PS3060: Perception and Action

# (L.3) Driving a vehicle: control of heading, collision avoidance, braking

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- the ecological approach to vision: from insects to humans
- standing up on your feet, keeping posture control
- visual control of speed and travelled distance
- collision: judging time to impact, braking a vehicle
- heading: how you know in which direction you are moving
- staying on the road: strategies to coordinate eye, head, steering wheel

*http://www.pc.rhul.ac.uk/zanker/teach/Ps3060/L3/Ps3060_3.htm*
(see also chapters 11, 12 of Bruce, Green & Georgeson 2003)

## the ecological approach to vision - evolution & development

- perception happens in an ecological context: surfaces offer rich information and are behaviourally relevant
- direct perception: visual information is directly used for behavioural control, without any high-level processing, storage, representation

insects: can be regarded as simple systems operating like automats
extensive evidence for direct visual control mechanisms (lecture 2)

what about humans? complex control, planning, decision making

- driving vehicle as example of most advanced case, clearly learned (but still largely automatically ?)
- some basic aspects appear to be innate: defensive response to approaching objects (Dunkeld and Bower 1980)

>>> interesting to look at development: fast behavioural responses without previous experience could be interpreted as 'direct perception'

## the visual cliff

crucial for all terrestrial (walking, climbing) animals: not to drop from large heights >> needs to be learned? what is the crucial visual information?

visual cliff paradigm (Gibson & Walk 1960): move along a platform with two sides: deep and shallow, covered by (invisible) glass

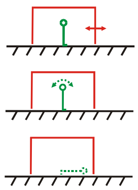
- human babies from earliest crawling age (6 months) avoid to cross the deep side
- increase pattern size on deep side (both sides identical static images) > still avoiding deep side > motion parallax used as cue
- decrease pattern size on one of two shallow sides (same motion parallax) > avoiding smaller texture > texture size used as cue

- two sources of visual information : texture gradients and motion parallax
- sensory mechanisms mature faster than locomotion: no experience required
- innate ? comparative approach (deprived animals)

# posture control

standing up = defining moment of humanity ? - learn control mechanisms ?
mechanical (proprioceptive, vestibular) and visual (exteroceptive) signals

moving room >>> adjust body posture



26 % sway
23 % stagger
33 % fall

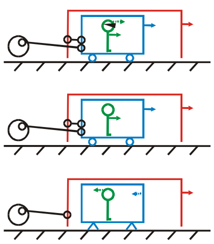
visual input to posture not restricted to standing !

similar results for sitting (Butterworth and Hicks 1977); visual feedback is used before an infant stands or walks >> not acquired in the context of walking !

# kinaesthesis 1

perhaps vision has a more general function in the control of posture?
>>> 'kinaesthesis' - the sensing of body movement, in adults

swinging room & trolley & walking or standing
(adult subjects don't fall over, but can report perceived egomotion Lishman and Lee 1973)



## passive condition

· moving blindfolded: perceived as moving

· moving together with environment: perceived as static

· static in moving environment: perceived as moving in opposite direction

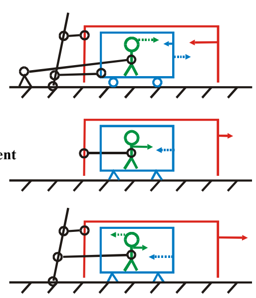
# kinaesthesis 2

## active condition

· walking person is driving trolley and (amplified) environment : perceived as increased speed

· walking on fixed trolley with environment attached: trolley perceived as moving

· walking on fixed trolley with amplified environment attached: perceived as moving backwards



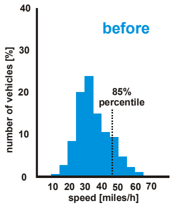
'kinaesthesis' - the sensing of body movement is based on a sophisticated interaction between vestibular, visual and motor command information

## speed perception

- simple psychophysics: misjudgement of speed, ambiguities from size, distance, field of view (Brown 1931, Zanker & Ryan 2001)
- what are the consequences for driving ? (Denton 1980)

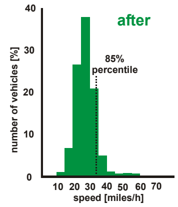
experimental study : driving simulator, reduce speed after adaptation period

- underestimation of actual speed
- stronger reduction of speed (overestimation) if additional markers are introduced (stronger with higher frequency of markers)




field study :
test measuring traffic speed before & after painting stripe pattern on roundabout

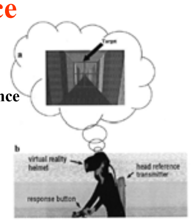
> speed reduction in redesigned roundabout !

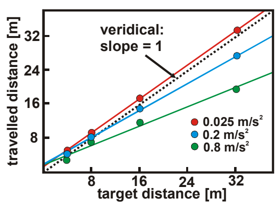



## travelling distance

virtual reality experiments (Redlick et al 2001):

- subjects are moving along a corridor: asked to stop at a defined (memorised) target distance
- subjects need to estimate travel distance from simulated optic flow






target distance ~ travel distance

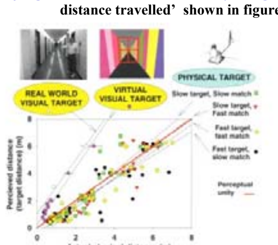
- constant velocity: undershoot
- constant acceleration (supra-threshold): good approximation of veridical distance

⇒ optic flow can be used for measuring travelling distance (remember the honeybee study…)

## mixed input - crossmodal interactions

combined visual and vestibular stimulation for distance estimation (Harris et al. 2000)

- presentation of target distance (‘perceived distance’): visually (real or virtual corridor) or physical (being moved in the dark to the target)
- judgement of travelled distance by being moved in the dark (‘actual physical distance travelled’ shown in figure), or by moving through virtual corridor




· good match of physically presented targets (perceptual gain approx. 1)

· substantial underestimation of target distance when presented visually (perceptual gain approx. 2)

visual motion (virtual) shows the inverse effects : visually targets are matched well (gain approx. 1), physical target distances are substantially underestimated (gain approx. 0.25)

=> different sensory signals are processed with different gains, good performance only in combined or consistent type of information !

## adaptation to missing sensory input

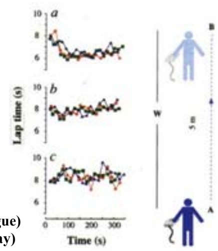
**perceived speed of locomotion shows impressive plasticity: surprising adaptation effects to extended treadmill exercise (Pelah and Barlow 1996)**

**measuring perceived walking speed after 10 minutes of jogging on treadmill, i.e. in the absence of visual feedback (no flowfield)**

**subjects are asked to walk up and down the room at constant speed after adaptation**

**(a) walking speed increases in test period, i.e. it is initially overestimated (like walking on conveyer belt: you think that you are faster than your visual input tells you), & later readjusted : aftereffect of sensory deprivation**

**no such effect (b) after running outdoors (no fatigue) or (c) without adaptation period (not natural decay)**




**=> previous experience of flowfields does affect the perceived walking speed, i.e. there is limited use of proprioceptive information (compare driving : flowfield adaptation, no proprioceptive information)**

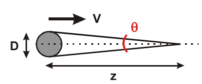
## judging the collision of objects

**time to impact (or TTC) of objects moving at constant velocity on frontoparallel or approach trajectories can be estimated from simple optical parameters**

**critical variable tau: inverse of relative expansion rate**

**Fred Hoyle (The Black Cloud)**

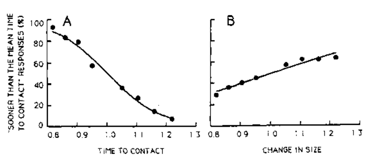
**rediscovered in the spirit of Gibson by D. N. Lee: various animals (plummeting gannets, Lee and Reddish 1981; landing pigeons, Lee et al. 1993) seem to be using such variables to trigger responses**




$D/z = \tan\theta \cong \theta$

$D \cong \theta * z \leftrightarrow 0 \cong \theta * z' + \theta' * z$

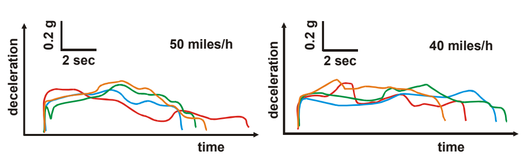
$TTC = z/V = z/z' \cong \theta / \theta' = \tau$




**experiments with simulated approaching objects of variable size, speed, travel distance provide evidence that this variable can actually be extracted by humans (Todd 1981; Regan and Hamstra 1993)**

## braking

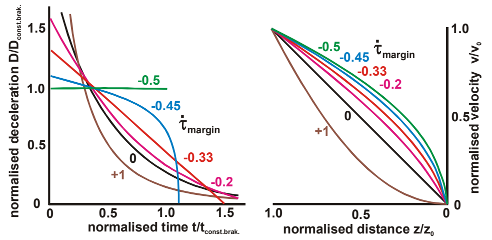
**characteristic deceleration profiles which do not seem to depend much on the initial speed (Spurr. 1969) -- what is the general strategy?**




**based on the time-to-collision geometry, leading to the simple optical variable tau, a mathematical theory of safe braking using visual control is developed (Lee. 1976)**

# braking cont.

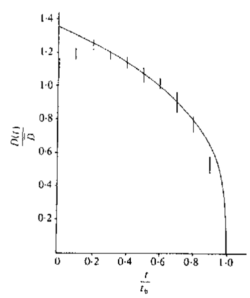
zero velocity at the intended stopping point without the need to increase deceleration (smooth braking) requires to keep the temporal derivative of tau (tau-dot, change of tau) above a critical value of -0.5 (constant deceleration)




note that values of tau-dot higher than -0.5 generate a monotonical decrease of deceleration, larger initial deceleration and longer stopping time! (safety margins)

# braking cont.

the average data measured for drivers (Spurr. 1969) are well approximated by a deceleration profile with a critical tau-dot of -0.425 !



this is interpreted as if humans use a close to optimum tau-dot strategy when stopping for a static obstacle

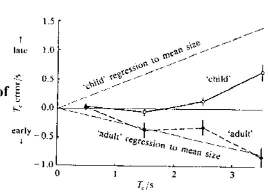
# size cues

using direct optical variables, like tau, to control braking =>
no need to extract variables like size, speed, distance (computationally demanding)
is braking really that simple ?

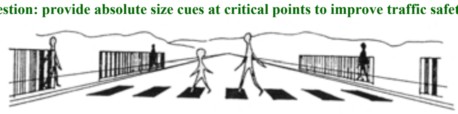
realistic driving situations >> more cognitive strategies can be used, e.g. knowledge of familiar size of pedestrians (Stewart et al 1993)

simulated approaches towards static objects of different size ('child' and 'adult'): estimate arrival time …

- timing errors grow with longer TTCs
- larger objects lead to underestimation, and smaller objects to overestimation of TTC !!!



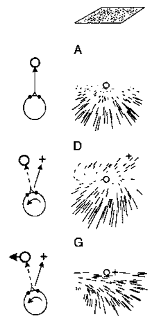

suggestion: provide absolute size cues at critical points to improve traffic safety !!



## control of heading

**collision avoidance is not the only task that is crucial for traffic safety - important 'simply' to stay on the road - role of visual information?**

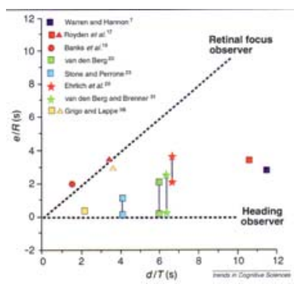
**Gibson's original notion of flowflieds already conceptualised that the structure of velocity vectors provides rich information about the direction of heading**




- **moving and looking straight ahead leads to a characteristic expansion pattern with the centre of flow (focus of expansion, pole) in the centre of fovea (fig A)**
- **when a moving observer is not looking in the direction of translation, the pole of the flowfield is located outside of the fovea**
- **eye movements due to fixating an object on the ground >> characteristic distortions of the flowfield (shearing) and disparity between pole and heading direction (fig D)**
- **eye movements due to tracking a moving object >> similar distortions of the flowfield (superposition of rotational component) and disparity between pole and heading direction (fig G)**

## control of heading, cont.

**extraretinal signals (eye movement signals) could be used to resolve such ambiguities, but on the other hand the structure of the flowfield can provide sufficient information itself (Lappe et al. 1999)**

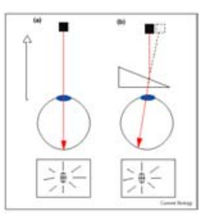


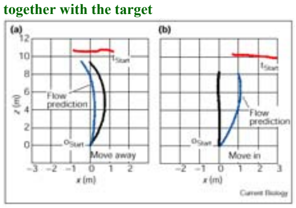

**presenting mixed (translation + rotation) flowfields to an observer fixating a static target (no extraretinal signals) & judge heading >> conflicting results (estimation error as function of simulated eye movement component) and a continuing debate …**

## shifting targets in real locomotion

**prisms shift the angular position of the retinal image - an observer using such a displaced landmark for navigation would start walking in the wrong direction, keeping a constant error angle, which should lead to a path correction and a curved path**

**an observer using the focus of expansion (FOE) for navigation, minimising the difference between FOE and target location, would walk on a straight path after an initial correction, because the FOE is shifted together with the target**





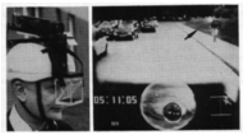

**curved paths observed under such conditions are interpreted as evidence against the use of flowfields to judge heading during walking (Rushton et al. 1998)**

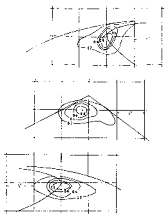
**however: using the location of FOE for control of body rotation ?? flowfield in absence of landmarks ??**

## staying on the road

**what do drivers do when steering a car through the real world?**

**the eye and steering movements of drivers have been recorded while negotiating a 'tortuous' road, suggesting simple pragmatic geometrical strategies that can produce adequate driving stability (Land and Lee. 1994)**





**drivers are found to keep their gaze in the direction of the tangent point of a curve for a large proportion of the time**

**this is thought to be an important point because its angle relative to the car's heading is a good predictor of the curvature of the road - keeping a constant angle is a simple pragmatic rule to keep the car on the road! (Land. 2001)**

## summary: control of locomotion

- **posture, locomotion, vehicle control involves a lot of low-level mechanisms that can be related to direct perception**
- **such strategies seem to be mature before the onset of the relevant locomotor activity, do not require learning, are innate in certain animals**
- **travelling speed and distance can be estimated from optic flow, but is not always accurate**
- **a simple optical variable, tau, can be used to estimate the time until collision with objects, and may be used in braking - but its scope is debated**
- **the direction of heading can be derived from the analysis of the optical flowfield - but again, the actual importance of such mechanisms is debated**
- **the behaviour of drivers in real life can offer some surprises - a simple geometrical strategy has been identified for negotiating sharp bends**

## specific reading


- **Bruce V, Green PR & Georgeson M (1996) Visual Perception: Physiology, Psychology and Ecology (3rd ed.) Hove: Psychology Press, (152.14 BRU) (ch 12, 13)**
- **Land, M F 2001 "Does Steering a Car Involve Perception of the Velocity Flow Field" In JM Zanker & J Zeil (Eds.), *Motion Vision - Computational, Neural, and Ecological Constraints.* (pp. 227-235). Berlin Heidelberg New York: Springer. (resources room)**
- **Lappe M, Bremmer F, Van den Berg AV 1999 "Perception of self-motion from visual flow" *Trends in Cognitive Sciences* 3, 329-335 (resources room)**
- **Lee DN 1976 "A theory of visual control of braking based on information about time-to-collision" *Perception* 5, 437-459**
- **Lishman JR, Lee DN 1973 "The autonomy of visual kinaesthesis" *Perception* 2, 287-294**
- **Tresilian JR 1999 "Visually timed action: time-out for 'tau'?" *Trends in Cognitive Sciences* 3, 301-310 (resources room)**


**complete reference list at :**
***http://www.pc.rhbnc.ac.uk/zanker/teach/Ps3060/L3/Ps3060_3.htm***