Looming detection within natural scenes and potential errors in roadside judgments

Damian Poulter\textsuperscript{1}, John Wann\textsuperscript{1}, Catherine Purcell\textsuperscript{1}, Kate Wilmot\textsuperscript{2}

\textsuperscript{1}Royal Holloway, University of London, UK
\textsuperscript{2}Oxford Brookes University, UK

Introduction

- Detection of looming is critical for successful collision avoidance.
- Regan et al. (1973–96) have been foremost in documenting humans’ sensitivity to looming and MID.
- Regan & Beverley (1979) reported thresholds for looming lower than 0.02 degs.
- Hoffman (1994) determined angular velocity threshold at 0.11 degs (0.032 radians) for static watching videos of approaching vehicles.
- Various methodological factors make it difficult to extrapolate from these measures to performance in natural settings.
- The current study was concerned with looming thresholds in the context of roadside behaviour and aimed to dissociate detection of looming from simple detection of edge motion, by including lateral horizontal and vertical displacement of the image as well as isotropic expansion.

Methodology

- Adaptive (BEST-PEST) staircase procedures were run.
- Photo-realistic images of a motorbike or car were presented for 200ms.
- Aim to determine sensitivity to looming of vehicles in central or peripheral vision, under monocular viewing conditions.
- Vehicle images changed in size and expand to simulate approach at different speeds, but also moved laterally in the simulated scene by 40\textdegree\textsuperscript{v}axial horizontally and 20\textdegree\textsuperscript{v}axial vertically, simulating a discreet lateral change in approach trajectory.
- Display configuration ensured sufficient pixel resolution for all stimulus levels.
- The participant’s task was detection of looming, with interleaved null trials, for a vehicle image under three conditions:
  - Detection of looming as opposed to simple lateral image displacement.
  - Scene displacement of 1\textdegree\textsuperscript{a}deg scaled with distance\textsuperscript{\textsuperscript{a}} (simulating observer forward movement while scanning for vehicles).
  - Scene rotation of 1\textdegree\textsuperscript{a}deg (5\textdegree\textsuperscript{a}axial) randomly oriented in 1 of 4 diagonal directions (simulating re-orienting of gaze while scanning a road).
- For rotation and displacement conditions, lateral image translation was also included.
- All thresholds reported in degs (Looming).\textsuperscript{\textsuperscript{a}}

Experiment 1: Background

- Assessed whether presenting stimuli in front of a neutral (Fig. 1a) or contextual background (Fig. 1b) had an effect on looming thresholds.
- Participants (n=8) detected central looming of a car at 3s TTC in front of a neutral grey background & in front of a road scene.
- Looming thresholds slightly higher for contextual backgrounds ($M=0.138$, SD = 0.106), but not significantly different from grey ($M=0.109$, SD = 0.041).

Experiment 2: TTC 3s

- A photo-realistic image of a car was presented against a naturalistic road scene background (see Fig. 2 below).
- A simulated TTC of 3s was used - critical decision point after which crossing would involve risk of collision.
- Looming thresholds slightly higher with vehicle displacement ($M=0.159$, SD = 0.079), but not significantly different from no_motion threshold ($M=0.101$, SD = 0.031).
- Looming threshold with scene rotation ($M=0.446$, SD = 0.149) was significantly higher than both no_motion and displacement thresholds.

Experiment 3: TTC 5s

- A photo-realistic image of a car was presented against a naturalistic road scene background (see Fig. 3 above).
- A simulated TTC of 5s was used - critical decision point after which crossing would involve considerable risk of collision.
- Looming thresholds slightly higher with vehicle displacement ($M=0.194$, SD = 0.069), but not significantly different from no_motion threshold ($M=0.071$, SD = 0.023).
- Looming threshold with scene rotation ($M=0.280$, SD = 0.092) was significantly higher than both other thresholds.

Experiment 4: Peripheral

- Looming thresholds 4.25deg in periphery were investigated (see Fig. 4 below), including thresholds in upper & lower visual fields.
- Participants (n=7) viewed a photo-realistic image of a car presented against a naturalistic road scene background.
- A simulated TTC of 3s was used - critical decision point after which crossing would involve considerable risk of collision.
- Looming thresholds with no_motion similar for lower ($M=0.317$, SD = 0.079) & upper visual field ($M=0.356$, SD = 0.010).
- Looming thresholds with vehicle displacement similar for lower ($M=0.962$, SD = 0.607) & upper visual field ($M=1.020$, SD = 0.363).

Discussion

- When there was a neutral background and no lateral motion, we found looming thresholds slightly higher than those reported by Regan et al. under more constrained psychophysical conditions, but thresholds were significantly higher under scene displacement and rotation conditions.
- We also found a significant increase in thresholds when stimuli were presented in the periphery by only 4.25deg (3deg vertical, 3deg horizontal).
- The results suggest that, in displays that contain the contrast and edge-detail of natural scenes, and where other motion information such as rotation may be present, detection of looming may be significantly poorer than previously reported.
- This still allows for accurate detection if the object is foreshortened, but in a cluttered scene if the observer glance slightly off-target they may fail to detect fast approaching vehicles.
- In real-world terms, when you are stationary and the vehicle directly, but require 3 seconds to cross the road, the threshold for looming equates to detecting a vehicle travelling as quickly as 200mph (which therefore is 267m away and very small). But when you are in motion and not looking directly at the vehicle, the raised threshold means that you may fail to detect a vehicle travelling faster than 25mph (e.g. 33m away, with 3sec TTC).
- This could be a factor in crashes classified as ‘fatigued, but did not see’.
- This may be particularly a problem for smaller profile vehicles such as motorcycles and may help explain driver errors with respect to these.

Table 1: Means (SD) values for car & motorbike under all settings

<table>
<thead>
<tr>
<th></th>
<th>Car</th>
<th>Motorbike</th>
</tr>
</thead>
<tbody>
<tr>
<td>No_Motion</td>
<td>0.112 (0.07)</td>
<td>0.186 (0.19)</td>
</tr>
<tr>
<td>Displacement</td>
<td>0.159 (0.053)</td>
<td>0.053 (0.329)</td>
</tr>
<tr>
<td>Rotation</td>
<td>0.426 (0.288)</td>
<td>0.396 (0.354)</td>
</tr>
</tbody>
</table>

Fig. 1a: Grey background
Fig. 1b: Contextual background
Fig. 2: Stimul at 3 TTC
Fig. 3: Stimul at 5 TTC
Fig. 4: Peripheral stimuli
Fig. 5a: Car at 3 TTC
Fig. 5b: Motorbike at 3 TTC
Fig. 5c: Grey background

Research supported by the UK ESRC ES/F017650/1