A proposal for a repeatable demonstration of the CSR

I started this in about 2006 after writing the SBS paper, and have basically found my life going in different directions, and no longer have the space to devote a year to writing a formal peer reviewed paper and going through the peer review process.

However, this project is well worth pursuing, and if anyone is interested in taking it up, the following is a detailed description of an experiment to demonstrate the CSR in a way that is universally repeatable.

Experiment description

Modern digital cameras are of high enough definition so that it is possible to capture the CRI/10-second CSR using an ordinary digital camara – or even a digital phone camera!

Pixel definition

(This section calculates the minimum camera resolution to detect the CRI using digital photography)

Where P = number of pixels across image

W = full width of image at same focal distance as target (mm)

H = full height of image at same focal distance as target (mm)

d = movement due to CSR (mm)

w = width of head (mm)

n = No of pixels displacement

M = No of megapixels in image

n = P.d/W

A standard ratio of W/H for photographic images is 1.5, which gives :

P = sqrt(Mx1E6/1.5) = 816.5.sqrt(M)

Based on palpatory evidence, the amplitude of the cranial rhythm to be detected (d) is of the order of 1 mm, and a minimum measurable displacement that would provide an unambigious "signal" would be of the order of 5 pixels (n_{min} =5).

If we have a 3 megapixel image (M=3), then, assuming W=300mm :

Pixel resolution = 816.5.sqrt(3).1/300 = 4.7 pixels/mm

This is on the lower bounds of required resolution, and so a camera resolution of at least 3 megapixels is required.

A recent MRI study[1] of the cranial rhythm has shown that motion is measurable, with a resolution of about 0.5mm. Whilst there is less fixed control of targets in the protocol described here, digital photography provides the potential for a far higher resolution than MRI, at a fraction of the cost. And as described below, the potential for distortion due to differential skin/soft tissue motion can be substantially reduced by a) taking photographs from orthogonal directions, and b) checking the absolute magnitude of distortion due to various facial grimaces, breath, pulse, etc before conducting the main experiment.

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1 William T Crow, Hollis H King, Rita M Patterson & Vincent Giuliano (2009) Assessment of calvarial structure motion by MRI. Osteopathic Medicine and Primary Care, 3:8 doi:10.1186/1750-4732-3-8. Available online at http://www.om-pc.com/content/3/1/8

<u>Target Design</u>

(A number of targets can be fixed to a subjects head using theatrical makeup glue or white latex glue (used to stick fabric and carpets). This section discusses the design of these targets)

Digital images are stored in a 1.67million color palette based on a 3 byte RGB format, where each of R (Red), G (Green) and B(Blue) is assigned 1 byte (8 bits) of storage, giving a maximum resolution for each band on an integer scale of 0..255. The following table gives examples of pure color 3-byte pixels :

Decimal	Hexadecimal	Color
0, 0, 0	x000000	Black
255, 255, 255	xFFFFFF	White
255, 0, 0	xFF0000	Red
0, 255, 0	x00FF00	Green
0, 0, 255	x0000FF	Blue

The colour least likely to be confused with other colours that might occur on a persons face, clothing or in the background is (0,255,0 or #00FF00) GREEN. Blue may be present in the eye iris, and red may be produced by red-eye or may be present in skin colour.

Standard bitmap green can be defined in 256 discrete colors between pure green and pure white, giving a maximum potential linear resolution of 1/256 pixel if the green target is on a white background. In practice, this resolution is limited by :

- Camera Motion and subject motion during the shutter period (edge blurring)
- Lens optical accuracy (edge blurring)
- Imperfect edge resolution of the printed target (edge blurring)
- Imperfect colors for target and background (reduced color resolution)

Choice of target

Target shape : A circular target was chosen, giving a uniquely identifiable maximum horizontal size at all rotational angles.

Target color : If a suitable target is chosen, this will readily be identifiable from any other color on the image. Green `(x00FF00)` is the least likely color to be present on a photograph of a human face. Therefore target of green is used, and all other background colors during the experiment are selected so that they are as far from green as possible.

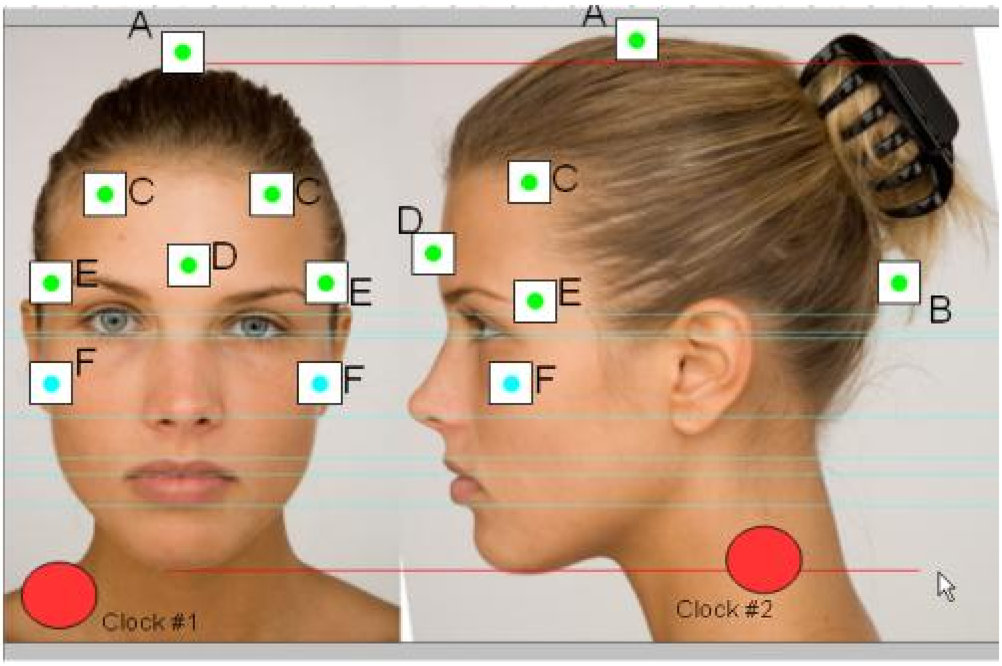
Target size : this is unimportant, except that the targets should be large enough to be easily identified as unique objects on the image. A target diameter of 10mm was chosen. A square white background approximately 25mm across (variable) was used.

Target background : If a readily identifiable target background is used, the location of the target edge (and hence the target center) can be defined to better than 1 pixel by measuring the color change. Therefore a white target background was slected, giving a theoretical maximum possible target edge (based on color mixing) of 1/256 of a pixel.

Target printing : In practice, an edge resolution better than 1/10 pixel should be achievable, giving a potential target definition better than 1 part in 50 (5 pixels x 10) for a 1mm motion using a 3 megapixel image. Standard home printers will print green spots but the edge resolution is quite poor and the green colour is not particularly well controlled – so the targets should be printed by a commercial printer using a professional quality batch colour laser printer. One A4 or letter sheet of 10mm diameter green spots at suitable professional definition and colour control costs about £25 in the UK. With targets at approx 40mm centres on a white background, one sheet contains enough targets to run several experiments.

Target Mounting : The individual green spots are cut using very sharp scissors with at least a 10mm white border. If the edge is ragged or too close to the green target, it could interfere with automatic pixel recognition software. This approx 30mm square paper is glued onto an approx 35mm cube of high density polystyrene, of the type used to package electrical equipment. This material will cut cleanly with a sharp modelling nife without need for a heated wire. The glue should be of a type that does not penetrate the paper – i.e. it should not affect the target colour! These cubes to be re-shaped so that when glued onto a persons head (as detailed below), the targets face approximately forwards (anteriorly) and sideways (laterally) so as to be approximately face on to the two recording cameras. This does not have to be exact, because any angular distortion is accommodated by the use of a circular target.

Target location : Targets were located on areas of minimum thicknesses of flesh. Suggested bony locations chosen are shown in the figure below. Critical targets are colour coded green, and secondary (optional) targets are colour coded blue.



Target schedule (see image) :
(Ant = Anterior camera, Lat = Lateral camera, Both = two targets : i.e. one target circle for each camera on a single target block)
All these have been selected to give minimum skin cover over bone

A : approx apex of head on saggittal suture (faces Both)
B : approx inion (faces Lat)
C : approx frontal eminence (faces Both)
D : metopic suture (faces Both)
E : approx anteriolateral edge frontalof frontal (faces Both)
F : approx anteriolateral edge zygomatic arch (faces Both)

A watch is also located in each of the images so that the timing on the photos can be synchronised. A ruler may be added as an optional extra, but if the target cubes are cut with a moderate degree of precision, this will give sufficient accuracy of scale for the purposes required. Alternatively the distance between tagres B-D and targets E-E can be physically measured before the data capture begins. Extra possibly heavy objects such as watches, rulers would be better held in place by some kind of external device like a laboratory clamp (as opposed to being glued to the subjesct body). As can be seen on the photos, hair could get in the way, so for these purposes bald is beautiful.
The subject image should be framed so as to provide a complete picture of the head with minimum border, so that the pixel resolution is as high as possible.

<u>**Image Frequency**</u>
(how many images to be taken and time interval between them)
Data has to be gated to at least 2 data points for every cycle of the fastest event, to prevent equivalence. In this case, the cardiac rhythm is about 1 second. However, there is no cardiac pulse detectable on the head with an amplitide of 1 to 2mm in healthy subjects. Therefore, no cardiac gating is strictly necessary for large amplitude motions. The breath is of a similar frequency to the CRI, and both breath and CRI may be as fast as about 5 seconds per cycle, but is usually about 10 seconds. The following time protocol is therefore proposed :

1. <u>Calibration A</u> : Rapid image capture at 0.3 seconds or faster (or whatever the camera can

achieve) for approx 15 seconds to demonstrate cardiac pulse (if any)

2. Calibration B : A set of images to be captured at approx 1 second intervals, with subjects face in “neutral” (i.e. the facial expression they will adopt for the main data capture phase), followed by a series of different facial expressions (smile, frown, grimace, clench teeth/bite, etc?), then returning to neutral to demonstrate the differential motion of the targets under these circumstances.
3. Calibration C : A similar set of images captured with the head angled slightly up, down, left an dright and head cocked to L, then R. Then the subject returns head to neutral. Something exactly at eye level on the far wall that the subject can look directly at is a useful way of maintaining a head position. Some kind of stabilising barrier that the head can be lightly rested in is another option – obviously with the possible danger of disturbing the CSR.
4. Data Capture : The remainder of the images to be captured at a rate approx 0.5 to 1.0 seconds, giving a minimum of 5 frames per cycle of the CRI (and ideally about 10 frames). This capture to be continued for approx 30 seconds, to allow for longer CRI's and also to give the possibility of detecting motion due to mid and long tides. It can be continued for a longer period, but there are issues related to image storage and processing, so it is probably best to keep the total capture time less than 1 minute for CSR detection. It is also unreasonable to expect the subject to keep a constant facial expression for long periods, and so 20-30 seconds seems to be a good upper limit on this.

Methodology – equipment

Two (2) cameras are mounted on tripods, one looking at the front of the face and the second looking at the lateral aspect. Both these cameras should be ideally profesisonal digital SLR cameras, so that they have the option of

(a) automatic image capture in a series of rapid takes,

(b) a rapid image capture rate 0.3 seconds or faster

(c) a time/date stamp facility

If a time/date stamp is used, then the subject shoul dbe framed such that the date stamp does not obscure any part of one of the white target cubes or its target dot.

Two watches should also be fixed so that they are captured on film – this could completely replace the time/date stamp requirement.

A separate stopwatch may also be required.

A HeartMath sensor should be attached to the subject, so that HRV and pulse can be recorded at the same time as image data capture. This will also require a portable computer.

Some means of recording breath would be ideal. The simplest option is a rapid response temperature sensor located near a nostril and attached to a datalogger.

A skin galvanometer could also be added to the instrumentation to compare with the observed CRI, with ots output also captured using a datalogger

Ideally the cameras should be able to be downloaded immediately onto a PC so that the data can be analysed and the data capture repeated if necessary.

The room should be evenly lit with natural light, but no direct sun beams, and the walls showing in the background to the frame should be a light fairly neutral colour.

All the different instruments and clocks will have to be cross referenced so that there is a clear marker or known time offset that can be applied during the data processing. This is a really critical task. It's fiddly, needs quite a lot of clear logical ;thought and attention to detail, and you won't know that it's not been done properly (if ever) until you do the main data process stage. And everyone has gone home and had a beer.

Optional Extras

If you have adequate funding (or can beg, borrow or hire them), the following add-ons would be a great improvement

a) replace the HeartMath logger with a Pulse Oxymeter. the HeartMath device is a pulse oxymeter (plethysmometer) with the oxymetry function removed, so it observes changes in capilliary translucency and therefore detects the cardiac pulse. A Pulse Oxymeter will measure the pulse and also interpolate the relative oxygen content of the blood (which may correlate with the CRI)

b) replace the temperature probe under the nose with a proper strain gauge lung monitor – essentially a strain gauge on a spring plate strapped round the chest, it records motion of the thoracic ribs.

c) add a strain gauge bite pressure meter – a device that fits between the teeth records changes in bite pressure. This is the biggest possible effect on the vault shape that can be a possible alternative to the CRI observation, and a bite monitor will divert criticisms that the subject could have been falsifying the CRI by clenching their teeth.

Protocol, etc

After attaching the targets the other data capture equipment has to be started up and the clocks on this synchronised (or an offset determined) with the clocks used on the images.

Someone in the room must be able to detect the CSR so that the image capture start can be optimised – this might seem a simplistic statement, but if this experiment is to be repeated by anyone, this requirement must be stated in the peer-reviewed write-up!

The CSR behaves differently with subjects vertical compared to lying down, due to different ICP. It may possibly be necessary to alter the setup so that the subject is lying face up rather than seated.

Required personel :

1 x subject with lots of bits glued to their head
1 x coordinator
1 x operator for each camera
1 x timekeeper/event recorder
1 x datalogger operator
1 x HeartMath logger operator

Software and image processing

The images to be downloaded form the camera and batch converted (using IrfanView) to .BMP format. IrfanView can also be used to identify the pixels/cm (or /inch) scale of the images, and the colour of the green target dots can be easily sampled using Pixie.

AC has written a target recognition program (in Fortran 77 – yes – that's the programming language I still use!) that will take the target locations from each image and calculate offset to about 0.3 pixels or better. Alternatively this can be done manually or you can write your own software. The centre of each circular target should be measured at least accurate to 1 pixel.

Relative motion and plots relative to all other data capture device readings can be processed using a standard spreadsheet programme. With modern cameras able to capture 7 or 10MB images, a substantial amount of free disk space is necessary <u>on the C: drive</u>! (at least 10GB free space <u>after</u>

any system software hs alocated its necessary buffer space. Any less than this will either result in a blue screen of death or you'll have to go on holiday for a week to wait for the images to process). The HRV data can analysed for comparable time periods using HRV analysis software provided by Mika Tarvainen at the University of Kuopio (ask AC for a copy of this)

The data capture takes about an hour to set up ready for action, maybe 30 minutes for a few trial runs and then 2 minutes to do the final capture. Data processing to see a motion graph of one data set will take about an hour (maybe a little more) for a quick view to check that the data shows the CSR. So a full day should be allocated to run this, and you might get half a day off for merit if everything runs smoothly. The complete data processing to account for all cross-referencing of target locations and check back to calibration data will take about 2 full days. Write-up to peer-review standard and submission (to Journal =? some careful thought needed on this one for maximum impact) will be about 2 full weeks work, plus the usual to-and-fro from reviewers.

After publication, I suggest that the original data (datalogger files, BMP images) are posted on a publicly accessible FTP site.