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Cyclist gaze behavior in urban space: An eye-tracking experiment on the bicycle network of Bologna

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ABSTRACT

The increase of cyclist presence in urban areas and of the number of cyclist accidents on roads lead researchers to explore the in-traffic visual behavior and hazard perception of cyclists.

In this study the actual cyclist gaze behavior while cycling on bicycle tracks—exclusive or shared with pedestrians is analyzed. The intent is to allow a better comprehension of those elements representing interferences, which can influence user's trip.

Field tests were performed in the urban center of Bologna, Italy. 16 participants were asked to wear mobile eye tracking glasses and cycle along a defined route. From gaze data recorded by the mobile eye detector, we analyzed which visual information are detected. By applying fixations detection algorithm and then a frame-by-frame analysis we calculated the proportion of fixations—number and duration-across different areas of interest. Proportion of fixations and fixation time are assumed as a proxy of visual workload. Thus, the relative frequency of fixation has been used to rank those elements that draw cyclist attention.

Three are the main outcomes: first, an equilibrium of attention location between the central (trajectory) and lateral parts of the visual scene can be assumed as the optimal cycling visual condition. This condition results compromised when the presence of pedestrians is high. Second, discontinuities of the path (like intersections and crosswalks) and the presence of pedestrians are the elements requiring more attention. Third, the absence of physical and visual separation between cyclists and pedestrians seems to lead to a lack of attention to these risk elements.

These outcomes about cyclists' visual behavior allowed to recommend design measures to increase comfort and safety on shared-with pedestrian-cycling paths. Thus, suggestions are addressed in the conclusions.

1. Introduction

The use of bicycle is increasing for commuting trips in cities, in Europe as well as in Italy (Candappa et al., 2012; Eurobarometer, 2014). Many efforts to make cities more cycling-friendly are being concerted, in order to increase bicycle modal split and to head communities towards a more sustainable urban mobility. Municipalities and administrators refer to guidelines and manuals to intervene on the urban transport network to improve bicycle use. The increase of cyclist presence in urban areas and the low reduction of the number of cyclist accidents on roads call for a deeper study of riding behavior, in order to make the infrastructural investments effective and the urban cycling network safer. Simultaneously, the attention on bicycle's use has been increasing in the last twenty years, focusing on infrastructure design (CROW, 2007; NCHRP, 2010; NACTO, 2012; Levasseur, 2014), definitions of level of service measures (Botma, 1995; Landis et al., 1997; Allen et al., 1998; HCM, 2010a,b), accidents and risk analysis (Kim et al., 2007; Chong et al., 2010; Teschke et al., 2012; Schepers et al., 2014), but the study of cycling gaze behavior is also necessary to understand cyclist travel preferences. The definition and correct design of cycling facilities (i.e. which type and where they should be allocated) is imperative to give a cyclist-attractive power to urban transport networks. Indeed, even if separated cycling paths are generally providing a safer and more pleasurable cycling experience (Sener et al., 2009; Stinson and Bath, 2003; Menghini et al., 2010), sometimes their use is quite low if compared with the use of adjacent roadway (Aultman-Hall and Hall, 1998; Sener et al.,

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2009; Tilahun et al., 2007; Bernardi and Rupi, 2015). This suggests that cyclist route choices are not only determined by the presence of dedicated infrastructures.

As the human factor is one of the main causes of car accidents, also in cycling the visual perception of facilities plays an important role in bicycle crashes (Schepers et al., 2014). A wrong or confusing reading of the path can cause the user perception of an unsafe environment (Sener et al., 2009); lack of visual information or an inconsistent design can increase hazard. Moreover, a high visual workload determines an excessive need of concentration that can lead the user to perceive the path as uncomfortable and to modify his travel choice (Schepers et al., 2014). The elements on which user attention focuses should be investigated in order to understand which factors really influence his behavior.

In the recent years the advancements in head eye-tracking devices have provided high-precision human gaze position records and this technology has been not limited to indoor and fixed viewing environments (as in marketing, reading, advertising and design studies) but it has been applied also in dynamic environments. By allowing head-and-body movements it is possible to investigate the relation between gaze and locomotion (Duchowski, 2002; Patla and Vickers, 2003; Land, 2009; Franchak and Adolph, 2010). Driver's visual behavior has been studied using eye tracking devices firstly for on-road vehicles, to understand steering behavior entering a curve (Land, 1992); to determine where and how long car drivers look (Underwood et al., 2003; Costa et al., 2014); to investigate attention caption and distraction under different levels of task difficulties (Victor et al., 2005; Engström et al., 2005; Harbluk et al., 2007; Wang et al., 2014). All this brought to an increase of knowledge of human factors and driver psychology. While the amount of research focusing on the role of vision in car driving and walking is considerable, gaze behavior in cycling is still poorly documented. Furthermore, the suitability of car driving models for cycling has been discussed, due to the differences in speed, unrestricted visual and environmental conditions and balance maintenance (Vansteenkiste et al., 2013a,b; Schepers et al., 2013).

The first applications of head eye trackers to cycling are recent. Some studies have been conducted to analyze bicycle steering (Vansteenkiste et al., 2013a,b) and the effect of different levels of quality of bicycle paths on speed and gaze allocation (Vansteenkiste et al., 2014a,b, 2015). Other studies tried to evaluate cyclist attention allocation during junction negotiation (Frings et al., 2014), and the mental workload on elderly cyclists (Vlakveld et al., 2015). Nevertheless, a lack of realism can be found in the majority of the studies on cyclist eye movements: many of these have been based on tests conducted in controlled in-door environment (Vansteenkiste et al., 2013a,b), or have resorted to videos recorded in real environment (Frings et al., 2014) or to simulation (Vlakveld et al., 2015). Furthermore all these applications only focused on singular maneuver, like steering (Vansteenkiste et al., 2013a,b; Frings et al., 2014) and, even if performed on real cycling facilities (Vansteenkiste et al., 2014a,b, 2015), they did not consider other types of users, like pedestrians, sharing space with cyclists. This circumstance is frequent in Italy where often cycling facilities are designed on sidewalks. On sidewalks, pedestrians rarely follow the active circulation rules and they frequently cause disturbance to cyclists (Bernardi et al., 2016).

This study aims to ride out these limitations by executing on field tests in real urban environment, for different types of cycling paths shared with pedestrians and other vehicles. The intent of this experiment is to allow a quantitative study of the actual cyclist gaze behavior in real urban environment and a better comprehension of those elements perceived by the user as interferences, which can influence users' trip.

A brief description of the equipment used and the main principles of vision and eye movements is provided in Section 2. Section 3 describes the experiment: details on participants, path features and field test procedure will be given (Paragraphs 3.1 and 3.2). Paragraph 3.3 shows the data analysis and results. In this section a methodological procedure of field test data analysis is defined and the obtained results discussed. In the last Section 4 conclusions and lessons from this case of study are reported, together with possible future research developments

2. Description of the equipment for the study of eye movements

Eye movements were recorded by using ASL Mobile Eye-XG system which consists in two digital high resolution cameras mounted on lightweight glasses, a portable wireless Data Transmit Unit (DTU), a laptop and two software: EyeVision and ASL Results Plus GM (Fig. 1). Of the two cameras, one is infrared and records the participant right eye pupil position and corneal reflex, the other records the scene seen by the cyclist. Three infrared lights (not visible to humans) are projected on the eye by a set of LEDs mounted on the glasses; the reflections on the eye's cornea of these IR lights are recorded by the infrared camera, as vertex of a triangle named Spot Cluster. The pupil center moves relative to the spot cluster during eye movements; the eye direction is detected, through a calibration operation, by evaluating the vector formed by the pupil and the light reflection positions (corneal reflections CR). Data are recorded at a speed of 30 Hz with an accuracy of 0.5° and stored by using a SD card on the portable DTU and the wearable unit is attached by a coaxial cable to the small recording device; this assessment allows the cyclist to ride along the test-route without impediments while recording eye movements.

Using EyeVision Software, it is possible to perform the calibration procedure that allows to integrate the two recorded images in a single video which shows the "image scene" with a superimposed cursor that identifies gaze position. The video image scene and eye image resolutions are both of 640×480 pixels; cyclist gaze position is measured in pixel on the screen and it does not provide visual angles measures but x, y coordinates relative to the scene image (with increasing values as gaze moves to the right and downward).

Fig. 1. ASL Mobile Eye XG Glasses on the left, complete equipment with DTU on the right.