Conference Paper

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Publication Date:
2018-01-14

Permanent Link:
https://doi.org/10.3929/ethz-b-000222474

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Risk Perception and Gaze Behavior during Urban Cycling – A Field Study

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Abstract. We investigated the relation of risk perception and gaze behavior during urban cycling in a naturalistic real world setting. Participants rode a bike on five route segments while wearing a mobile eye tracking device, and subsequently marked, described, and rated all areas they thought to be dangerous. Their gaze was focused on the areas they marked as potentially dangerous. The participants’ gaze was also more focused on areas they felt to be subjectively dangerous (but where no accidents had previously occurred) as compared to areas where accidents had occurred (but that also were subjectively dangerous).

Keywords. Mobile eye tracking, risk perception, urban cycling

1. Introduction

The risks and hazards associated with cycling represent greater obstacles than the involved physical effort (Schepers et al., 2014). A source of risk in traffic can be defined as every object potentially increasing the probability of an accident. Risk perception can consequently be defined as the process whereby road users perceive the existence of these risks (Haworth et al., 2005). Sørensen & Mosslemi (2009) differentiate between subjective and objective risks. Subjective risk perception consists of several components (e.g., perceived accident probability and consequences, as well as the capability of being in control of a situation). Objective risks relate to the number of accidents relative to the ridden distance.

Processing a high visual workload is integral to urban cycling and the risks associated with it (Schepers et al., 2014). Mobile eye tracking has only recently been introduced to analyze gaze behavior during real world cycling, and primarily in very controlled settings (e.g., Vansteenkiste et al., 2014).
Mantuano et al. (2017) studied cyclists’ gaze behavior in a real urban environment shared with pedestrians. They concluded that discontinuities in the path (e.g., intersections) and the presence of pedestrians draw additional attention. The absence of physical and visual separations between pedestrians and cyclists may result in a lack of attention for those potentially risky elements. However, research on risk perception of drivers suggests that experienced drivers focus their visual attention of areas containing potential hazards (e.g., Borowsky et al., 2010).

The aim of this research is to provide further insights into the relation between (explicit) subjective risk perception during urban cycling and (more implicit) gaze behavior in a naturalistic setting. First, we investigated to what extent cyclists focus their gaze on areas they assume to be potentially dangerous. Second, we attempted to differentiate between objectively and subjectively dangerous areas, and examined gaze behavior towards these areas.

2. Method

Based on data of a local crowdsourcing project on cycling safety, we selected five test locations (TL1-5) in the city center, connected in a circular route of about 5.5km length, with two different starting points (but consistent travel direction) thought to reduce positioning effects. The vast majority of the circular route both at and between the TL consisted of designated cycling lanes. Eighteen participants (9 females; age: $M = 26.6$ years, $SD = 7.46$) with high self-reported cycling experience ($M = 5.55$, $SD = 1.05$ on a 7-point scale) were tested individually on days with good weather conditions only. Participants were equipped with a bike adjusted to their height and a mobile eye tracking system (SMI Eye Tracking Glasses V1). At each TL, participants studied a map indicating a marked route with start and terminal point. They were instructed to cycle to the terminal point, before marking all areas they identified as potentially sources of hazards on a map depicting the previously cycled TL, providing written explanations, and rating each marked area’s hazardousness on 7-point scales, respectively. Using BeGaze, eye tracking data were annotated on allocentric reference maps including all stable traffic relevant elements (e.g., streets, cycling lanes), separately for each TL (see Figure 1, and Wenczel et al., 2017, for more details). Fixations on non-stable elements (i.e., other road users) were annotated separately, but excluded from all analyses reported below. All gaze data were log-transformed with LN - 1 to achieve a better data distribution.
3. Results

In a first step, we examined the relation between the areas participants marked as subjectively dangerous and their gaze behavior (see Figure 1). We used the Gridded AOI function of the BeGaze software to cluster the gaze behavior across all participants into a regular grid ranging from 10×16 to 12×16 cells, depending on the shape of the respective TL. Next, we assigned the participants’ markings on their maps to the respective cells. Hazard ratings were summed up across all participants as an indicator of each cell’s hazard level. Pearson correlations for each cell’s dwell time and the summed hazard level indicated that the participants’ gaze was highly focused on those areas they marked as sources of potential hazards for three test locations (TL1: \( r = .39, p < .001; \) TL3: \( r = .63, p < .001; \) TL4: \( r = .44, p < .001 \)), with TL5 bordering significance (\( r = .14, p = .06 \)), and TL2 showing deviating results (\( r = .05, p = .50 \)). The finding that cyclists focus their gaze on areas they assume to be a source of potential hazards begs the question whether cyclists miss to look at certain directions, thus increasing their (objective) risk to be involved in an accident.

In a second step, we operationalized the level of objective risks based on official accident statistics of the last three years including information about

![Figure 1. Illustration of TL4. The underlying map was used as reference image during the annotation process. The overlaying grid illustrates the Gridded AOI function. The red dotted line indicates the travelled route (starting on the left). White numbers indicate each cell’s summed hazard level across all participants. Blue to red colors indicate increasing dwell time across all participants. Orange boxes indicate the category AOI subjectively dangerous, purple boxes indicate the category AOI objectively + subjectively dangerous.](image)
accident type and accident partners. Accidents involving cyclist-car or cyclist-cyclist collisions relevant to the travelled paths had occurred at TL1-4. We extrapolated travelling directions of all parties involved in these accidents, and defined AOIs consisting of the respective approach vectors (with the reasoning that the direction of a potentially approaching car is more relevant than the actual location of an accident). A comparison with the participants’ markings revealed that these areas were also perceived as subjectively dangerous. We subsumed these areas in the category AOI objectively + subjectively dangerous. At TL2-4, we found additional clusters of the participants’ markings. We correspondingly identified and defined these areas as a second category AOI subjectively dangerous. At TL1, participants’ markings all fell into the category AOI objectively + subjectively dangerous. No AOI subjectively dangerous could be defined, and TL1 had to be excluded from this analysis. We computed a 3 (Test location: TL2 vs. TL3 vs. TL4) × 3 (Risk type: AOI objectively + subjectively dangerous vs. AOI subjectively dangerous vs. Other spaces) ANOVA with normalized dwell time as dependent variable (which accounts for the differently sized AOIs). The ANOVA revealed a main effect of Risk type, $F(2,159) = 13.51, \eta_p^2 = .15, p < .001$ (see Figure 2). Dunn-Bonferroni post-hoc tests indicated that participants gazed significantly more on AOI subjectively dangerous as compared to both other risk type AOIs (both $p < .001$). There was no significant difference between AOI objectively + subjectively dangerous and Other spaces ($p = .44$). A main effect of Test locations, $F(2,159) = 4.70, \eta_p^2 = .06, p < .05$, was further qualified by an interaction effect, $F(2,153) = 9.71, \eta_p^2 = 16, p < .001$. An inspection of Figure 2 suggests that these effects stemmed from TL2, where the participants’ gaze behavior was about equally distributed between the three different risk types. At TL3 and TL4, participants focused their gaze at (accident-

Figure 2. Normalized dwell time (and standard errors) for AOI objectively + subjectively dangerous, AOI subjectively dangerous, and Other spaces, separately for TL2-TL4.
free) areas the assumed to be dangerous, but neglected areas where accidents had previously occurred.

4. Conclusion

This research is one of the first to link gaze behavior and risk perception during urban cycling in a naturalistic setting (but see Mantuano et al., 2017). Participants tended to focus their gaze on those areas they identified as potentially dangerous when explicitly asked to report about them (Borowsky et al., 2010). We used cycling accident statistics to extrapolate the approach vectors of potential accident partners as an indicator of areas with an increased objective risk. Participants marked these areas as subjectively dangerous as well, implying that urban cyclists correctly spot potentially hazardous locations. However, they also marked other areas as subjectively dangerous where no accidents had recently occurred. At TL3 and TL4, normalized dwell times for areas without accidents were higher than for those areas where accidents had occurred. At TL2, gazes were more evenly distributed, with the descriptively highest normalized dwell time in the category AOI objectively + subjectively dangerous. This location was the only one where we found no correlation between gaze behavior and summed hazard levels. Also, one AOI objectively + subjectively dangerous at TL2 received the second-highest summed hazard level of all TL, thus pointing towards a correct identification of accident-prone area by the participants. (TL1 had to be excluded for a similar reason.) A possible conclusion from the findings at TL3 and TL4 is that in certain situations, urban cyclists miss to spot specific approaching vectors of potential collision partners, thus increasing the risk of an accident.

There are a number of caveats. First, determining the level of objective risk based on accident statistics represents a potentially biased approximation. The base rate of accidents is (luckily) too low to guarantee a bulletproof indicator of objective risk. Furthermore, accident statistics do not account for the more frequent near misses that presumably affect cyclists’ risk perception and behavior (Sanders, 2015). However, an extensive observation of the TL for near misses was beyond the scope of this research. Second, we interpreted the available data (e.g., accident type, traffic situation) to extrapolate the area participants should have looked at to the best of our possibilities, but the specific circumstances of the actual accidents might have been different. Our investigation also highlights the inherent relation of subjective and objective risks: If urban cyclists believe a road segment to be dangerous, they will adjust their behavior (e.g., lower their travelling speed), and thus reduce the probability of an accident. Therefore, areas where no accidents had previously occurred may have remained accident-free only because cyclist felt at risk. This begs the question whether we can identify specific infrastructural
or configurational factors that trigger the perception of subjective risk, or lead to the neglecting of (objectively dangerous) areas, respectively. A possible direction could be to capture the shape of the visible space through isovists (Benedikt, 1979). We speculate that a high variability in the visual field (i.e., rapidly changing isovist properties) could induce a high risk perception in a cyclist closing in on an intersection, and also affect gaze behavior.

Taken together, our research suggests that feeling exposed and endangered at a specific location makes cyclists look out for potentially hazards at this particular location. However, the actual danger may result from feeling comparatively safer at other locations, as cyclist miss to gaze into the directions of potential threats.

References