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The impact of fatigue on latent print examinations as revealed by behavioral and eye gaze testing

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ABSTRACT

Eye tracking and behavioral methods were used to assess the effects of fatigue on performance in latent print examiners. Eye gaze was measured both before and after a fatiguing exercise involving fine-grained examination decisions. The eye tracking tasks used similar images, often laterally reversed versions of previously viewed prints, which holds image detail constant while minimizing prior recognition. These methods, as well as a within-subject design with fine grained analyses of the eye gaze data, allow fairly strong conclusions despite a relatively small subject population. Consistent with the effects of fatigue on practitioners in other fields such as radiology, behavioral performance declined with fatigue, and the eye gaze statistics suggested a smaller working memory capacity. Participants also terminated the search/examination process sooner when fatigued. However, fatigue did not produce changes in inter-examiner consistency as measured by the Earth Mover Metric. Implications for practice are discussed.
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Latent print examiners often find themselves in situations where fatigue may affect their performance. The Expert Working Group on Human Factors [5] identified fatigue along with stress, complacency, overconfidence, and task overload as examples of adverse mental states of an examiner. In addition to these mental state changes, physical changes can occur such as eyestrain and back pain from looking through a loupe at latent print impressions. The Working Group report specifically identified several factors that could contribute to fatigue, including being on call for crime scene investigation, working through backlogs, and long hours as practices that could reduce performance. However, the literature contains relatively little direct evidence of the effects of fatigue on latent print examination.

To measure the effects of fatigue in tasks that resemble actual casework, we tested examiners both before and after a visual matching task that was designed to induce fatigue. We recorded both behavioral accuracy as well as eye gaze, which will allow within-subject comparisons in both measures to assess the effects of fatigue and allow for a mechanistic explanation of the changes in behavioral performance.

While relatively little work has been done with latent print examiners and fatigue using eye gaze methodology, work with radiologists has suggested that fatigue can produce reduced accommodation abilities due to eye strain after extended radiological viewing [7]. The authors suggest that this difficulty in focusing may make it more difficult for radiologists to detect abnormalities and may increase viewing time.

Van Orden et al. [13] used a nonlinear regression model to explore the relation between fatigue and eye blink duration, eye fixation duration, and pupil diameter. They replicated prior work suggesting that eyelid 'perclose' (a slight droop in the eyelid) was related to fatigue, and also identified a much stronger relation between fatigue and fixation dwell time. Their model suggests that not only do eye movements reflect elements of fatigue in a visual processing task, but that they could be used as an online diagnostic tool to measure fatigue.

More recent work has argued for the integration of fatigue measurement tools into workstation design and a daily routine [10]. This would allow a metric that relates the amount of fatigue, as estimated through external measures such as eye movements,

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to productivity. Such a metric would quantify the costs of extended viewing sessions, to suggest when a period of diminishing returns might be reached.

Fatigue can also influence the decision making process, which has been termed *decision fatigue*. Danziger et al. [4] studied parole-based decisions and found that parole board members were much less likely to grant parole toward the end of a set of parole hearings. However, the parole granting rate rises abruptly after a food break, when presumably the parole board members are feeling refreshed.

Working memory is subject to limitations due to fatigue. Helton and Russell [6] addressed the effects of fatigue on verbal and spatial working memory tasks during a successive target detection task. Fatigue induced decrements in performance, especially when paired with a concurrent working memory task. This suggests that high cognitive resource demands brought on by a challenging task will use, and ultimately exhaust, working memory resources. This reduces sensitivity during target detection, as well as increasing reaction time.

Together these results suggest that fatigue can affect reaction times, search accuracy and attention, as well as low-level eye gaze metrics such as fixation durations and working memory. In addition, decision fatigue may affect the conclusions drawn by participants while fatigued. Given that all of these perceptual and cognitive capacities are required to conduct latent print examinations, the goal of the current study is to provide an initial comparison between fresh and fatigued performance during tasks that resemble latent print examinations. Should we find effects of fatigue with a relatively modest sample, the results may indicate the extent of the problem, as well as suggest the manner in which fatigue affects performance and guide more extensive studies using larger samples.

1. Method

1.1. Overview

Testing was done with a relatively small number of participants (five) but tested in a within-subjects design that improves experimental power. Participants were tested in two 20-min eye tracking sessions, separated by a demanding hour-long perceptual matching task that used fingerprint fragments embedded in visual noise. The two eye tracking sessions were limited to 20 min, which is the comfort limit of our eye tracking headgear. We designed the set of comparisons such that there were more comparisons than an examiner could be expected to complete in this 20 min period.

The first eye tracking session was conducted in the morning while participants reported still being relatively alert. Participants were then sent to lunch, after which they undertook an hour-long matching task that was designed to induce fatigue. Immediately after this session they participated in a section eye gaze experiment to examine the effects of fatigue on eye gaze and behavioral responding.

1.2. Participants

Participants were recruited from a large forensic science laboratory. Participants ranged in age from 26 to 31, and ranged in latent print experience between 3 and 8 years. All participants were aware that they would be tested twice, and that the two sessions would be separated by lunch and an hour-long perceptual matching task just prior to the second recording session. Participants were otherwise naïve to the goals of the study. Of the five participants, three wore glasses or contacts, and all three were in a corrected state when participating in the study. The other two had uncorrected vision.

1.3. Equipment and stimuli

There were two testing booths, each of which contained a 15″ Macbook pro laptop. This allowed for two participants to be tested at a time. Images were displayed on the built-in laptop screen using custom Java software that included gamma correction. The stimuli were chosen from an extensive database of latent prints collected from participants at Indiana University that were typically of tenprint quality. The images were degraded by visual noise that was sampled from actual latent prints and then extended using a texture synthesis algorithm [9]. The visual noise was then combined with a fingerprint image using a multiplicative model that simulates the manner in which inks combine, as illustrated in Fig. 1. To combine the friction ridge detail and the noise in a realistic manner, both the noise and the fingerprint ridge detail were modeled as neutral density filters, each of which blocks

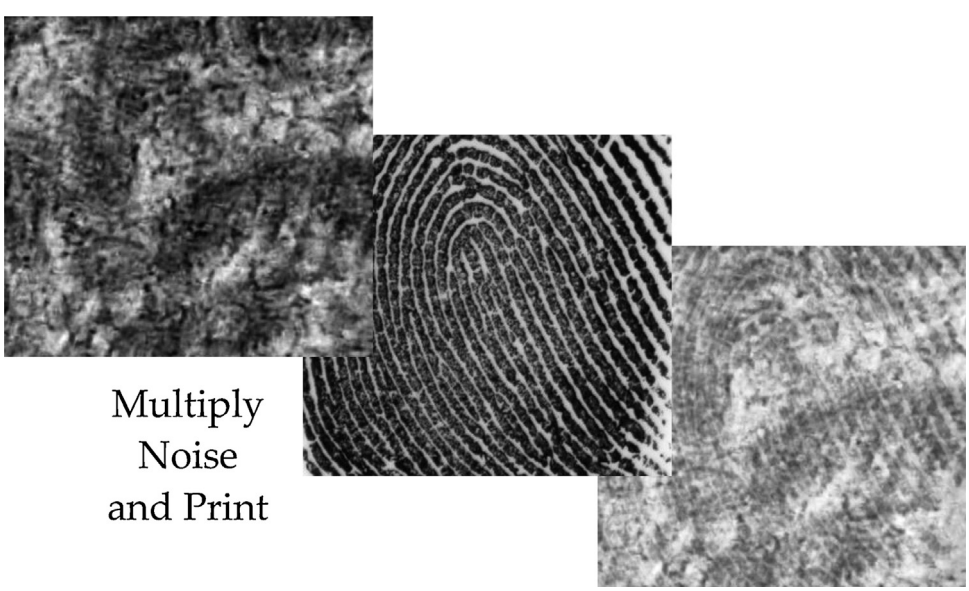

Fig. 1. Example image illustrating how multiplicative noise added to a ten-print quality image can create a realistic latent print while still allowing access to the ground truth ridge detail.

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