Transportation Research Part F 17 (2013) 45–51

Contents lists available at SciVerse ScienceDirect

Transportation Research Part F

journal homepage: www.elsevier.com/locate/trf

Time and space: The difference between following time headway and distance headway instructions

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ARTICLE INFO

Article history:
Received 12 March 2012
Received in revised form 7 September 2012
Accepted 7 September 2012

Keywords:
Distance headway
Time headway
Speed
Target headway
Estimation error

ABSTRACT

In order to guarantee safety, drivers are advised to keep large enough headways. However, headway advice is often provided in terms of time headway, without knowing whether this is the right way of presenting the advice. According to a psychophysics theory, attaining a time headway would indeed allow drivers to show higher headway choice accuracy compared to distance headway. The goal of the present study was to assess whether time headway instructions lead to more accurate headway choice compared to distance headway instructions, and whether this depends on vehicle speed and headway size. Two groups of twenty participants carried out headway instructions in a driving simulator (one time headway group and one distance headway group). Target headway size (1, 1.5 and 2 s) and vehicle speed (50, 80 and 100 km/h) were varied within participants. Absolute estimation errors (absolute difference between instructed and chosen headway) indicated a reduced accuracy for higher speeds and for larger target headways, for both time and distance headway instructions. Relative estimation errors (relative difference between instructed and chosen headways, representing a difference between under and over estimations) indicated a difference between time and distance headway instructions. Participants showed larger headways than instructed with higher speeds in case of the distance headway instructions. These results suggest that (a) time headway choice is not independent of vehicle speed thereby contradicting the predictions made by psychophysics theory; (b) relative and absolute estimation errors as the dependent variable produce dissimilar results; (c) in case of distance headway instructions, drivers choose smaller than instructed headways at higher vehicle speeds.

1. Introduction

In car driving, headway choice plays an important role in traffic safety, since keeping a short distance headway increases the likelihood of rear-end collisions (e.g. Knipling et al., 1993). In the Netherlands, Sweden and France, drivers are taught that a time interval of 2 s is considered to be safe. Applying this rule of thumb requires drivers to make quite an accurate estimation of their headway. Yet, little is known about the ability of drivers to make appropriate use of such headway instructions.

Various psychophysical laws (e.g. the Weber–Fechner law; Allan, 1979; Fechner, 1860; Stevens, 1961) have described the relation between the magnitude of a physical stimulus and the perceived magnitude of that stimulus. Irrespective of the differences between these laws, the common ground is the notion that, as the magnitude of a stimulus becomes larger, it becomes harder to accurately perceive the differences between stimuli of similar magnitude. This is then reflected in a greater variation

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http://dx.doi.org/10.1016/j.trf.2012.09.004

of the perceived magnitude. In return, the perceived magnitude of a stimulus should remain constant as the magnitude of the physical stimulus stays constant. Note that one characteristic of time headway is that a single safe headway value can be advised independently of speed. The time interval that has to be estimated does not change at higher speeds. According to psychophysical theory it may therefore be assumed that estimates of time headway should be unaffected by variations in speed, as long as the time value, that is to be estimated, remains constant. However, if time headway instructions are transposed into distance headway instructions changes in speed as well as changes in target headway change the size (magnitude) of the physical distance that is being estimated. In addition, Cutting and Vishton (1995) argue that the effectiveness of various depth cues, that are used by drivers to infer distance judgements, is reduced when physical distance becomes larger. This suggests that the perceived distance is sensitive to the size of the physical distance and that estimates of distance headway should be sensitive to variations in speed and target headway. Therefore, it may be proposed that varying vehicle speed does not affect driver ability to estimate a time headway while it affects driver ability to estimate distance headway. Due to the required estimation of greater physical distances at higher speeds distance headway estimation accuracy is expected to become lower.

Experiments on natural headway choice have shown that headway choice remains constant across different driving speeds (Van Winsum & Heino, 1996). However, when drivers are required to estimate a specific headway different results are found. For example, Taieb-Maimon and Shinar (2001) found that drivers estimates of a constant time headway (in seconds) grew larger with speed while estimations in meters showed no effect of speed. Time estimates were also significantly less accurate than distance estimates. These results contradict the psychophysical theory that the estimated magnitude of a constant physical stimuli leads to a constant perceived magnitude. Yet, when drivers are required to attain an instructed headway results are more in line with psychophysical theory. Taieb-Maimon (2007) instructed drivers to attain headways of one or 2 s or the respective distance in meters. Here the relative difference between the instructed and the chosen headway was smaller for time headway instructions compared to distance headway instructions. Speed had no significant effect on attaining the instructed headway.

With regard to the direction of deviation of the estimated from the actual headway, Taieb-Maimon and Shinar (2001) found that in relation to the actual headway, estimates of time headways yielded an overestimation which was greater than the observed underestimation of estimates of distance headway. Similar results by Taieb-Maimon (2007) show that chosen headways, following time based instructions, were smaller than the instructed headways (reflecting an overestimation), while chosen headways, following distance based instructions, were larger than the instructed headway (reflecting an underestimation). However, here the absolute difference in chosen headway from the instructed headway was greater for distance based instruction than for time based instructions.

To assess driver performance the above mentioned studies use different measures; the relative estimation error (Taieb-Maimon, 2007) and the absolute estimation error (Taieb-Maimon & Shinar, 2001). However, this makes the results of these studies somewhat difficult to compare as these measures inherently provide different information. The absolute estimation error is better suited to describe headway choice accuracy. Only the relative estimation error can show the direction of deviation of a chosen headway from an instructed headway (i.e. under- or overestimation). While a comparison of both measures can illustrate the difference between the two, to our knowledge, this has not been performed in earlier studies.

While in one study (Taieb-Maimon & Shinar, 2001) estimates of headway appear to contradict predictions made by psychophysical theory, in another study (Taieb-Maimon, 2007) chosen headways are in line with them. Our present study aims to investigate further whether psychophysical principles can provide a theoretical foundation for the use of time headway instructions rather than distance headway instructions. Therefore, effects of vehicle speed and headway size on driver headway choice performance will be compared while drivers follow time or distance headway instructions. Our hypotheses are the following:

H1a. When following distance headway instructions, the accuracy of the chosen headway will decrease with increasing vehicle speeds.

H1b. When following time headway instructions, there will be no effect on headway choice accuracy with increasing vehicle speeds.

Furthermore, when vehicle speed remains constant, larger values of the headway instruction will affect headway choice following both time headway as well as distance headway instructions. This leads to the following hypotheses:

H2a. Increasing target headways will lead to decreased accuracy of the chosen headway when following distance based instructions.

H2b. Increasing target headways will lead to a decreased accuracy of the chosen headway when following time based instructions.

Instructions based on time or on distance headway may affect the direction of the deviation of a chosen headway from the instructed headway differently. Following time based instructions will cause drivers to choose headways closer to the lead vehicle than instructed. Following distance based instructions will cause drivers to choose headways further away from the lead vehicle than instructed.