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The contribution of visual information to human brake behaviour

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In this study the contribution of visual information to the onset and control of braking in front of a stationary target vehicle was investigated. In a first experiment, participants drove a go-cart along a linear track towards a stationary vehicle, in monocular and binocular conditions. They could start braking from a distance of 4, 7, or 10 metres from the vehicle. In a second experiment, the same braking task was executed under three visual conditions: normal vision, central vision and central vision with restricted peripheral vision. No significant differences between monocular and binocular vision were reported, whereas the restriction of peripheral vision was associated with more reserved brake behaviour. The results are discussed with respect to the functional significance of visual information during braking and related to the theoretical discussion on the exact nature of the information used.

Key words: Braking, Visual Information

INTRODUCTION
To be successful in the confusion of daily traffic, executing appropriate brake manoeuvres is an important skill. Visual information about the time available before making contact with the obstacle (time to contact or TTC) is necessary, but there are several ways of obtaining this information. As an object approaches, its retinal projection increases, hence TTC can be obtained from the inverse of the rate of dilation on the retina of the eye, which is the optical variable tau (Lee, 1976). Tau dot, the temporal derivative of tau, gives the driver the necessary visual information to avoid collision. The use of tau is based on monocular visual information. However, the tau-hypothesis is not free of controversy. In a more indirect way, perceived distance and velocity parameters can be combined to obtain TTC (TTC = D\text{perceived}/V\text{perceived}). The latest assumption has two implications. First, because depth perception by which distance is perceived is more accurate under binocular than under monocular vision, less accurate brake behaviour is expected in a braking task under monocular vision. Second, as the use of peripheral vision contributes to the perception of the drivers’ velocity (Bardy and Laurent, 1989), a restriction of peripheral vision mortgage appropriate brake behaviour. The purpose of present experiments was to investigate brake behaviour under monocular/binocular and central/peripheral vision.

METHODS
In the first experiment 13 female participants drove a go-cart along a linear trajectory at a speed of approximately 11 km/h. They could start braking at 4, 7 or 10 meters from a target vehicle when a red lamp on the rear of this vehicle was lit. The momentaneous position of the go-cart was measured at 200Hz with a laser (Noptel CMP2-30) and velocity and acceleration were calculated. From these data, several distance and time parameters throughout the braking process were calculated as principal dependent variables and submitted to a 3 (conditions of distance: 4m vs. 7m vs. 10m) x 2 (visus: monocular vs. binocular) ANOVA with repeated measures on the two factors.

The same braking task was executed in a second experiment by 17 male participants. Participants wore specially taped safety goggles in order to create 3 different visual conditions: normal vision (NV), central vision restricted to an angle of 10° (CV), and central vision (10°) + 10° restricted peripheral vision (CPV). A 3 (conditions of distance: 4m vs. 7m vs. 10m) x 3 (visus: NV vs. CV vs. CPV) ANOVA with repeated measures on the two factors was executed on the same variables as in the first experiment.
RESULTS
As expected given the set-up, a significant main effect of distance was found on all dependent variables in both experiments. The greater the distance in which participants were allowed to brake, the more time and distance was used.

No significant differences were found between the monocular and the binocular condition in the first experiment.

In the second experiment, several significant interactions were apparent, with an overall increase of difference between the visual conditions when the distance from which braking was allowed, increased (Figure 1). Under restricted vision, TTC at the onset of braking was perceived sooner, the participants took more time braking and stopped at a greater distance, mainly at the longest distance-condition.

Figure1. Interaction effects on $TTC_{\text{start}}$ ($p<.01$), Braking Time ($p=.056$), Distance Peak Deceleration ($p=.05$) and Stop Distance ($p<.01$)

DISCUSSION
Out of the data from the first experiment, it can be concluded that the monocular information of the optical variable tau can play an important role in the visual control of braking. No support is found that the use of binocular vision has a surplus value. A possible explanation is that the task constraints were not strong enough to produce differences. The second experiment shows that when there is enough time available for braking, the human system seems to use information out of peripheral vision in order to brake adequately. Whether this peripheral vision is used in order to estimate speed or the generated optical flow provides direct visual information about the correct braking response remains disputable.

REFERENCES