaches to quantifying bicycle handling quality still have strong limitations and lack validity (Schwab & Meijaard, 2013). Moreover, subjective evaluations are subjected to large inter-individual / inter-session variability and require very carefully controlled experiments. Therefore, there is a need to find criteria, based on measures that can be easily obtained in an ecological setting, to objectify the bicycle's handling quality.

Numerous parameters have been proposed in the literature to characterise bicycle motion. However, there is no strong evidence for an effective indicator of handling quality. Recently, a new indicator called the SST evaluation (Singular Spectral Transformation) has been proposed (Takagi et al., 2022) to predict a combination of rider's subjective perceptions. This study aims to investigate the link between perceived handling quality and the SST evaluation on a larger sample of the population (only 3 riders in (Takagi et al., 2022)).

Material and methods

This study included 30 adults participants who self-declared their riding proficiency as beginner to advanced. Participants were instructed to ride two commercially available bicycles (a Strida 5 foldable bike, and an Omnium Cargo V3 cargo bike) on a 130 m long track that was closed to traffic. The task was to maintain a constant speed and follow a path marked by a 9 cm wide white line on a flat and smooth tarmac. The path consisted of a straight line, a left turn, a slalom, and a right turn. Each participant completed three laps at three different speed instructions (S: "slowest possible," C: "comfort speed, which maximises the feeling of control," F: "faster than comfort speed") with both bicycles. The order in which the bikes and speed conditions were presented was randomised.

To assess the handling quality of the bicycles, participants were asked to rate their experience at the end of each lap using the Cranfield Aircraft Handling Qualities Rating Scale (CAHQRS, a 10 levels scale from 0 to 9). A higher score on the CAHQRS indicates that the bicycle is more difficult to control.

The bicycles were equipped with 3 XSens DOT sensors, which were placed on the rear wheel spokes, frame and handlebar. The sensors measured 3-axis accelerations, rate angles and magnetic field, at 120 Hz. Roll angle was obtained using the XSens DOT fusion algorithm.

SST evaluation is based on singular spectral transformation of linear regression residuals. The regression used is fitted between roll angle and handlebar angular velocity (Takagi et al., 2022). SST evaluation were calculated and averaged on each lap of the data-set.

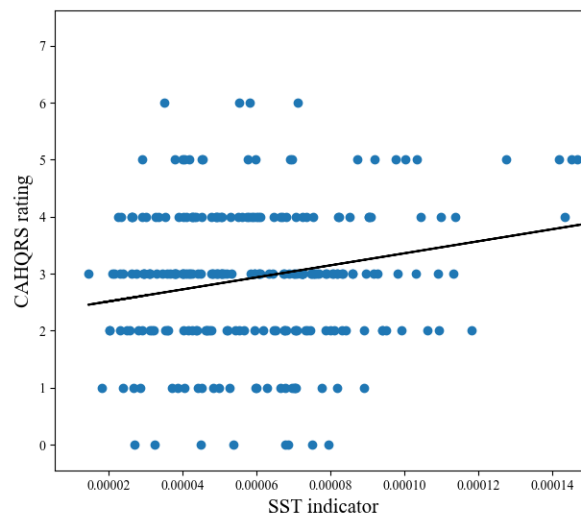


Figure 1. CAHQRS ratings against the mean value of SST evaluation for each lap of all participants

CAHQRS ratings were plotted against the mean value of SST evaluation on each lap. The link between perceived handling quality and SST evaluation were tested with a linear regression analysis.

Results and discussion

Regression analysis find out a statistically significant effect ($p < 0.05$) of SST evaluation on handling quality ratings. However, the fitted model explains poorly ratings variability ($r^2 = 0.047$). It could be that SST evaluation was initially assessed across a mixture of rider's perception (the first component of a PCA analysis over 10 different questions) and not only the difficulty to ride the bikes. Another possibility is the fact that handling quality results of a complex interaction between different characteristics. Indeed, an analysis of the rider's subjective perception for this experiment shows that handling quality is affected by stability (at low speed) and manoeuvrability (at high speed) (Ronné et al., 2023). Therefore, handling quality might be difficult to capture using a single criteria. This idea is also in line with the fact that, in the study by (Takagi et al., 2022), the effect of the SST evaluation on subjective ratings was not consistent across different experimental conditions.

This study fails to validate the SST evaluation as an objective indicator for the handling quality on a large sample of population. To date, such an indicator is still missing. Current work focuses building indicators of handling quality that take into account different bicycle characteristics such as the stability at low speeds and manoeuvrability at higher speeds.

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