Annual Cognitive Paper Prize Award

Promoting a stable visual world with serial dependence

Mauro Manassi & David Whitney

Keywords: *Visual stability; Serial dependence; Visual illusion.*

Parts of this article were originally published on The Conversation:
https://theconversation.com/everything-we-see-is-a-mash-up-of-the-brains-last-15-seconds-of-visual-information-175577

OUR EYES are continuously bombarded by an enormous amount of visual information – millions of shapes, colours and ever-changing motion all around us. For the brain, processing this cacophony is no easy feat. On the one hand, the visual world fluctuates continuously because of changes in light, viewpoint, and other factors. On the other, our visual input constantly changes due to blinking and the fact that our eyes, head, and body are frequently in motion. To get an idea of the 'noisiness' of this visual input, place a phone in front of your eyes and record a live video while you are walking around and looking at different things. The jittery, messy result is exactly what your brain deals with in every moment of your visual experience. This can be seen also in this video (https://youtu.be/Lub3lsJdko0). The white circle on the right shows potential eye movements, and the blurry blob on the left reveals the jumpy visual input in every moment.

Yet, seeing never feels like work for us. Rather than perceiving the fluctuations and visual noise that a video might record, we perceive a consistently stable environment. So how does our brain create this illusion of stability? This process has fascinated scientists for centuries (Al-Haytham 1083, Von Helmholtz 1866), and it is one of the fundamental questions in vision science.

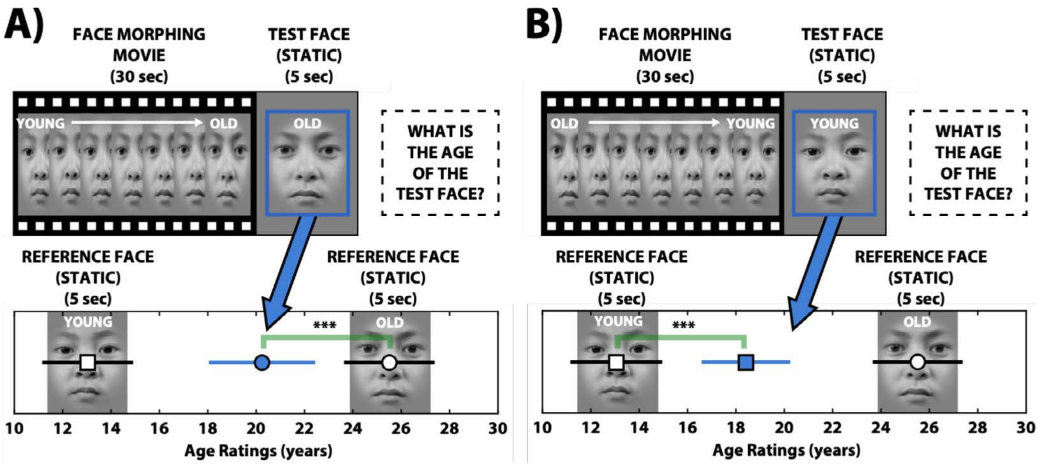
The time machine brain

In our latest research (Manassi & Whitney 2022), we discovered a new mechanism of serial dependence that, among others (Simons & Chabris, 1999; Smithson & Zaidi, 2004; Simons & Rensink, 2005; Wurtz 2008; Foster 2011; Webster 2015), can explain this illusory stability. The brain automatically smoothes our visual input over time. Instead of analysing every single visual snapshot, we perceive in each moment a running average of what we saw in the past 15 seconds. By smoothing the appearance of objects over time, so that they seem more similar to each other, our brain tricks us into perceiving a stable environment. Living slightly 'in the past' can explain why we do not notice subtle changes that occur over time.

In other words, the brain is like a time machine which keeps sending us back in time. It is like an app that consolidates our visual input over 15 seconds into one impression so that we can handle everyday life. If our brains were always updating in real time, the world would feel like a chaotic place with constant fluctuations in light, shadow, and movement. We might feel like we were hallucinating all the time.

We created an illusion to illustrate how this serial dependence stabilisation mech-

Figure 1:



Republished with permission from Manassi & Whitney (2022). A) Two groups of observers were asked to rate the age of a young or old static face embedded in a blue frame (white square and circle; reference faces). A third group was presented with a face morphing movie gradually aging from young to old and was then asked to rate the age of the old face embedded in a blue frame (blue circle, test face). Although the test face and reference faces are identical, the old test face was rated as much younger than what it actually was (green bracket). White text is shown for illustration purposes. (B) A fourth group was presented with a face morphing movie gradually rejuvenating from old to young and was then asked to rate the age of the young face embedded in a blue frame (blue square; test face). The young test face was rated as much older than what it actually was (green bracket). ***P < 0.0001.

anism works. In this video (https://youtu.be/cLqVwvdOzuk), the face on the left side slowly ages for 30 seconds, and yet, it is very difficult to notice the full extent of the change in age. In fact, observers perceive the face as ageing more slowly than it actually is.

To test this illusion, we recruited hundreds of participants and asked them to view close-ups of faces morphing chronologically in age in 30-second timelapse videos (Figure 1). When asked to tell the age of the face at the very end of the video, the participants consistently reported the age of the face that was presented ~15 seconds before (younger face illusion; Figure 1A, blue dot). To test whether our illusion was due to a simple unidirectional bias in age ratings, another group of participants watched the same movie of a rejuvenating face that gradually morphed from old to young (inverse age direction). Again, the participants reported the age of the face that was presented ~15 seconds before (older face illusion; Figure 1B, blue dot).

As we watch the video, we are continuously biased towards the past because the brain constantly averages over the previous ten to 15 seconds. Instead of seeing the latest image in real time, humans actually see an average that includes earlier versions because our brain's refresh time is about 15 seconds. This illusion demonstrates that visual smoothing over time by serial dependence can help stabilise perception (Fischer & Whitney, 2014;Manassi & Whitney, 2022).

One possibility is that the brain is essentially procrastinating. It is too much work to constantly deal with every single snapshot it receives, so the brain biases our percept towards the past because the past is a good predictor of the present. Basically, the brain recycles information from the past because it's more efficient, faster, and less work.

This idea of mechanisms in the brain, called *Continuity Fields* (Cicchini, Anobile et al. 2014; Fischer & Whitney, 2014), that continuously bias our visual perception towards our past visual experience, is also supported by other results (Fischer & Whitney, 2014; Manassi, Liberman et al., 2017; Cicchini, Mikellidou et al., 2018; Manassi, Liberman et al., 2018; Murai & Whitney, 2021). A consequence of continuity fields is that our visual system sometimes sacrifices accuracy for the sake of a smooth visual experience of the world around us. This can explain why, for example, when watching a film, we don't notice subtle changes that occur over time, such as the difference between actors and their stunt doubles (https://www.mirror.co.uk/lifestyle/going-out/film/status-quo-rick-parfitts-stunt-2013755).

Repercussions

There are positive and negative implications of the smoothing process in perception. This running average—serial dependence—is great for preventing us from feeling bombarded by visual input every day, but it can also risk life-or-death consequences when absolute precision is needed. For example, radiologists examine hundreds of images in batches, seeing several related images one after the other. When looking at an X-ray, clinicians are typically asked to identify any abnormalities and then classify them. During this visual search and recognition task, we have found that radiologists' decisions were based not only on the present image, but also on images they had previously seen, which could have grave consequences for patients (Manassi, Kristjánsson et al., 2019; Manassi, Ghirardo et al., 2021).

Our visual system's sluggishness to update can make us blind to immediate changes because it grabs on to our first percept and pulls us toward the past. Ultimately, though, continuity fields promote our experience of a stable world. At the same time, it's important to remember that the judgements we make every day are not totally based on the present, but strongly depend on what we have seen in the past.

The authors

Dr Mauro Manassi
School of Psychology,
University of Aberdeen, UK
mauro.manassi@abdn.ac.uk
Twitter: @MauroManassi
https://www.mauromanassi.com/

Prof David Whitney
Department of Psychology,
University of California,
Berkeley, California, USA.
Helen Wills Neuroscience Institute,
University of California, Berkeley,
California, USA.
Vision Science Group,
University of California, Berkeley,
California, USA.
dwhitney@berkeley.edu
https://whitneylab.berkeley.edu/

References

Al-Haytham, I. (1083). *The optics of Ibn Al-Haytham* (AI Sabra, Trans.). London: Warburg Institute.

Cicchini, G.M. et al. (2014). Compressive mapping of number to space reflects dynamic encoding mechanisms, not static logarithmic transform. *Proceedings of the National Academy of Sciences, 111*(21), 7867–7872.

Cicchini, G.M. et al. (2018). The functional role of serial dependence. *Proceedings of the Royal Society B, 285*(1890), 20181722.

Fischer, J. & Whitney, D. (2014). Serial dependence in visual perception. *Nature neuroscience, 17*(5), 738–743.

Foster, D.H. (2011). Color constancy. *Vision Research, 51*(7), 674–700.

Manassi, M. et al. (2021). Serial dependence in the perceptual judgments of radiologists. *Cognitive Research: Principles and Implications, 6*(1), 1–13.

Manassi, M. et al. (2019). Serial dependence in a simulated clinical visual search task. *Scientific Reports, 9*(1), 1–10.

Manassi, M. et al. (2017). The perceived stability of scenes: serial dependence in ensemble representations. *Scientific Reports, 7*(1), 1–9.

Manassi, M. et al. (2018). Serial dependence in position occurs at the time of perception. *Psychonomic Bulletin & Review, 25*(6), 2245–2253.

ÍManassi, M. & Whitney, D. (2022). Illusion of visual stability through active perceptual serial dependence. *Science Advances, 8*(2), eabk2480.

Murai, Y. & Whitney, D. (2021). Serial dependence revealed in history-dependent perceptual templates. *Current Biology, 31*(14), 3185–3191. e3183.

Simons, D.J. & C.F. Chabris. (1999). Gorillas in our midst: sustained inattentional blindness for dynamic events. *Perception, 28*(9), 1059–1074.

Simons, D.J. & R.A. Rensink. (2005). Change blindness: Past, present, and future. *Trends in Cognitive Sciences, 9*(1), 16–20.

Smithson, H. & Zaidi, Q. (2004). Colour constancy in context: Roles for local adaptation and levels of reference. *Journal of Vision, 4*(9), 3–3.

Von Helmholtz, H. (1866). *Handbuch der physiologischen Optik* [Handbook of physiological optics]. Hamburg, Germany: Voss.

Webster, M.A. (2015). Visual adaptation. *Annual Review of Vision Science, 1,* 547–567.

Wurtz, R.H. (2008). Neuronal mechanisms of visual stability. *Vision Research, 48*(20), 2070–2089.