Bicycle handling quality perception: mixed effect of stability and manoeuvrability

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Abstract

Growth of urban bicycles functions and expectations (such as cargo or foldable) pushes designs to evolve. Design rules which guarantee good handling quality (the ease a bike can be controlled) could be beneficial to support designs evolution. Although the link between bicycle design and its dynamics is well established, its impact on the handling quality remains poorly understood. Complex interactions between very different design parameters can lead to equivalent handling. Despite extensive research these last years, theoretical approaches to quantify the bicycle handling quality still have strong limitations and lack of validity (Schwab & Meijaard, 2013; Takagi et al., 2022), and experimental approaches remain necessary. Yet, there is no strong evidence of which experimental parameter could be used to characterise handling quality. Handling quality is suspected to result of a complex interaction between stability and manoeuvrability, which are both highly speed dependant. This study aims to investigate this link between handling quality, stability and manoeuvrability. We expect that handling quality perception is affected by a lack of stability at low speed and affected by poor manoeuvrability at higher speed.

Material and methods

Thirty adults (self declared as beginner to advanced riders) were asked to ride two different commercial bicycles on 130 m long track closed to traffic. They were asked to maintain a constant speed and to follow as much as they can a path painted on a flat and smooth tarmac. The path was made of a 9 cm wide white line (one straight line, one left turn, a slalom and a right turn). Each participant rode 3 times at 3 different speed instructions (S: “slowest possible”, C: “comfort speed, which maximise the feeling of control”, F: “faster than comfort speed”) with both bikes. Bikes and speed conditions were presented in a randomised order. At the end of each lap, participants were asked to fill a questionnaire about their riding feelings made of 4 items (See Table 1). The fist item evaluates the Handling quality thanks to the Cranfield Aircraft Handling Qualities Rating Scale (CAHQRS, the higher the score, the harder to control the bicycle is.) (Harris et al., 2000). Remaining items are adapted from (Takagi et al., 2022) (the higher the score, the stronger the feeling is). Experimental bicycles were chosen to be uncommon and with extreme design parameters: Strida 5 (foldable bike) and Omnium Cargo V3 (cargo bike). Bicycles were equipped with 3 IMUs (Xsens DOT) (rear wheel spokes, frame and handlebar), although these data will not be analysed in this first study. The effects of speed instruction (“S”, “C”, “F”) and bicycle were statistically tested on the scores for each item score with a repeated measurement two-way ANOVA and post-hoc tests.
Table 1. Questionnaire about the riding feeling.

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAHQRS</td>
<td>Handling quality</td>
<td>0 to 9</td>
</tr>
<tr>
<td>Q1</td>
<td>Feeling the need to wobble the handlebar</td>
<td>1 to 5</td>
</tr>
<tr>
<td>Q2</td>
<td>Feeling instability during turns</td>
<td>1 to 5</td>
</tr>
<tr>
<td>Q3</td>
<td>Feeling the line is hard to follow</td>
<td>1 to 5</td>
</tr>
</tbody>
</table>

Figure 1. Mean and standard deviation across subjects of scores given to the questionnaire’s items, spread by bicycle and speed instruction. * and # indicate a significant difference (p<0.05) between speed instructions or bicycles, respectively. Handling quality exhibit a non-monotonic effect of speed instructions.

Results and discussion

Statistical test on CAHQRS ratings find out a significant effect of speed instructions (p<0.001). "Slow" and "Fast" laps are characterised by a poor handling quality compared to "Comfort" laps. A similar effect was found for the feeling of instability during turns (Q2) and the feeling of difficulty of the line following task (Q3). On the opposite, the feeling of "handlebar wobbling" (Q1) was clearly higher for "Slow" laps than for "Comfort" and "Fast" laps (no difference between these last two conditions). The only difference found between the two bicycles was a higher difficulty of the line following task (Q3) for "Fast" laps for the Omnium Cargo bike.

As expected, handling quality perception exhibit a statistically significant non-monotonic effect of speed instructions. "Low" speed have been characterised by oscillating handlebar feeling (Q1), which is consistent with unstable weave mode. "Comfort" and "Higher" speeds distinguish themselves by the instability during turns feeling (Q2) which is also consistent with limited manoeuvrability at higher speed. Despite very different designs, few differences were observed between the two bikes. It could be explained by the fact both bikes are tried-and-tested designs. The only difference appears on "Fast" laps, where Omnium V5 bicycle were more difficult to ride probably caused by its large wheelbase (1.6m versus 0.9m for Strida bike).

Preliminary results confirm that handling quality is affected by stability and manoeuvrability. It suggests that describing a bicycle handling quality requires to characterise both of these characteristics across usage speed range. Future work will focus on handling quality perception prediction based on signals that have been collected by IMUs set on both bicycles. Objective indicators are expected to discriminate between bicycles better than subjective ratings.

References


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