*Japanese Psychological Research*
2005, Volume 47, No. 3, 230–237
*Special Issue: Visual perception and perceptual processing in real and virtual environments*

*Short Report*

# Perception of relative distance in a driving simulator[1,2]

BERNARD BAUMBERGER and MICHELANGELO FLÜCKIGER
*Laboratoire de Psychologie des Perceptions, FPSE, University of Geneva, Geneva 1205, Switzerland*

MARTIN PAQUETTE and JACQUES BERGERON
*Laboratoire de simulation de conduite, University of Montréal, succ Centre-Ville, Montréal (Qc) H3C 3J7, Canada*

ANDRE DELORME
*University of Montréal, succ. Centre-Ville, Montréal (Qc) H3C 3J7, Canada*

**Abstract:** The aim of this experiment was to test, in a driving simulator, how a subject can control his approach towards several simulated car-targets in different driving contexts. We assume that increasing complexity might influence driving performance according to the difficulty of perceiving distances properly. The subjects' first task consisted of placing their car at an equal distance between two preceding cars. In the second task, the subjects had to place their car level with the preceding car. The target cars were either static or running at 40 or 60 km/h. The results showed a more precise distance perception when the difficulty of the task decreased. In all conditions the subjects underestimated distances. Subjects were better at 60 km/h than at 40 km/h and the performance improved with smaller car distances. In conclusion, the alignment tasks produced better performances than the mid-distance tasks, as a consequence of their lower complexity. However, physical constraints due to the increase in velocity, as well as shorter distances between vehicles, improved performances.

**Key words:** distance perception, driving, simulation, velocity, optical flow.

Estimating distances is a task that is carried out continuously and automatically while driving a car. Simply coming to a halt at a stop sign requires that drivers adjust their position relative to their environment. In tasks such as overtaking, for instance, estimating distances is more complex. Drivers must take into account the distance of the different vehicles in front of them, as well as that of vehicles coming from the opposite direction, and possibly the distance of vehicles behind them, prior to making a decision to overtake. In such situations, drivers need to estimate the position and the speed of other vehicles in addition to the position and velocity of their own vehicle.

The vehicle body often partially occludes the lateral vision of the driver, who still has to assess his own position efficiently without direct visual information about surrounding vehicles and road limits. The objective of this research was to study, in these situations, how drivers position their vehicles within their environment.

[1] This research was supported by a grant from the Swiss National Research Foundation (FNSRS) project N°1114–067104.01.

[2] Correspondence concerning this article should be sent to: Bernard Baumberger or Michelangelo Flückiger, Experimental Psychology Laboratory of Perception, FPSE-University of Geneva, 40, bd du Pont d'Arve, 1205 Geneva, Switzerland. (Email: bernard.baumberger@pse.unige.ch or michelangelo.fluckiger@pse.unige.ch)

Stopping in a given position, near static visible objects, is relatively easy. However, estimating the position of objects that are also in motion is much more complex. Vehicles are often built in a way that partially masks lateral vision. Thus, the bonnet (hood), the windshield frame and the doors will mask small objects on the ground. It should be noted that the bonnet also masks a significant portion of the road surface that is located right in front of the driver (approximately 3 m). Consequently, accurately positioning a vehicle in space generally requires estimating the distance, memorizing this estimation, then transposing it according to the information available at the time of the final estimation. In most cases the information available at that time is located in front of the vehicle.

In such situations, the driver's task consists of memorizing the relative position of objects and then estimating, without any visual feedback, his own position relative to the objects present in the visual environment. In an experimental memorization situation, Bradley and Vido (1984) have shown the existence of a significant compression in the scale of perceived distances. Johnston (1991) reports that at a distance of 1 m the apparent eccentricities of a cylindrical surface were correctly perceived. These depth surfaces were compressed at further distances and expanded at shorter distances. This depth compression was relatively small at 2 m (approximately 15%) and increased to 50% or more at distances of 40 m (Philbeck, 2000). Lateral distances on the other hand are generally overestimated. Levin and Haber (1993) have evidenced an overestimation of distances perpendicular to the line of sight with little effect being noted on the estimation of distances parallel to this line (in depth). This distortion in the perception of space is called anisotropy and has been confirmed by a number of experimental studies (Levin & Haber, 1993; Loomis & Philbeck, 1999; Philbeck, 2000; Todd, Tittle, & Norman, 1995; Toye, 1986; Wagner, 1985).

In general, distance estimation is affected by the height of the eyes (Sedgwick, 1986; Wohlwill, 1963), texture (Cutting & Vishton, 1995), the angular height between the horizontal plane and the target position (Galanter & Galanter, 1973), motion parallax, binocular disparity[3] (Cutting & Vishton, 1995; Ohtsuka, Ujike, & Saida, 2002; Ono, Rivest, & Ono, 1986; Rogers & Graham, 1982), and the slope of the gaze relative to the particular position of an object on the ground (Wallach & O'Leary, 1982). Several authors have stressed the importance of active experience in learning to assess positions and distances (Cohen, Weatherford, & Byrd, 1980; Poag, Cohen, & Weatherford, 1983). As evidenced in studies on automobile driving, Cook (1978) also reported significant interindividual differences, together with a high level of consistency in estimations when these were repeated.

In a *moving environment*, a modification in the apparent size of objects indicates that these are moving toward or away from the observer. In dividing the apparent size of an object by the speed of its expansion or contraction, the time required to make contact with this object is obtained. In optical ecology, this variable, called Tau, corresponds to the time to contact (TC) and is extracted directly from the environment by the perceptual system without any need for calculation (DeLucia & Novak, 1997; Kaiser & Phatak, 1993; Kim, Turvey, & Carello, 1993; Lee, 1998; Wann, 1996; Yilmaz & Warren, 1995). In contrast, several authors (Bardy, Baumberger, Flückiger, & Laurent, 1992; Bardy & Laurent, 1989; Bardy, & Warren, 1997; Baumberger, Chanderli, & Flückiger, 1994; Cavallo, & Laurent, 1988; Laurent, & Cavallo, 1985; Smeets, Brenner, Trebuchet, & Mestre, 1996) propose that it is necessary to combine distance estimation with the speed of displacement in order to obtain TC. Although such methods might apply when moving around and avoiding objects in the environment, they do not permit a quantitative estimation of distances. In this latter respect it is the apparent size, the height relative to the horizon (Galanter & Galanter, 1973), and the angle of the gaze (Wallach & O'Leary, 1982) that are involved.

[3] As in most drive simulators that use generally 2-D visual displays, the parallax and binocular disparity cues probably contribute to the underestimation of distance, but without interfering with the illusion of locomotion (vection).

In research conducted using a textured flow generator, Flückiger and Baumberger (1988) studied the spatial localization of a target within a moving visual environment (Baumberger, 1993; Baumberger & Flückiger, 1993, 2004; Lepecq, Jouen, & Dubon, 1993). The main result showed that the error in distance estimation was directly dependent upon the retinal speed and the direction of the flow of elements surrounding the target object (Baumberger, 1993; Baumberger & Flückiger, 2004).

Using an optical flow to simulate displacement in research pertaining to the estimation of distances traveled, Brenner and van Damme (1999) showed that the error in estimating traveled distances was lower than 3% in a virtual environment, whether the virtual displacement presented was constant, sinusoidal, or complex. The only situation that negatively affected this performance was the reproduction of the traveled distance in the absence of visual information. This study showed that subjects were capable of accurately integrating the distance traveled while at the same time taking into account their average traveling speed. Similar results have also been evidenced in real-life displacement situations (Berthoz, Israel, Georges-Francois, & Grasso, 1995). In brief, after the target disappearance of the visual field, subjects were able to estimate distance from optical flow.

Finally, we postulate that the constraints and the degrees of freedom associated with the type of task have a direct impact on the quality of the estimations required and that the velocity of the vehicles will influence the estimation performance. In an environment populated with objects (cars) that are also in motion, a driver is unable to use static elements in the environment in order to estimate distances. In such situations, performances are degraded, as the driver can rely only on objects that are also moving.

## Method

### *Population*

The study population consisted of 14 adults (seven men and seven women) between 20 and 56 years old (mean $27 \pm 9.6$ years). Their driving experience ranged between 2.5 and 32 years (mean $9 \pm 8$ years) and they drove between 1000 and 25 000 km per year (mean $13\,000 \pm 7800$ km). One participant whose data were not exploitable was excluded from the analyses.

### *Material and experimental design*

The easiest way to study driver's perception of distance is to use a driving simulator. Some research (Jamson, 2001; Kemeny & Panerai, 2003) has shown that, according to the size of the simulated visual field, the perceptive performance is not identical to that observed in reality. This is true particularly for the speed perception (Jamson, 2001). In a straight line, simulated speed is generally overestimated regardless of the size of the simulated visual field. For this research on relative distance, the driver's speed is in direct relation to the velocity of the vehicles used to make the distance judgment (B and C; Figure 1). In addition, we showed that the feeling of vection (Baumberger & Flückiger, 2004) does not influence distance estimation in a moving environment.

Our car-driving simulator (Bergeron, L'Archevêque, Pacquette, Thiffault, Ouimet, & Joly, 1995) was designed by Professor J. Bergeron of the University of Montréal (Bergeron, Marcil, & Laflamme Cusson, 1996; Marcil, Audet, & Bergeron, 1999) to carry out research on road safety. It is composed of a standard issue car ("Honda Civic"), the visual field of which is simulated. In the experiment the simulation (visual field of 60°) was displayed on a large-sized screen ($3 \times 2.45$-m projection) placed in front of the car (3-m distance from the driver's eye). The visual environment was simulated using a silicon graphics station and was directly connected to the controls of the car. The virtual environment was composed of a straight road lying ahead of the car. The surrounding scenery was covered with grass, bushes and trees. Drivers could actively change the visual speed of their vehicle, which was moving in the left lane of the simulated road. To decrease the difficulty of the driving task and to increase the quality of the distance estimation, the subjects could not change direction and could only break or accelerate. Two reference

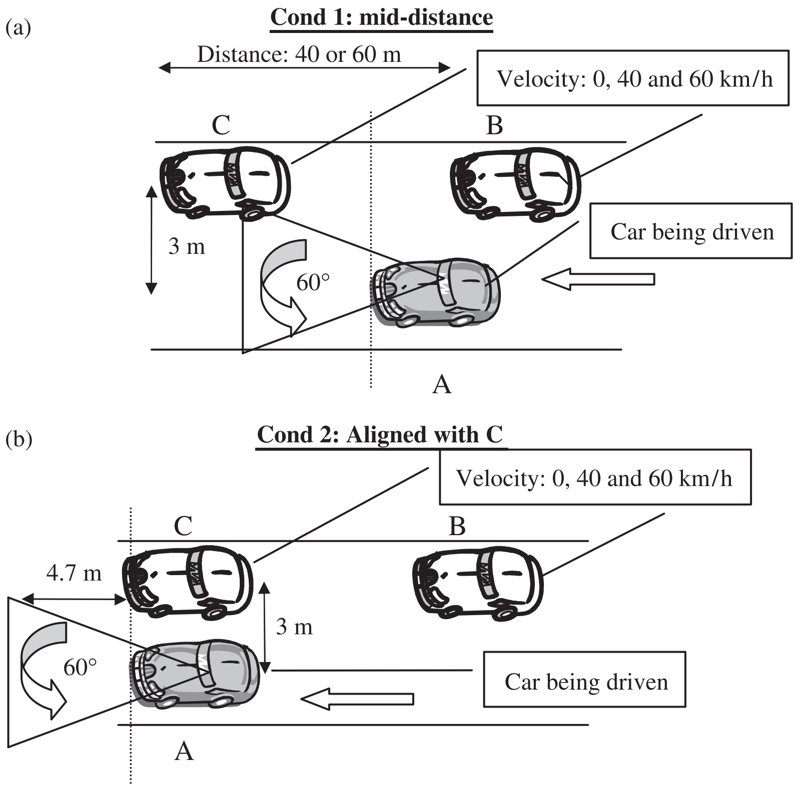


**Figure 1.** Schema presenting the situations simulated in the experimental conditions. (a) In condition 1 (mid-distance task) drivers had to position the front of their vehicle at mid-distance between B and C. (b) In condition 2, they then had to indicate when their car was abreast with vehicle C (alignment). The 60° angle represented in front of the vehicle being driven (A) corresponds to the visual field. The 4.7-m distance corresponds to the error drivers would make if they reported being aligned with car C at the time it disappeared from their visual field.

vehicles (B and C) were positioned in the right lane (see Figure 1) at a distance of 40 m or 60 m (distance factor, 34.5 m and 54.5 m between the rear end of C and the front of B, respectively). These vehicles were either motionless (0 km/h) or in motion at 40 km/h or 60 km/h (speed factor). The task required of the drivers was to position the front of the car they were driving (A) according to the position of vehicles (B and C) in three situations of distance estimation. Each of the estimations was reproduced three times in one session.

Before the first task, the driver was asked to position the front of his vehicle (A) at the same distance as that separating the two vehicles B and C that he was following. This first answer was used mainly to reduce their speed. In the first task, the driver was required to position the front of his vehicle (A) at mid-distance between B and C (condition 1, mid-distance between B and C). Finally, in the last task he was asked to position the front of his vehicle (A) abreast with vehicle C (condition 2, aligned with C). Figure 1 presents the relative positions of the vehicles in conditions 1 and 2.

The virtual simulation corresponds to a 60° vision of the environment (30° left and 30° right). The driver could not see any objects located beyond 30° of lateral vision. Consequently, as illustrated in Figure 1, a vehicle positioned 3 m to the right of the car being driven, with the front end positioned at 4.7 m in front of the driver, was displayed on the screen for longer (as it disappeared from the visual field). In conditions 1 and 2, the driver had to take this difference into account in order to make accurate distance estimations.

### *Procedure*

Starting off from a point located some distance away, the driver was required to pilot (only break or accelerate) the vehicle so as to mark the position corresponding to each of these situations (slow-down task then conditions 1 and 2) by coming to a halt in the motionless situation (0 km/h) and by activating the brake in the moving situation (40 or 60 km/h). Once the answer had been given it was not possible for the driver to correct his position.

### *Data collection*

For each subject-driver the simulation program generated a file recording the position of each vehicle (A, B, and C) as well as data corresponding to the brake and the accelerator. A Microsoft Excel program was used to automatically identify the positions given in answer to the tasks. The median of the three repeated trials was used for the statistical analyses.

## Results

A repeated measures ANOVA was carried out with three intrasubject factors: condition (cond: mid-distance and aligned); speed of displacement (spd: 0, 40 or 60 km/h) and distance between vehicles (dist: 40 or 60 m). The analysis was carried out on the positioning error of the subject-drivers' car. A positive answer corresponds to an overestimation, meaning that the answer has overshot the mid-distance position in the mid-distance task (condition 1) and has overshot the alignment position in condition 2. Conversely, a negative answer corresponds to an underestimation, meaning that the answer given was placed before the correct position.

The results presented in Figure 2 show that subjects underestimated distances. The error observed in the mid-distance task is significantly higher, $F(1,1) = 47.28$, $p < 0.01$, than that observed in the alignment task. Performances were significantly better, spd: $F(2,22) = 26.07$, $p < 0.01$, in the static target condition (0 km/h) than in the two moving-target conditions. Also, in the mid-distance task, subjects were more accurate when they were moving at 60 km/h than 40 km/h, type × spd: $F(1,12) = 8.25$, $p < 0.014$. Finally, in the mid-distance task, subjects' estimations were more accurate, type × dist: $F(1,11) = 16.17$, $p < 0.01$, when the distance between the vehicles was smaller (40 m).

This distance effect between vehicles corresponds to the Weber law. A post hoc ANOVA, with only the mid-distance task, on the positioning error relative to the distance between vehicles (Weber ratio) does not show any

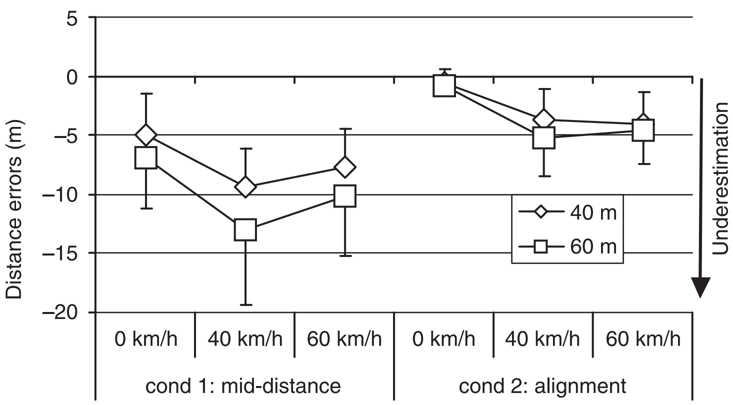


**Figure 2.** Positioning error observed in the two experimental conditions (mid-distance and aligned). At 0 km/h, subjects responded, on average, in the correct position. Globally, positions were underestimated.

significant effect of the distance between the vehicles. Thus, localization error is only influenced by the speed (spd: 0, 40 and 60 km/h $F(2,22) = 13.6$, $p < 0.001$ and the comparison between 0 and 40 km/h, $t(10) = 4.42$, $p < 0.001$, 0–60 km/h, $t(10) = 2.48$, $p < 0.032$ and 40–60 km/h, $t(10) = 2.87$, $p < 0.015$) and correspond, respectively, to an error of 12.1, 22.5 and 18% of the distance between vehicles (B and C).

## Discussion

These results show that, globally, drivers tend to underestimate distances. From a road safety standpoint, such behavior affords a margin for error to avoid accidents and provides additional safety. It seems safer to estimate the distance of a car as being closer than it is in reality. From a perceptual point of view, the results observed confirmed that of classical research on distance estimation (Levin & Haber, 1993; Loomis & Philbeck, 1999; Philbeck, 2000; Todd et al., 1995; Toye, 1986; Wagner, 1985) and on driving simulation (Panerai, Droulez, Kelada, Kemeny, Balligand, & Favre, 2001), but the interpretation is complex. It seems important to note that the position that is to be estimated disappears from the drivers' visual field when the final adjustment is required. If drivers did not use the front of their vehicle as a reference, but rather the moment at which the position to estimate disappeared from the visual field, then a systematic underestimation of approximately 4.7 m should have been observed (see Methods and Figure 1). The results show that it is only when the drivers are required to stop at the level of the nonmoving vehicle that they are able to compensate for the disappearance from their visual field of the car to be estimated. In all other situations, subjects underestimated distances by at least 4.7 m. The data from the alignment task does not permit us to decide whether the noncompensation (due to the disappearance of the position to be estimated), or an actual underestimation of distances, is responsible for the results observed. In contrast, in the mid-distance task, we can propose that, at minimum, the portion in excess of 4.7 m is due to an actual underestimation of distances. Further research should permit settlement of this question.

Our hypothesis concerning drivers' poorer performance when required to position themselves relative to other moving vehicles was confirmed. In the nonmoving condition, performances were systematically better than in the moving conditions. Positioning oneself between two vehicles (mid-distance task) involves controlling many more parameters than when coming abreast with another (alignment task). The results confirm the hypothesis that an increase in constraints related to the type of task has a direct impact on the quality of the estimations. Although this hypothesis is validated concerning the difficulty of the tasks, this is not the case with respect to the increase in physical constraints (degrees of freedom) represented by the speed and distance between the vehicles. Indeed, our results showed that subjects' performance improved with an increase in speed and with a decrease in distance between the vehicles. Drivers probably believe that the slower the speed and the greater the distance, the less they need to be accurate.

In conclusion, underestimating the distance of vehicles in front of but moving in the same direction of the car one is driving should normally increase safety. However, transposed to real traffic conditions, such behavior can become a liability. Indeed, the task required of subject-drivers in the mid-distance experiment is similar to estimating distances between two vehicles in order to pull in after overtaking. While the underestimation adds to the safety where the vehicle in front moving in the same direction is concerned, the situation is different for the car that is overtaken. If the driver doesn't look in the lateral or rear-view mirror, permitting them to monitor the position of the vehicle that has just been overtaken, then an underestimation might lead to the risk of pulling in too early, creating an accident. In such a case the solution consists in estimating whether the distance between the vehicles is sufficiently large and pulling in as close as possible to the vehicle in front that has just been overtaken. In future studies, we intend to simulate a situation of actual overtaking in order to analyze drivers' behavior from both a perceptual and road safety perspective.

## References


Bardy, B. G., Baumberger, B., Flückiger, M., & Laurent, M. (1992). On the role of global and local visual information in goal-directed walking. *Acta Psychologica*, **81**, 199–210.

Bardy, B. G., & Laurent, M. (1989). Use of peripheral vision in the decision to brake. *Perceptual and Motor Skills*, **69**, 163–166.

Bardy, B. G., & Warren, W. H. (1997). Visual control of braking in goal-directed action and sport. *Journal of Sport Sciences*, **15**, 607–620.

Baumberger, B. (1993). *La localisation spatiale dans un environnement visuel mobile [Spatial localization in a moving visual environment]*. Unpublished thesis no. 194, FPSE, University of Geneva, Geneva, Switzerland.

Baumberger, B., Chanderli, K., & Flückiger, M. (1994). Locomotor pointing to an "ever fleeing" target. In K. Taguchi, M. Igarashi, & S. Mori (Eds.), *Vestibular and neural front* (pp. 91–94). Tokyo: Elsevier.

Baumberger, B., & Flückiger, M. (1993). Bisection from different heights of observation in an optical flow. In S. Valenti & J. Pittenger (Eds.), *Studies in perception and action II* (pp. 284–287). Hillsdale, NJ: Laurence Erlbaum Associates.

Baumberger, B., & Flückiger, M. (2004). The development of distance estimation in an optical flow. *Perception*, **33**, 1081–1099.

Bergeron, J., L'Archevêque, C., Paquette, M., Thiffault, P., Ouimet, M.-C., & Joly, P. (1995). *Le développement d'un simulateur de conduite automobile et son utilisation auprès des conducteurs [The development of a driving simulator and its drivers use]*. Montréal: Department of Psychology, University of Montréal.

Bergeron, J., Marcil, I., & Laflamme Cusson, S. (1996). Cheminement et perséverance des clients qui entreprennent un programme de réadaptation en toxicomanie [Road traveled and compliances by subjects who undertake a rehabilitation program for drug addiction]. *Science et Comportement*, **24**, 173–190.

Berthoz, A., Israel, I., Georges-Francois, P., & Grasso, R. (1995). Spatial memory of body linear displacement: What is being stored? *Science*, **269**, 95–98.

Bradley, D. R., & Vido, D. (1984). Psychophysical functions for perceived and remembered distance. *Perception*, **13**, 315–320.

Brenner, E., & van Damme, W. J. M. (1999). Perceived distance, shape and size. *Vision Research*, **39**, 975–986.

Cavallo, V., & Laurent, M. (1988). Visual information and skill level in time-to-collision estimation. *Perception*, **17**, 623–632.

Cohen, R., Weatherford, D. L., & Byrd, D. (1980). Distance estimates of children as a function of acquisition and response activities. *Journal of Experimental Child Psychology*, **30**, 464–472.

Cook, M. (1978). The judgment of distance on a plane surface. *Perception and Psychophysics*, **23**, 85–90.

Cutting, J. E., & Vishton, P. M. (1995). Perceiving layout and knowing distances: the integration, relative potency, and contextual use of different information about depth. In W. Epstein & S. J. Rogers (Eds.), *Perception of space and motion. Handbook of perception and cognition* (2nd ed., pp. 263–325). San Diego, CA: Academic Press.

DeLucia, P.-R., & Novak, J.-B. (1997). Judgments of relative time-to-contact of more than two approaching objects: Toward a method. *Perception and Psychophysics*, **59**, 913–928.

Flückiger, M., & Baumberger, B. (1988). The perception of an optical flow projected on the ground surface. *Perception*, **17**, 633–645.

Galanter, E., & Galanter, P. (1973). Range estimates of distant visual stimulus. *Perception and Psychophysics*, **14**, 301–306.

Jamson, H. (2001). *Image characteristics and their effect on driving simulator validity*. Paper presented at the International Driving Symposium on Human Factors in Driving Assessment, Training and Vehicle Design, Aspen, Colorado, USA.

Johnston, E. B. (1991). Systematic distortions of shape from stereopsis. *Vision Research*, **31**, 1351–1360.

Kaiser, M. K., & Phatak, A. V. (1993). Things that go bump in the light: On the optical specification of contact severity. *Journal of Experimental Psychology: Human Perception and Performance*, **19**, 194–202.

Kemeny, A., & Panerai, F. (2003). Evaluating perception in driving simulation experiments. *Trends in Cognitive Sciences*, **7**, 31–37.

Kim, N. G., Turvey, M. T., & Carello, C. (1993). Optical information about the severity of upcoming contacts. *Journal of Experimental Psychology: Human Perception and Performance*, **19**, 179–193.

Laurent, M., & Cavallo, V. (1985). Role des modalités de prise d'informations visuelles dans un pointage locomoteur [The role of visual input modality in a locomotor pointing task]. *L'année Psychologique*, **85**, 41–48.

Lee, D. N. (1998). Guiding movement by coupling taus. *Ecological Psychology*, **10**, 221–250.
Lepecq, J.-C., Jouen, F., & Dubon, D. (1993). The effect of linear vection on manual aiming at memorized directions of stationary targets. *Perception*, **22**, 49–60.
Levin, C.-A., & Haber, R.-N. (1993). Visual angle as a determinant of perceived interobject distance. *Perception and Psychophysics*, **54**, 250–259.
Loomis, J. M., & Philbeck, J. W. (1999). Is the anisotropy of perceived 3-D shape invariant across scale? *Perception and Psychophysics*, **61**, 397–402.
Marcil, I., Audet, T., & Bergeron, J. (1999). Determinants motivannionnels des exces de vitesse en milieu urbain chez de jeunes conducteurs [Motivational factors underlying the intention to exceed speed limit in urban context in young male drivers]. *Science et Comportement*, **27**, 1–15.
Ohtsuka, S., Ujike, H., & Saida, S. (2002). Relative distance cues contribute to scaling depth from motion parallax. *Perception and Psychophysics*, **64**, 405–414.
Ono, M. E., Rivest, J., & Ono, H. (1986). Depth perception as a function of motion parallax and absolute-distance information. *Journal of Experimental Psychology: Human Perception and Performance*, **12**, 331–337.
Panerai, F., Droulez, J., Kelada, J.-M., Kemeny, A., Balligand, E., & Favre, B. (2001). *Speed and safety distance control in truck driving: comparison of simulation and real-world environment.* Paper presented at the DSC2001, Sophia Antipolis, France.
Philbeck, J. W. (2000). Visually directed walking to briefly glimpsed targets is not biased toward fixation location. *Perception: London*, **29**, 259–272.
Poag, C. K., Cohen, R., & Weatherford, D. L. (1983). Spatial representations of young children: the role of self versus adult-directed movement and viewing. *Journal of Experimental Child Psychology*, **35**, 172–179.
Rogers, B.-J., & Graham, M.-E. (1982). Similarities between motion parallax and stereopsis in human depth perception. *Vision Research*, **22**, 261–270.
Sedgwick, H. A. (1986). Space perception. In K. R. Boff, L. Kaufman, & J. P. Thomas (Eds.), *Handbook of perception and human performance: Sensory processes and perception: Vol. 1* (pp. 33–90). New York: John Wiley.
Smeets, J. B. J., Brenner, E., Trebuchet, S., & Mestre, D. R. (1996). Is judging time-to-contact based on "tau"? *Perception*, **25**, 583–590.
Todd, J. T., Tittle, J. S., & Norman, J. F. (1995). Distortions of three-dimensional space in the perceptual analysis of motion and stereo. *Perception*, **24**, 75–86.
Toye, R. C. (1986). The effect of viewing position on the perceived layout of space. *Perception and Psychophysics*, **40**, 85–92.
Wagner, M. (1985). The metric of visual space. *Perception and Psychophysics*, **38**, 483–495.
Wallach, H., & O'Leary, A. (1982). Slope of regard as a distance cue. *Perception and Psychophysics*, **31**, 145–148.
Wann, J.-P. (1996). Anticipating arrival: Is the tau margin a specious theory? *Journal of Experimental Psychology: Human Perception and Performance*, **22**, 1031–1048.
Wohlwill, J. F. (1963). Overconstancy in distance perception as a function of texture of the stimulus field and other variables. *Perceptual and Motor Skills*, **17**, 831–846.
Yilmaz, E. H., & Warren, W. H. (1995). Visual control of braking: a test of the t hypothesis. *Journal of Experimental Psychology: Human Perception and Performance*, **21**, 996–1014.

(Received March 16, 2004; accepted March 26, 2005)