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Keeping Up with Clara Casco, an Ever Moving Target

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Note: To view the movies, open the camera app on your iPhone, frame the QR code and tap the notification bar at the top of the screen. For an Android phone, download a QR reader of your choice and follow its instructions.

We start with some history of the work that I, the first author here, Stuart Anstis, have done with Clara Casco. My research productivity, always erratic, took a great leap forward when Clara Casco came to visit me in California in 2006. I had 50 good reasons to ask Clara to write a paper on motion perception with me, in particular, she had published at least 50 papers on motion perception, my favourite area.

Visitors who are escaping the damp miseries of England often exclaim at the beautiful South California weather. Not Clara. The climate in Padua is every bit as good as in Del Mar. And coming from a university that was founded in 1222 she was hardly overawed by a stripling college such as UCSD that did not even exist until 1960. However, she did enjoy staying with me in my little white house in Del Mar overlooking the Pacific. I found that instead of sitting and gazing out of the window at the ocean as I usually do, I was dragged along by Clara's energy and accomplished ten times as much with her as I had ever done without her. Every day her partner Luciano would phone her from Italy for long, fond, expensive international phone calls. Her head may have been in California but her heart was in Italy. And my, how hard she worked. And when I subsequently visited the beautiful city of Padova I was pleased to find that I was visiting Clara and Luciano. I have to admit that our 2006 effort is possibly the only paper that Clara has ever published that contains no actual data. But it is still one of my favorite papers; perhaps because Clara has always been one of my favorite collaborators. Our mental powers overlapped; arguably her two worst papers are my two best ones.

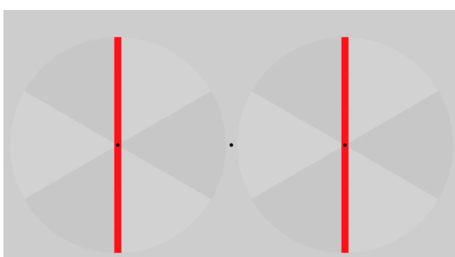
We published the work we did during her stay in the *Journal of Vision* (Anstis & Casco, 2006). In the article we reported how a moving background completely reorganized the perceived motion of two tests (bluebottle flies in this case), changing the perceived size of circular paths of motion or even making them look like linear movement.

Three long years went by and Clara and I published a second article, called 'Perceived shrinkage of motion paths', together with two of her students, Michele Sinico and Giulia Parovel (Sinico, Parovel, Anstis, & Casco, 2009). Michele and Giulia had laboured long hours to do most of the work involved. This again involved motion paths, both linear and rotary where we noticed (as with the bluebottle flies) that the motion paths seemed shortened or shrunken compared to their physical extent. At slow speeds, observers were relatively accurate, but, as the speed increased, the size of the path was progressively underestimated, by up to 35%. This underestimation imposed little memory load and did not require tracking.

Conversations with the two students, Michele and Giulia, confirmed my suspicions that Clara was an excellent supervisor, guide and friend to them both. They have subsequently gone on to successful scientific careers at the University of Siena (Giulia) and the University IUAV of Venice (Michele). I cannot think of a nicer trio of universities – Padova, Siena and Venice! Giulia has not lost her imaginative Italian flair – I see that in 2021 she wrote a paper on "How to make a square amusing" …

Since these projects with Clara, I have continued to work on these two topics (A) path shortening, and (B) induced position shift with Patrick Cavanagh, another great admirer of Clara's work. Patrick and I have concentrated our efforts on two novel phenomena that are both related to the well-known flash lag effect (Nijhawan, 1994, 2002, 2008), in which a short vertical line moves at constant speed from left to right. When a spot is flashed up exactly on the line in mid trajectory, the spot appears to lag behind the line.

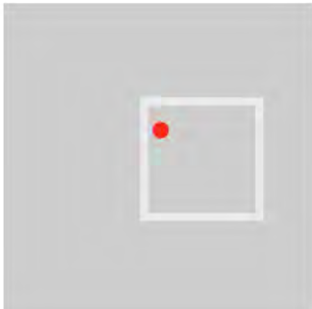
We called our first effect the "flash grab" illusion. A sectored disc rotates back-and-forth through (say) 90° and each time the motion reverses in direction a vertical line is flashed on the diameter of the disc. (Movie #1) So the line flashes at 12 o'clock just as the disc starts to rotate clockwise, and it is perceptually dragged clockwise to about 1 o'clock. When the disc reverses and starts going back counterclockwise the line flashes again and is now dragged counterclockwise to about 11 o'clock. We also showed that the travel of the sectors themselves also comes up short, linking the effect directly to the earlier path shortening (Sinico et al 2009). For some reason, the flash at the moment of reversal is grabbed by the sector edge and is seen at the (path shortened) location of the edge



Movie 1. Flash Grab (Cavanagh & Anstis, 2013). Scan the QR code on right to view movie. The sectored disks when they appear rotate back and forth and on each reversal of direction, a pair of vertical colored lines appear briefly. Although the lines are vertical and parallel, they may appear tilted in (red) and then out (green) at each subsequent appearance. The moving backgrounds will fade in and out in to show that the lines are vertical and parallel. Fixate the central dot for best effect. Go to this address if you are unable to use the QR code: https://cavlab.net/Demos/Clara/Movie 1. FlashGrab.m4v

We call our second phenomenon a "frame effect". A square outline frame moves back and forth horizontally, and two spots are flashed inside the square each time the motion reverses. The spots are both at the same location, but they appear as two widely separated spots, one to the left and to the right of their true physical location. In fact, it appears that the spots' separation is judged not in absolute terms but in terms of their positions relative to the moving square when they flash, as if the square were stationary. Yet observers can clearly see the movement of the square. This phenomenon is related to the effect that the moving background had on our bugs (Anstis & Casco 2006) and earlier in the displays of Duncker (1929) and Wallach (1959), Wallach et al. (1978). Our new stimulus uses flashing tests and that turns out to be critical. In previous work on the effect of a moving frame, the tests were continuous: our bluebottle flies (Anstis & Casco, 2006) moved up and down sinusoidally, Wallach et al.'s (1978) target moved along a vertical straight line, and Duncker's (1929) targets were stationary. With Duncker's continuously visible target, the moving frame only produces a small, reversed motion in the target (induced motion) when the frame's motion is so slow it is near the motion threshold (Nakayama & Tyler 1978). But the illusory displacement induced into our flashed targets was more than *ten times* greater than that reported by Duncker. We speculate that a continuously visible target accumulates steady information about its true physical position that countermands any position or motion induction from the moving background.

We divide the recent work that we report here into two sections. The section headed "Paths shortening" was inspired by Sinico, Parovel, Casco and Anstis (2009) and the section headed "Induced position" was inspired by our bluebottle paper (Anstis & Casco 2006).



Movie 2. The frame effect (Özkan etal., 2021). Scan the QR code on right to view movie. The two red disks are vertically aligned and flash at the reversals of the frame's motion. Although aligned, they appear separated by almost the displacement of the frame. Go to this address if you are unable to use the QR code: https://cavlab.net/Demos/Clara/Movie 2. Frame Effect.m4v.

Further details can be found in Cavanagh and Anstis (2013), Anstis and Cavanagh (2017), Özkan, Anstis, 't Hart, and Cavanagh (2021), Cavanagh et al. (2022), and Takao, Anstis, Watanabe, and Cavanagh (2022).

A. Path shortening

Sinico et al. (2009) found that the path of a moving spot often looks much shorter than it really is. For instance, three spots arranged at the corners of an imaginary equilateral triangle were made to move bodily along a common circular path. Observers adjusted the diameter of these circular paths until they judged that the three circles just touched in the middle. In fact they underestimated the dots' trajectories and selected circular paths that overlapped considerably. We now extend this work by showing similar path shortening for various kinds of motion -- not only for spots moving in a straight line or around a circle, but also for lines rotating back and forth around their centres. We found in all cases that the motion paths looked shorter than they really were.

We attribute this path shortening to a travelling averaging-window, producing a perceived location that is the average of the test positions over a short period of time. Figure 1 shows that time-averaging will round the corners off a triangular motion path and reduce its perceived amplitude. Over a certain range, the longer the integration time the more the perceptual amplitude is compressed.

Figure 1.

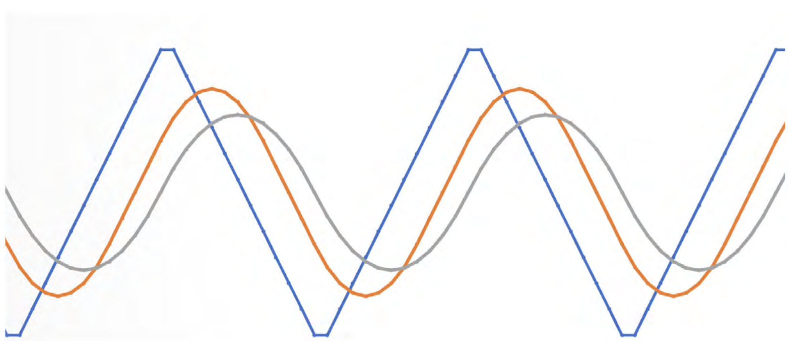


Figure 1. *Blue triangular wave shows the path of a spot that moves back and forth. Time-averaging windows, shown as orange and grey vertical bars, compress this wave into the orange and grey sinewaves, of reduced amplitude. (Bars are drawn here with sharp edges but would actually be Gaussian windows).*

Here are three examples of motion paths that looked short: 1. A dot moving back and forth horizontally, 2. A line that rotated back and forth through 180°, 3. Dots arranged around the edge of a rotating circle.

1. Apparent shortening of linear motion. A small spot moved back and forth at constant speed along a linear motion path at rates ranging from 0.3Hz to 3Hz, like the blue triangular wave in Figure 1. The motion path was either 3°, 4° or 6° in length, and observers adjusted the length of a static horizontal line to match the apparent path thanks. Results were pooled for the three path lengths, and the ratios of the perceived to the actual path lengths are plotted in Figure 2. It can be seen that the perceived amplitude fell off linearly with increasing speeds.

Figure 2.

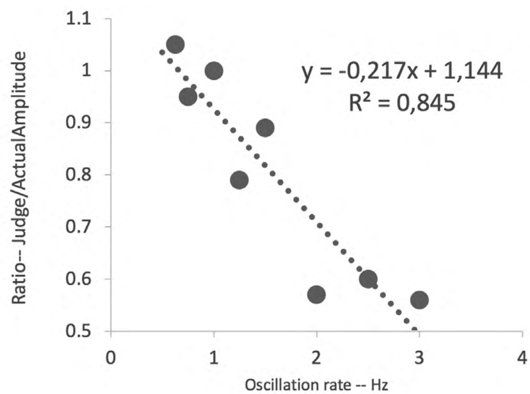
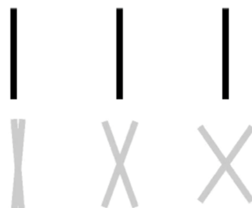


Figure 2. Apparent shortening of rotation. *We rotated a black vertical rod back and forth through 180° (half a revolution) at frequencies ranging from 0.375 to 3 Hz (1 Hz = 1 back & forth rotation) Observers adjusted a nearby pair of rods forming an X, setting their X-angle to a perceptual match with the perceived amplitude of rotation (which was always 180° but looked progressively smaller with increasing speed).*

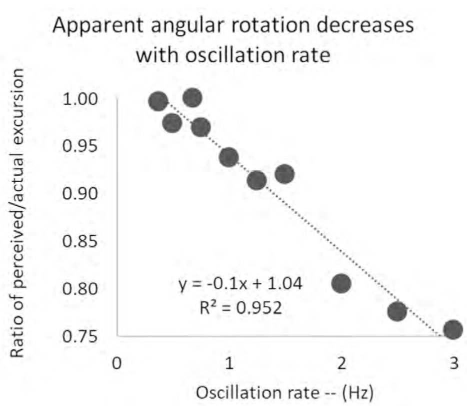
Movie #3 shows typical matches made, and results are graphed in Figure 3. This graph implies a physiological integrating time of **182 ms.**

Figure 3.



Movie 3. Path shortening (Sinico et al., 2009). Scan the QR code on right to view movie. Go to this address if you are unable to use the QR code: https://cavlab.net/Demos/Clara/Movie 3. PathShortDemoLoop.m4v. Top row shows a line oscillating through 180° at different speeds. Bottom row shows typical settings made to match the line's apparent excursions, which decrease as speed increases.

Figure 3. *Results from Movie 3. Perceived excursions of oscillating line decrease as speed increases (path shortening)*



2. Apparent shortening of spot rotations. Movie **4** shows the apparent shortening of four spot paths. The spots do move through 90° so that their virtual paths just touch, but they seem not to. So we set up 3, 4, 6 or 8 spots equally spaced around a circle. These spots rotated back and forth, and five observers adjusted the amplitude of the motion until the paths of adjacent spots just seemed to touch. Result: they made the arc-shaped motion paths 30° -- 40° too long so that they overlapped, as shown in Figure 4. The spots' perceived motion paths had been shortened by the motion and the observers had to compensate by making the physical path longer.

Figure 4.

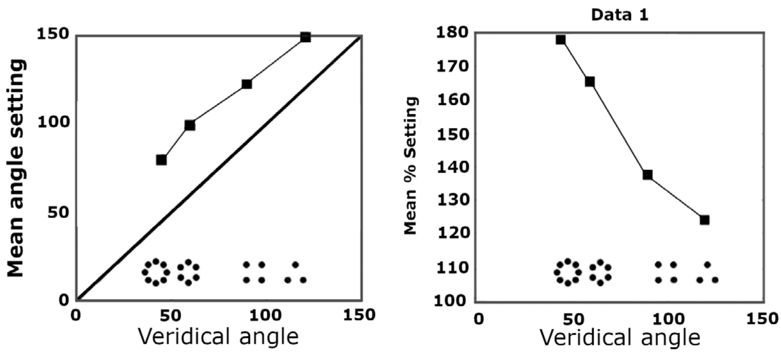
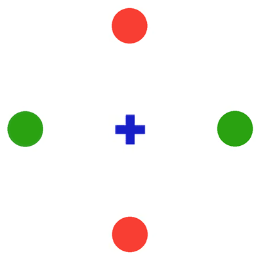


Figure 4. *(Left), Settings were 30° -- 40° above veridical in order to look correct. Vertical lines show ±1 SE: most were smaller than the plotting symbols. (Right), Same data replotted as percentages shows that path lengths were set to 120% -- 180% of correct length. Veridical settings would be along the 100% horizontal line at the bottom of graph.*

Results. Results are plotted in Figure 4, in ***left*** as actual settings and in ***right*** as a percentage of the actual rotation. Veridical settings would always lie at 100%, but most observers' settings lay between 120% and 180%. This means that the observers set the physical rotation to 20% to 80% greater than the correct setting to look correct – a strong apparent shortening of the rotary path length in every condition. This path shortening is similar to the motion path shrinkage described by Sinico et al (2009)



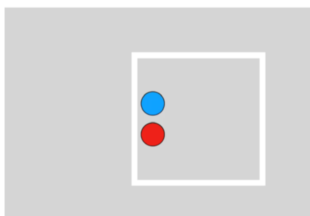
Movie 4. Path shortening. Scan the QR code on right to view movie. Go to this address if you are unable to use the QR code: https://cavlab.net/Demos/Clara/Movie 4. PathShorten90.m4v. Paths of adjacent spots actually touch but look shorter than they are.

B. Induced position.

In 2006 Clara and I found that moving backgrounds could alter the perceived motions of small moving objects. These observations confirm and extend the pioneering work of Duncker (1929) and Wallach (1959), Wallach et al. (1978). Their stationary targets seemed to move opposite to the moving backgrounds over a short path, while our moving targets combined their real motions with the illusory induced motion. Since then Patrick Cavanagh and I have found that an induced path of displacement can be increased up to *tenfold* if the targets are simply flashed instead of being visible all the time (Özkan et al 2021). When the targets are continuously visible they show almost no visible displacement. Duncker (1929) used such stationary targets, into which the moving frame induced only a very small opposite motion; and the frame's motion needed to be so slow that it approached the motion threshold.

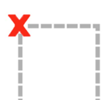
In **Movie 5,** a moving square frame initially contains two stationary spots, which may appear to move slightly against the moving square (Duncker's 1929 induced motion effect). However, when these same two spots start flashing in alternation at the moments when the frame reverses its direction, they appear to be separated by almost the same distance as the square's displacement (Cavanagh et al., 2022). We speculate that in the first case (equivalent to Duncker's stimulus), the continuous presence of a stationary target accumulates evidence as to its actual position, which resists induction from the moving frame. This suggests that the position of the flashed target is judged not in coordinates of the stationary world but in frame coordinates, as though the frame were perceived as stationary, even though paradoxically the motion of the frame is seen quite clearly (Özkan et al 2021). These demonstrations are available here:

https://cavlab.net/Demos/FrameEffect/



Movie 5. Frame effect with static vs flashed probes. Scan the QR code on right to view movie. Go to this address if you are unable to use the QR code: https://cavlab.net/Demos/Clara/Movie 5. StaticVSFlash.m4v. While the frame moves the static spots look stationary (no induced movement), but the flashed spots appear to jump back and forth through almost the entire distance of the square's displacement.

We also tested the effects of this induced position shift on young versus old observers. Here we found that the illusory displacement of a flashing target looked very real – to the extent that many older observers found it virtually impossible to point at such targets. We set up a target that kept flashing in the same position while a square moved around continuously behind it. The spot appeared to jump to locations in the opposite direction to the square, and we asked observers to move the cursor onto the target. We first invited young volunteers from the UCSD student body and then visited a local retirement home in search of older volunteers. My student Kaylee Ryan was far more successful at recruiting their help than I was. Seeing me reminded them that they were old, and seeing her reminded them that they used to be young. We found that all of those under 65, and half of those older than 65, could do this task without any trouble within a few seconds. But the other half of the over -65s (including SA but not PC) had great difficulty with this apparently trivial task. They would move the cursor towards the general area of the target and then flail the mouse around almost at random until they got lucky and landed on the target. This could take them anything from one to two minutes. Somehow the moving background disrupted their sense of the target's position as can be seen in the data of Figure 5 (Anstis 2019a). We never really understood this age-related disability, but we did show that our observers' difficulty was perceptual, not a motor problem with controlling the mouse, since they found it surprisingly easy to hit a target that was actually jumping around in real motion. It was only the illusory displacement that caused the trouble.



Movie 6. Four flash frame effect for localizing probes. Scan the QR code on right to view movie. Go to this address if you are unable to use the QR code: https://cavlab.net/Demos/Clara/Movie 6. SquareForOldies.m4v. The red and blue crosses are in the same place, but the moving dashed square confuses many people over 65 and they are unable to move a cursor on to the crosses.

I spent many happy times with Clara, first in my home city of San Diego and then in her home city of Padua. I am in awe of a university whose alumni include the scientists Copernicus, Galileo Galilei, Vesalius and William Harvey, the physician John Caius (co-founder of Gonville & Caius College, Cambridge), the Elizabethan spymaster Sir Francis Walsingham, the composer Giuseppe Tartini, the poet Torquato Tasso, the great Casanova himself, and Clara Casco. Overall, some of my best times in science have been spent with Clara Casco. So I dedicate this chapter to her, my favorite Professoressa and collaborator.

Figure 5.

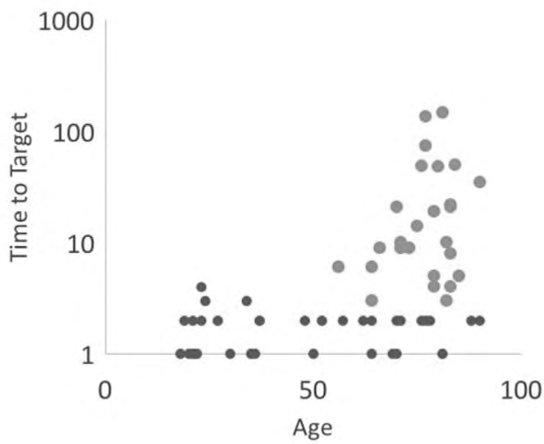


Figure 5. *Time-to-target (s) versus age. Note that 61% of all seniors over 65 years were slow to hit the target (light gray datum points). (Anstis 2019)*

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