Working memory, anxiety, and photography: an evaluation of a digital camera as a tool for enabling creativity under stress.

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The structure and function of working memory.

Alan Baddeley defines working memory (WM) as “a brain system that provides temporary storage and manipulation of the information necessary for such complex cognitive tasks as language comprehension, learning, and reasoning” (Baddeley, 1992). WM is closely tied to long-term memory: WM retrieves stored LTM knowledge relevant to the tasks at hand, manipulates LTM material to allow interpretation of new stimuli and discovery of new information and solutions to problems, and finally encodes the outcome of its operations back into LTM (Baddeley & Logie, 1999, p. 31).

In their 1974 paper “Working Memory” A. Baddeley and G. Hitch proposed that working memory is composed of three separate components: the attention-controlling *central executive* aided by two subsystems called the articulatory loop and the visuospatial scratchpad (Baddeley, 2002, p. 86). The two subsystems were later renamed the *phonological loop* and the *visuospatial sketchpad*. Let’s look at the three original components of the model in more detail. [1]

The phonological loop. As its name implies, the phonological loop is the component of WM that stores acoustic and verbal information. According to Baddeley’s model, the loop itself is composed of two components: a passive phonological store and an active articulatory rehearsal process (Baddeley & Logie, 1999, p. 30; Baddeley, 1992). The role of the phonological store is to hold acoustic and speech-related information—information that decays within about two seconds unless refreshed by the articulatory rehearsal system through subvocalization (Baddeley & Logie, 1999, p. 30). In addition, the phonological loop can “translate” visually presented material like words or nameable pictures and register them in the phonological store (Baddeley, 1992). A common real-world example of the phonological loop in action is looking up a phone number and rehearsing it subvocally until it is no longer needed.

The visuospatial sketchpad is a component of WM responsible for temporary storage of visual and spatial information (Baddeley, 2002, p. 86) such as patterns, shapes, colors, position of objects in space, etc. Like the phonological loop, this system is also composed of two components: a passive visual cache and an active spatially based rehearsal system called the “inner scribe” (Baddeley & Logie, 1999, p.

[1] The recently postulated fourth component—the episodic buffer—is beyond the scope of this paper’s discussion.

30). While the visual cache is responsible for retaining visual patterns, the inner scribe retains the sequence of movements (Baddeley & Logie, 1999, p. 30). Support for this dichotomy comes from Logie and Marchetti's interference experiments where they observed that retention of spatial patterns, but not visual information (shades of color) was disrupted by subjects' arm movements; and, conversely, the retention of visual information, but not spatial patterns was disrupted by visual interference tasks (Baddeley & Logie, 1999, p. 35).

The central executive can be thought of the "heart" of working memory, or, to use a computer metaphor, its processor. Baddeley and Logie define central executive as an attentional system that controls processes in working memory (Baddeley & Logie, 1999, p. 30). While it does not seem to have any storage capacity of its own, it coordinates the phonological loop and the visuospatial sketchpad by manipulating the material held in these two subsystems (Baddeley & Logie, 1999, p. 30). The central executive also focuses the available attentional capacity on the task at hand and plays an important part in dividing and switching of attention (Baddeley, 2002, p. 86). Finally, the central executive is believed to be involved in forming an interface between the two subsystems and the LTM (Baddeley, 2002, p. 91).

The limits of working memory.

Working memory is commonly described as the bottleneck between the perceptual system and LTM, the former providing a nearly limitless stream of stimulation and the latter possessing a nearly limitless capacity. In evolutionary terms, the limited capacity of working memory is often justified as a way for us to filter the incoming information and to direct our attention to what is important.

The limits of the phonological loop. Baddeley documents several interesting phenomena associated with the phonological loop that points to its volatility and limited capacity. For example, the *phonological similarity effect* accounts for the observation that a series of phonologically similar items (i.e. letters *B, V, G, T, C, D*) is more difficult to recall than a set of phonologically dissimilar items (i.e. letters *F, K, Y, W, M, R*) (Baddeley, 2002, p. 86). In addition, longer words are more difficult to recall correctly than shorter words (Baddeley, 2002, p. 86). Baddeley explains this *word length effect* in terms of how long it takes to articulate the words subvocally when memorizing and rehearsing them: since longer words take more time to say, fewer of them can be rehearsed before their memory trace starts fading (Baddeley, 1999, p. 50). In fact, Baddeley uses this observation to define memory span, or capacity, in terms of how long it takes to say the items to be remembered, rather that the actual number of items (Baddeley, 1999, p. 52). This represents a departure from George Miller's definition of immediate memory[2] capacity which he expressed in terms of the number of items, or chunks, stating that "the number of chunks of information is constant for immediate memory" (Miller, 1956).

The limits of the visuospatial sketchpad. The capacity of the visuospatial sketchpad seems to be even more limited than that of the phonological loop. Baddeley and Logie cite several studies suggesting that "visual memory may be able to hold only a single pattern, but its complexity and the similarity of pattern elements to one another may constitute additional limitations on the capacity of the system" (Phillips & Christie, Walker et al., and Broadbent & Broadbent cited in Baddeley & Logie, 1999, p. 36).

The limits of the central executive. Since controlling attention is considered to be its primary role, it follows that the central executive is responsive for our inability to attend to more than one stimulus at a time. Baddeley has also implicates the central executive in slips (Baddeley, 2002, p. 90), where intending to do one thing a person does something else, based on a perceptual cue that activated an inappropriate script. In fact, according to Don Norman, slips and our ability to focus on only one thing at a time are related: since we often do several things at once, some actions must be performed without conscious attention (Norman, 1988, p. 106). This creates fertile ground for slips—a common phenomenon in skilled behavior (Norman, 1988, p. 106).

Forgetting vs. available WM capacity. While the debate about the exact mechanism of forgetting continues, the results of studies cited so far suggest that recency, similarity and interference all play a role. There is, however, another way of looking at WM limits: not in terms of the properties and interactions of memorized items, but in terms of cognitive processes that occur simultaneously with task

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[2] For the purposes of our discussion, working memory, as it is defined in Baddeley's model, is synonymous with Miller's immediate memory.

performance, competing for WM's available "space." According to Michael Eysenck, anxiety gives rise to one of those processes.

Working Memory and Anxiety.

Eysenck's processing efficiency theory states that "anxiety interferes with cognitive performance by preempting some of the processing and storage resources of the working memory" (Eysenck and Calvo cited in Wetherell, Rynolds, Gatz, & Pedersen, 2002, p. 246). In particular, Eysenck's theory proposes that anxiety produces worry—thoughts of potential threats that compete for resources in WM (Wetherell et al., 2002, p.246). A way of coping with that threat is to allocate additional resources to the task (Calvo & Eysenck, 1996, p. 291). Allocating more resources makes it possible to maintain task effectiveness, but at the expense of efficiency (Calvo & Eysenck, 1996, p. 291). The net effect is that less work gets done.

Can anxiety lead to increased performance? Eysenk believes so. Anxiety, just like any other stressor, produces an increase in one's overall level of arousal. In a task environment, this arousal can prompt an individual to put more effort into the task (studies by Eysenk cited in Baddeley, 1998, p. 400). In effect, the person "rises to the challenge." Therefore, anxiety has a motivational effect. Wickens et al. note, however, that while a moderate amount of stress can increase performance, there is an optimum level of arousal. Overarousal leads to a decrease in performance (Wickens et al., 2004, p. 330).

One of the ways overarousal degrades performance is by prompting perceptual narrowing—where an individual's attention is restricted to one stimulus, ignoring the surrounding information sources (Wickens et al., 2004, p. 330). As a result an individual can become too absorbed in one task oblivious to what's going on around him. Jef Raskin tells of a tragic plane crash where all three of the plane's pilots became so absorbed trying to fix a landing gear light that they didn't notice the multiple alarms signaling that the plane was losing altitude (Raskin, 2000, p. 25). In addition to perceptual narrowing, cognitive narrowing also occurs. It is characterized by a tendency to focus on only one problem-solving strategy, failing to consider alternatives (Wickens et al., 2004, p. 331). To support their point Wickens et al. cite findings showing decreased performance on tests of creativity under stress (Shanteau & Dino cited in Wickens et al., 2004, p. 331).

Of course, limited creativity is not acceptable for professional photographers—the user base for the product evaluated in this paper's case study. The stressors present during a typical photo shoot leave no room for any additional anxiety generated on the part of the camera. The camera must function quickly and flawlessly, becoming almost an extension of the photographer's physical body. The camera should never compete for the photographer's attention and should never be a source of anxiety. Tracking the subject, framing the shot, watching the light and many other continuously changing variables are enough to fill much of the photographer's available working memory capacity. Attempting to be creative in these conditions places an additional burden on memory. Therefore, any additional memory burden imposed by the camera, be it anxiety or simply time delay will take away from the photographer's ability to capture the best possible shot.

The purpose of the following case study is to estimate (a) what, if any, additional stress Canon's new semi-professional digital camera imposes on the photographer and (b) to what extent it's advanced technology works to reduce the anxiety inherent in taking pictures professionally.

The case study: Canon EOS 20D Digital Camera.

EOS 20D is Canon's latest digital SLR camera aimed at advanced amateur/enthusiast and entry-level professional photographers. Its feature set, discussed throughout this case, is impressive. Let's see

how implementation of these features might impact the performance of the photographers using it.

One of photographers' biggest fears is that the picture will not come out the way they intended. Digital cameras in general remove much of the anxiety related to this by letting the photographer view the picture on the camera's built-in LCD screen immediately after taking it. Canon 20D is no different. Its picture review function is great for checking the exposure accuracy of an image. Unfortunately, neither the LCD display's pixel resolution nor the maximum level of magnification is sufficient to view the image "pixel for pixel" on the LCD screen. This means that it is impossible to check just how accurate the focus really is by using the camera's built-in image review capability. As a result, the photographer will need to be more careful when taking a picture, watching more closely —being mindful of—the camera's focus to make sure it is spot on. Since this "minding" competes for "space" with other cognitive processes operating in working memory, the photographer's performance—response time as well as creativity—on the primary task of shooting may deteriorate as a result.

Sometimes, however, a photographer doesn't even have the luxury of re-shooting. For example, during fashion shows, the subjects can walk by the photographer so quickly that he can barely have the time to get a single shot of the model. A wedding is another such situation. Luckily, the camera has an exposure bracketing feature: the camera takes three consecutive shots, one properly exposed, one slightly underexposed and one slightly overexposed. Camera's 5-frame-per-second shooting speed ensures that this occurs very quickly. This means that the photographer doesn't need to worry about slight over- or underexposure, being able to better concentrate on shooting rather than operating the camera.

There is, however, an implementation problem here: enabling and disabling bracketing is done through the camera's menu system. Unfortunately, navigating on-screen menus takes A LOT more time than changing just about any other setting (which is usually done by simply pressing a button and rotating one of the two command wheels). As a result, the camera becomes the photographer's locus of attention for too long. This limits those photographers who will want to use this feature selectively (on and off) during a photo shoot. Both of the likely coping strategies—changing the setting ahead of time or trying to change it while the subject is waiting—are bound to be accompanied by increased levels of anxiety and decreased levels of creativity, not to mention disgruntled subjects.

While fashion shows and weddings are usually very noisy, other environments require completely silent operation. This is often the case when taking pictures of wild animals or birds that can be easily spooked. While most high-end Canon lenses feature ultra-sonic (silent) focusing motors, the camera's own shutter release sound is quite loud, even by SLR standards. This means that a photographer may only have one chance to capture a shot before the animal becomes aware of his presence. This increases anxiety, because the photographer realizes that he has only one opportunity to take the shot. To make sure the shot comes out as intended, the photographer may need to double check the camera's settings. This directs his attention away from the subject and to the camera, making it easier to miss that perfect shot. This, in turn, creates even more anxiety!

Subjects are not the only things normally occupying photographer's WM. Camera settings are something that a photographer must be aware of all the time as well. Status LCDs are great for reducing working memory demands here, because the photographer is not forced to keep all the settings in working memory, but can just check them all by glancing at the LCD. Unfortunately, one setting that has a significant impact on the picture quality—the ISO speed—is excluded from both the top of camera status LCD and the viewfinder's status display. Both of the advanced users of this camera interviewed for this case study admit to having taken pictures at incorrect ISO speed.

Sometimes the camera must be operated in the dark. Unfortunately, none of the buttons or button labels are lighted. This means that, in complete darkness, the photographer must operate the camera by touch only. While the photographer may remember which button controls which function, he may need to count the buttons off by touching the first button in the row of buttons at the top or left of the camera until he reaches the desired one. Needless to say, this time-consuming tactic shifts the photographer's attention from the subject to the camera. Note that this problem also exists in case the photographer's eye is "glued" to the viewfinder (in which case he can't look at the buttons).

Here is another nigh-time shooting problem: the LCD screen, while lighted, remains lit for six seconds regardless of whether any other buttons are being pressed. This means that the user needs to be mindful of the number of seconds the light has been on when changing settings to make sure it does not go out before he's finished making the changes. This creates timing-induced anxiety.

Finally, the remaining battery power indicator has only 3 power level gradations. This makes it difficult to estimate with certainty how much power is remaining, let alone how many shots, representing yet another source of anxiety. By contrast, a competing camera from Nikon not only indicates the remaining battery power in much finer increments, it actually shows the number of remaining shots!

While this review has purposely been focused on the camera's shortcomings, Canon 20D is still an amazing photographic tool. The high pixel count means the photographer does not need to worry as much about precisely framing the shot, because here are enough pixels to crop the image significantly without sacrificing quality in print. The photo-centric design—tapping the shutter release in play mode returns the camera to capture mode—means the photographer does not need to worry about the camera's current mode in order to be able to take a picture. Fast card write speed means the photographer doesn't need to worry about the camera not being ready for the next shot. And Canon's unique automatic depth of focus feature that varies the aperture automatically to keep all of the subjects in focus ensures the photographer doesn't need to worry about the depth of focus either. All of these features allow the photographer to keep his attention on the task of being a creative photographer rather than a camera operator.

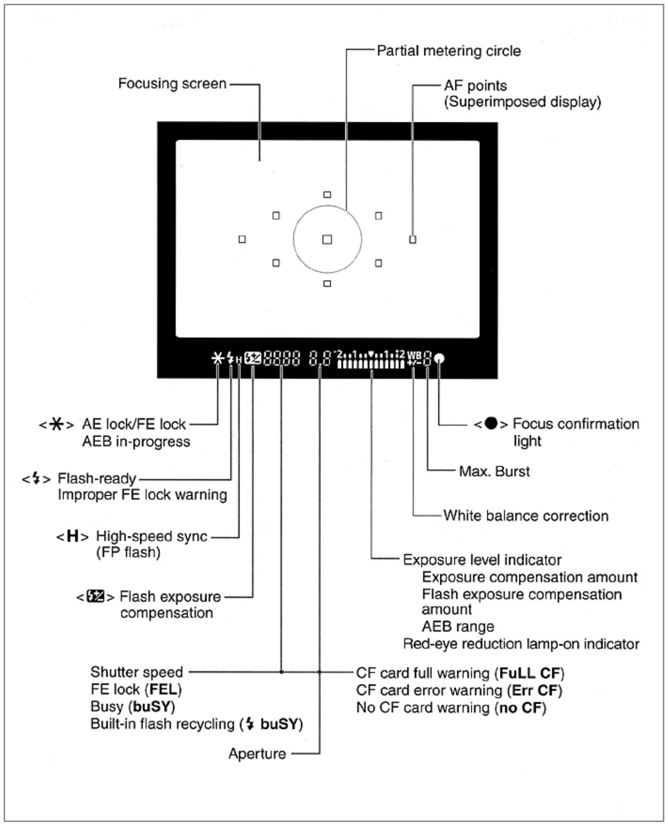
Recommendations for Canon 20D.

Even though Canon succeeded in designing a great camera, there is still some room for improvement. The suggested changes are:

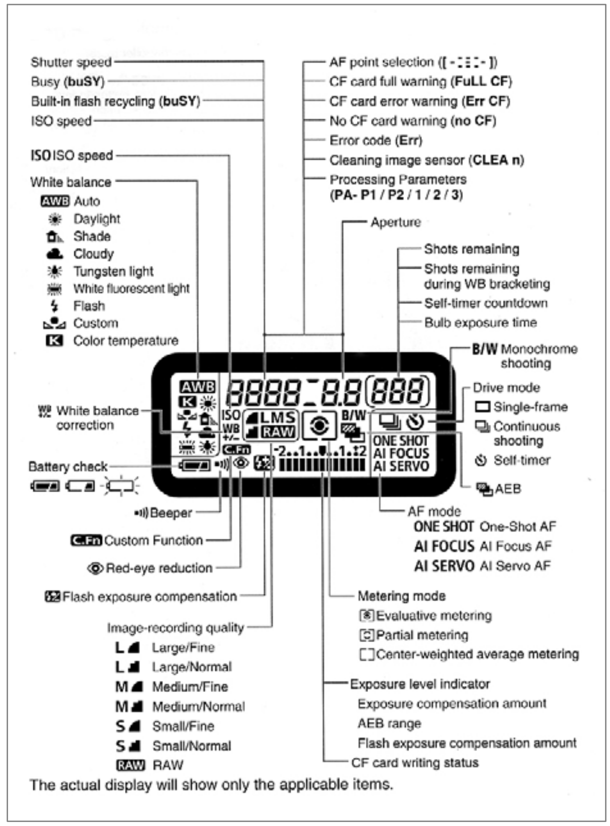
- provide a higher resolution LCD screen *and* higher image playback magnification to enable checking focus accuracy at the pixel level;
- enable turning exposure bracketing on and off without going into the camera's menu system;

- make the shutter mechanism quieter. Canon's own, more expensive, EOS-1D camera has a "quiet shutter" mode, where the mirror is returned to its initial position slower, making the shutter much quieter;
- display the currently selected ISO speed in the viewfinder. Consider showing the white balance setting in the viewfinder as well. Nikon's pro-grade D2H shows both in its viewfinder;
- consider adding backlighting to the most frequently used buttons. If this is not feasible, use paint that "glows" in the dark. Also, adding a tiny ridge to the middle of the three identical buttons on the top of the camera will make it easier to locate the correct button by touch alone;
- make sure the LCD screen remains lit while buttons are being pressed and for some time after;
- provide a more informative remaining battery power indicator, expressing the remaining battery power in terms that are meaningful to the photographer like the number of shots or time.

Appendix. Additional camera views and displays.



The viewfinder display diagram.



The top LCD display diagram.

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